UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into Energy Generating Tiles -Pavegen

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Submitted to Dr. Steve Oldrige and the AMS Stakeholders

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Abstract

Clean, renewable and environmentally friendly energy generation has always been an issue that needs to be solved. Technologists have created various methods such as solar panels, wind turbine, hydro electricity and so forth. However, Pavegen has come up with another innovative idea, which is to generate electricity from kinetic energy. Since there are a large number of students patronizing the Student Union Building, the AMS is considering installing Pavegen tiles into the new SUB building in an effort to promote sustainability. This paper will investigate the advantages and disadvantages of the installation of Pavegen using triple bottom line assessment.

From the economical aspect, the tiles payback period is much longer than the lifetime of the tiles which means that the cost of this project exceeds its economical benefit. Meanwhile, from the social aspect, there is a possibility that Pavegen can help raise the awareness of sustainability amongst the students patronizing the SUB and strengthen the image of UBC as global leader of sustainability. However, Pavegen may bring up some ethical issues such as harvesting human energy without their consent. Lastly, from the environmental aspect, based on an observation and a few assumptions, the total evergy Pavegen will produce in its lifetime is found not able to cover the carbon footprint resulted from the manufacturing and shipping of the product.

In conclusion, triple bottom line assessment shows that the implementation of Pavegen in the new SUB will be beneficial to the society but will negatively impact the economy and environment. Unless another company that manufactures a similar product is chosen from the United States or Canada, it is recommended that UBC should not install the tiles.

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List of abbreviations

AMS – Alma Master Society

CDN – Canadian Dollar

CH4 – Methane

CO2 – Carbon Dioxide

GHG – Green House Gas

H – Height

kWh – kilo Watt hour

L – Length

LCA – Life Cycle Assessment

LED – Light Emitting Diode

SUB – Student Union Building

UBC – University of British Columbia

W- Width

Introduction

Pavegen tiles is a device that generates electricity by converting kinetic energy that is obtained when mechanical stress is applied on the device. When someone steps on the tile, a certain amount of energy will be generated and stored in the built-in battery, which will power low energy consumption appliances such as street light, alarms and battery charger. In the new SUB, this energy can be used to power up the LED display that highlights the sustainable features of the building.

Pavegen Company claims that the durability of its product is 20 million steps (Gizmag, 2011). Each footstep on a tile can generate about 0.29 watts per hour on average (based on our calculation in the following section). Meanwhile, the battery can be customized depending on the requirements. The cost of each tile is $4,052CDN, taxes not included. The product is made of recycled rubber and aluminum (WorldArchitectureNews, 2011). The AMS is considering on introducing this device into the new SUB by placing eight tiles of this device on the main stairway. In this paper, an assessment on the product is done using triple bottom line assessment that investigates the product's impacts through economical, societal and environmental aspects.

For the economic assessment, we calculated the breakeven point to find out what the lifetime of the Pavegen tiles ought to be to cover the costs. We also compare with other alternativeenergy source that can be purchased using the same amount of money used to cover the costs of the Pavegen tiles. For social assessment, sustainability awareness raised by implementing this product is used as an indicator. Futhermore, the safety and ethical issue are taken into consideration. Finally, for the environmental assessment , carbon footprint of shipping, manufacturing and diaposal is calculated and compared to the carbon footprint Pavegen will save over its lifetime.

1 Applications and Calculations

1.1 Application of Pavegen

In the past, being sustainable was never an important issue to technologist. Their main goal is to create instruments that are able to make human lives' more convenience, even if it hurts environment in return. However, currently in many universities, engineering and science students are being educated on the importance of being sustainable and designing products that are pro environmental. In order to spread this idea to the public and society, Pavegen has introduced tiles that generate electricity with every step on it. This energy in return can be used to power street lights, displays, speakers, alarms, signs or advertising (Gizmag, 2011).

Now, the tiles are being used in many places that have a high concentration of people passing through and many more are planning to do so as well. For example, Westfield Stratford City Shopping Centre is planning on installing the tiles and uses the generated power to power up the mall's entire lighting system. The tiles will be placed along the central crossing that between the mall and 2012 London's Olympic site (Webster, 2011). The tiles were also installed in Kent Grammar School's corridor, where the power is used for the corridor's lighting. Pavegen's CEO stresses that the tiles " addresses so many of the issues that are important to young people today - such us innovation, sustainability, energy" (Frontier, 2011). The tiles are able to create and raise awareness of the students about the topic of being sustainable and the usage of renewable energy.

Installing Pavegen tiles in the SUB corresponds to the objective of the company and may help spread the idea about sustainability. However, there are other points to be considered other than just raising awareness and they will be discussed further in this paper.

1.2 Amount of Power Generated

To make an analysis about the tiles, we first must calculate the amount of power they are able to generate in their lifetime. In a newspaper article on Washington State University, Kemball-Cook said that "250,000 footsteps created enough juice to charge 10,000 cellphones"(Peters, 2011).

According to Lawrence Berkeley National Laboratory (Standby Power, 2011), 1 cellphone needs about 3.68W per hour for 2 hours to be fully charged. Based on these data and the information given by Kemball-Cook, the energy generated by each footstep is calculated as follows:

$$10000*2*3.68\text{Wh} = 73.6\text{kWh}$$

$$\begin{aligned}\text{Energy per footstep} &= 73.6\text{kWh} / 250000 \text{ footsteps} \\ &= 0.294\text{Wh per footstep on average}\end{aligned}$$

On Thursday October 20th, we observed the number of people walking through the stairs in front of a sushi place in SUB and recorded the data as seen below.

Using data from our four 1-hour time slots, we plotted a normal distributed graph to estimate the amount of people that walks through the SUB every day. Figure 1 shows the bell curve plotted using computer software. By summing up the amount of people over the 10 hours in a day, we estimated about 6200 people walk through that stair every single day.

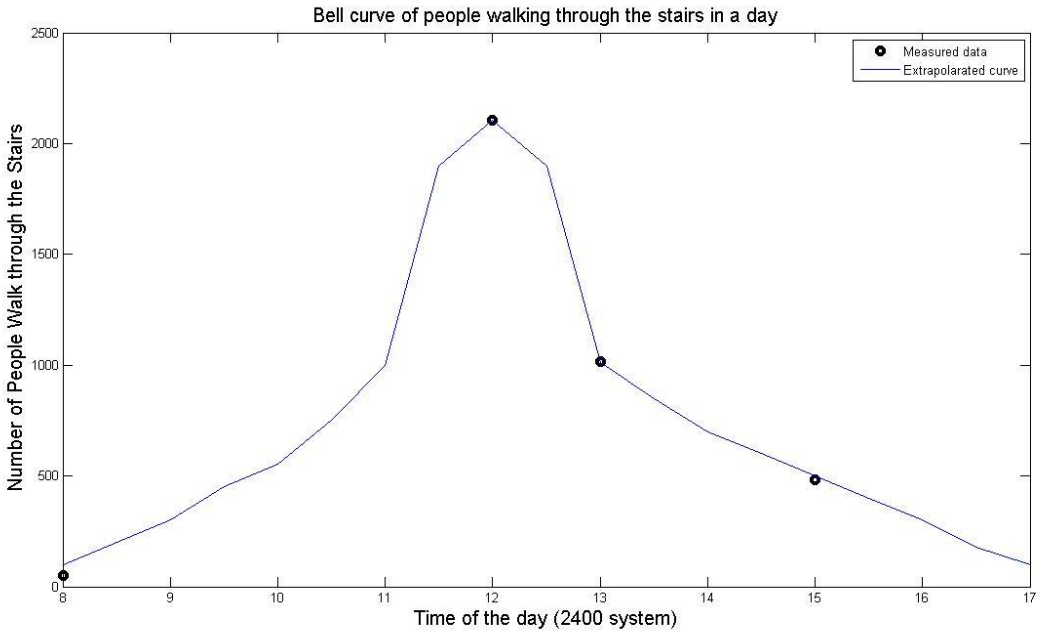

Figure 1: Normal distributed graph of people passing through SUB daily

With the information above, we calculate the energy that the product is able to generate over its lifetime. We made an assumption that the 6200 people will pass by everyday for 5 days a week and 4 weeks a month. Realistically, the above assumptions do not hold all the time, especially in summer. However, we used these assumptions to simplify the calculation. Based on the assumption above, the amount of passerby in the SUB for a year will be:

5days a week * 4weeks a month * 12 months a year * 6200 steps a day = 1488000 steps

With another assumption that each passerby will step on at least two tiles, the energy generated every year will be:

1488000 steps * 2 tiles * 0.293Wh per step = 863kWh per year

Since the lifetime of the product is 20 million steps (Gizmag, 2011), the lifetime in years is estimated to be:

20000000 / 1488000 = 13.4 years.

Energy generated over Pavegen lifetime will then be:

863kWh per year * 13.4 years = 11.6MWh.

2 Economic analysis

Our team researched on the Pavegen tiles and analysed it by computing its breakeven point and comparing it with other energy that has equal cost and output. These will be the indicators for the economic assessment.

With the result of the calculation for the energy generated above, we know that 863kWh is generated every year. This means every month, we generate an average of 71.9 kWh. From the table 1, we will compare the energy generated with energy that can be purchased from BC Hydro. Using the generated energy, every month we will save approximately 71.9 / 375 * 30.15 = $5.78. The lifetime of the tiles is approximately 13.4 years. Therefore, in its lifetime, we can save $5.78 * 12 months * 13.4 years = $929.40 on our energy bill.

Table 1: One month bill for various provinces

< Source: http://www.hydro.mb.ca/regulatory_affairs/energy_rates/electricity/utility_rate_comp.shtml>

One Month Bill For:					
Cities	**375 kWh**	**750 kWh**	**1,000 kWh**	**2,000 kWh**	**5,000 kWh**
Calgary AB	$50.17	$82.85	$104.63	$191.76	$453.16
Charlottetown PE	$69.76	$114.95	$145.07	$265.57	$541.57
Edmonton AB	$52.25	$83.77	$104.79	$188.86	$441.07
Englehart ON	$66.34	$111.92	$143.36	$272.82	$661.22
Halifax NS	$57.86	$104.88	$136.23	$261.63	$637.83
Kenora ON	$48.04	$83.49	$108.05	$210.55	$518.09
Moncton NB	$56.67	$93.61	$118.23	$216.73	$512.23
Montreal QC	$32.40	$52.62	$68.21	$143.31	$368.61
Regina SK	$59.07	$98.86	$125.38	$231.48	$549.78
Saskatoon SK	$59.06	$98.85	$125.37	$231.46	$549.74
Saint John NB	$49.09	$83.03	$105.65	$196.15	$467.65
St. John's NL	$50.63	$86.26	$109.86	$204.26	$487.47
Toronto ON	$54.72	$92.92	$119.26	$229.04	$558.37
Vancouver BC	$30.15	$58.06	$82.71	$181.31	$477.12
Winnipeg MB	**$31.68**	**$56.50**	**$73.05**	**$139.25**	**$337.85**

However, the cost for all eight tiles are approximately $30800 and we are only saving $ 929.40 throughout its lifetime. This means, we are losing $30800 - $929.4 = $29870.60. Ignoring the expected lifetime of the tiles, the breakeven point can only be achieved after 30800 / (5.78 * 12) ≈ 444 years. This means that the payback period is approximately 444 years and this is obviously unachievable. Thus, based on the above, we came to the conclusion that the Pavegen tiles are not beneficial to UBC based on the economic point of view alone.

3 Social Assessment

Social assessment is defined as the estimation, in advance, of the social consequences from a project development (Becker et.al. 2003). Social assessment has its own measurable units which are different from economy and environmental assessments. In Becker's book, he explores several indicators for social assessment. The most relevant indicators chosen to measure the social impact by Pavegen are:

i: change in knowledge and ways of living

ii: change in employment rate

iii: ethic issues

iv: safety

3.1 Change in Knowledge and Ways of Living

The purpose of installing Pavegen tiles in the new SUB is to provide an alternative way to generate electricity and to promote sustainability. Although there are other cheaper renewable energy sources like solar panels and wind energy harvesting, they do not engage people in the process. According to the website of North Tipperary County Council, the best way to promote sustainability is by involving the local community in the sustainability effort (North Tipperary, 2011). Pavegen tiles need students to step on it in order to generate electricity, which is a direct involvement of the society in the process of achieving sustainability and this will raise their awareness of sustainability.

Pavegen is able to change people's ways of living too. A research was done by Volkswagen by installing a "piano stairs" beside an escalator in a subway station in Stockholm to see if community's lazy behaviour can be changed. The results show that there is 66% more people using the stairs than the elevator because it is interesting (Dugdale, 2011). Similar achievement can be done by Pavegen as an LED will light up when people step on the tile. Installing Pavegen tiles on stair is as interesting as the "piano stairs", which will engage more people to use it. Although there is a 5% consumption of the energy generate to light up the LED, it is worthy because the LED will attract more people to use the stairs and indirectly make them more aware that what they are doing is sustainable.

Pavegen founder, Laurence Kemball-Cook, says that "Schools are a great way for people to learn about energy efficiency" in an interview (Harris, 2011). By installing Pavegen tiles in the SUB, the knowledge about sustainability among the students can be increased too. Soon, students will also realise that, every little thing they do in their life can impact in the achievement of sustainability, which will also inspire them to create a product that has similar concept with Pavegen or even find out other innovative ways to generate energy.

3.2 Change in Employment Rate

Installing Pavegen tiles in SUB will not increase the job opportunity in Canada in a short period of time. In the interview with Kemball-Cook, he mentions that Pavegen does not show any interest of starting company overseas (Harris, 2011). However, Pavegen tiles will need maintenance, so engineers in Canada can be trained in Pavegen company in UK to help maintaining Pavegen tiles

With the established reputation of UBC as a global sustainability leader, the use of Pavegen tiles will be known by the rest of Canada. When Pavegen gets popular enough, Pavegen might consider starting a company in Canada which will increase more job opportunities. However, that is a long term process which will not happen anytime soon.

3.3 Ethical Issues

One of the concerns associated with the installation of Pavegen is that Pavegen works by harvesting human energy without their consent. Hilario, in his thesis of energy harvesting exercise machine, mentions that "harvesting energy from a human brings the question of ownership. Who gets to claim the energy harvested? The owner of the equipment or the user?" (Hilario, 2011). By right, UBC owns the Pavegen tiles so, UBC claims the energy generated and use the energy to power the light and LED TV in the SUB without paying the students anything. This could possibly be an infringement of human rights. However, if the tiles are installed in such a way that students are able to choose whether they want to step on tiles or not, this issue will not be a problem as UBC does not force them to generate electricity.

Glaskowsky, in his article, argues that human energy harvesting is a "silly idea" because people will have to eat more (Glaskowsky, 2007). However, Chapple argues that, some scarification must be made in order to achieve sustainability (Chapple, 2008). In this case, the

sacrifice the students have to make is just to use a little of their energy to power the lights in the SUB and this is small in comparison to their contribution in making the world a better place to live in.

3.4 Safety

When people step on the surface of Pavegen tile, it deflects by 5mm as shown in figure 2 to generate electricity (Harris, 2011). Since UBC is planning to install Pavegen tiles on the stairs in new SUB, our team did some research to see if this will be a tripping hazard. Inspectapedia.com states that "[a variation] more than 3/8 of an inch (9.525mm) in variation of the height of steps from one step to another is a tripping hazard" (Inspectapedia, 2011). Since Pavegen only deflects by 5mm, it is safe to be installed on the stairs.

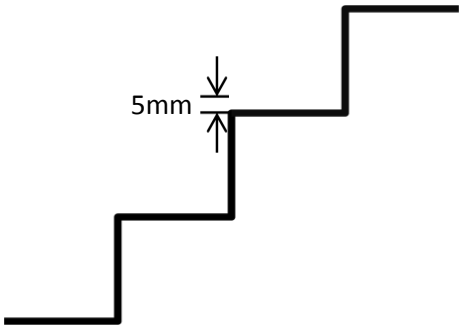

Figure 2: The deflection of Pavegen on stairs.

4 Environment assessment

The environmental analysis of Pavegen is the assessment of its total carbon footprint. Carbon footprint is a measure of total amount of carbon dioxide (CO2) and methane (CH4) emission of a defined population, system or activity (Wikipedia, 2011). It is an important method for the measurement of the impact of an object or a product on the environment. The carbon footprint of a product refers to the GHG emissions of the assessed product across its life cycle, the formation of raw materials through production, distribution, consumer use and disposal (Iribarren et. al. , 2010). In this project, the carbon footprint of Pavegen system is measured and will be used as the indicator for the environmental impact of Pavegen tiles. The main factors of the Pavegen system that contribute to the carbon footprint are the shipping, the manufacturing, the disposal and the amount of renewable energy it is able to produce.

4.1 Shipping

Pavegen Company is located in London and its product is manufactured locally. However, since UBC is located in Vancouver, thus the product will be used in Vancouver and this will cause shipment to be a major factor that may cause a large carbon footprint. The estimated emission of CO2 from London to Vancouver is about 0.67 ton (Carbon Footprint, 2011).

4.2 Manufacturing

The size of the product is 600*450*87 (L*W*H) mm and it is made of stainless steel as the base and covered by 95% recycled rubber on the top (WorldArchitectureNews, 2011). Analysis shows that the mean carbon footprint of the average rubber is 0.153 ton of CO2 per metric ton. In comparison, the use of recycled rubber in moulded products provides a substantial carbon foot advantage over the use of virgin plastic resins, having between 4 and 20 times lower carbon footprint (Tire Recycling, 2011). In this case, the total estimated carbon footprint of rubber to be used in the Pavegen system is about 0.0857 kg of CO2. Moreover, the carbon impact of steel products in the UK is 0.919 ton per ton (TATA Steel,2011). This implicates that the estimated carbon footprint of steel to be used in Pavegen system is 1.5kg of CO2. The total CO2 emission in this project is estimated to be 1.5857 kg of CO2.

4.3 Disposal

Since Pavegen Company is located in London, they cannot offer recycling products in Vancouver. The product is mostly made of steel and recycled rubber, hence it can be recycled. Recycling products is a good way to reduce carbon footprint. The product stores energy using lead acid and lithium battery and the toxic chemical and heavy metal can be a potential hazard to the environment. Hence, the disposal method of the product is an important issue. The carbon footprint of recycling battery is uncertain. However, it can be estimated to be very small since Pavegen Company uses the technology that can not harm the battery. Unlike other kinetic energy-harvesting systems based solely on piezoelectricity, the technology Pavegen uses gives constant flow of energy which, on large scale, extends the lifetime of the battery (Harris, 2011).

4.4 Energy

Based on the calculations made in the economical analysis of Pavegen provided above, the total energy Pavegen produces in its life time is computed to be 11.65MWh. In Canada, the LCA emission factor for hydropower is 0.024 ton CO2/MWh (Covenarnt of Mayors, 2011). Therefore, the energy that Pavegen produces in its lifetime can save approximately 0.28 ton of CO2.

4.5 Result of environmental assessment

Based on the analysis above, the total carbon footprint of Pavegen will save in its lifetime is calculated to be 0.67 + 0.002 - 0.28 = 0.39 ton, which means that Pavegen project will release 0.39 ton CO2 to the environment in its lifetime. Since the result of the assessment is opposite to our expectation in term of its carbon footprint, this product won't help to reduce green house effect, and it is not wise to introduce this device to the new SUB. However, the major cause of the carbon footprint is its shipping. If the shipping distance can be largely reduced, then the device will be recommended.

4.6 Alternative products

There are a few companies starting to make equivalent products. For example, POWERleap is a company that located in Michigan USA. However, since POWERleap is only on the prototype stage, there is not much information found. On the other hand, the location of the company is a good advantage since it is located nearer to Vancouver compared to the Pavegen and this can reduce the shipping carbon footprint. Considering that the new SUB

project will only start in one year, during this time, if POWERleap or any other similar companies in Canada or the United States is able to start manufacturing, they should be taken into consideration.

Conclusion and Recommendation

In conclusion, in terms of economy, Pavegen tiles are not feasible as its payback period is much longer than its lifetime. In terms of environmental, it produces more carbon footprint than the generated energy can save. However, it has some social advantage in which it can help raise the awareness of the society in UBC about the importance of sustainability.

Based on the result of the analysis done as seen above, we recommend that AMS do not install the Pavegen in the SUB unless Pavegen opens a manufacturing branch in north America. We also recommend that AMS to consider purchasing from another company that can manufacture a similar product such as POWERLeap that is based in north America since this can help reduce both the price and the carbon footprint produced by shipment.

Another option is to etch logos of sponsors onto the tiles' glass. This way, we can help promote our sponsors and at the same time reduce the cost that we have to spend on the tiles through sponsorship.

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