UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Investigating the feasibility of Implementing Pavegen energy - harvesting piezoelectric floor tiles in the new SUB

Joel Cramm

Ammar El-Sherif

Jinwook Lee

Jamie Loughlin

University of British Columbia

APSC 261

November 24, 2011

University of British Columbia – APSC 261

Investigating the feasibility of implementing Pavegen energy-harvesting piezoelectric floor tiles in the new SUB

UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Joel Cramm

Ammar El-Sherif

Jinwook Lee

Jamie Loughlin

November 24 2011

ABSTRACT

This report is a triple bottom-line assessment which investigates the economic, environmental and social aspects of installing eight energy-harvesting Pavegen piezoelectric floor tiles in the new Student Union building at the University of British Columbia. The Pavegen floor tiles use the kinetic energy of a footstep to strain a piezoelectric material. This strain produces a voltage, which when integrated into a circuit can be used to produce green electricity. This electricity can be stored in batteries and used to power various devices such as a display board in the foyer of the new SUB.

The investigation revealed that the installation of the Pavegen tiles would contribute to environmental awareness by promoting sustainability and green energy generation, and the amounts of electricity harvested over their 5 year lifespan could recover the costs of initial purchase, transport, installation, maintenance and disposal of the tiles.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC – Alternating Current

CIRS – Centre for Interactive Research on Sustainability

CO_2 – Carbon Dioxide

DC – Direct Current

GWh – Gigawatt hour (=1,000,000 kWh)

kWh – Kilowatt hour (=3600 Joules)

LEED – Leadership in Environmental Energy and Design

PZT - Lead Zirconate Titanate

SUB – Student Union Building

UBC – University of British Columbia

W – Watt (1 Joule/second)

1.0 INTRODUCTION

Construction of the new Student Union Building at the University of British Columbia is scheduled to begin in early 2012 (Alma Mater Society of UBC, 2010). The new SUB will follow the footsteps of UBC's CIRS building (Centre for Interactive Research on Sustainability), the most sustainable building in North America (UBC, 2011), and aim to receive LEED platinum certification. This means that an array of pro-sustainability features will be integrated into the building's design. These features will strive to promote UBC's sustainability initiative.

It has been suggested that eight energy-harvesting Pavegen piezoelectric floor tiles be installed in the new SUB as one of the many pro-sustainability features throughout the building (tiles shown in Figure 2). Pavegen Systems is a company based in the UK, and is currently the only company selling energy-harvesting piezoelectric floor tiles. The tiles take the kinetic energy of a human footstep to produce piezoelectricity, which is electricity generated due to the piezoelectric effect. The piezoelectric effect is a property of some special non-conductive materials, most of which are crystals or ceramics, where mechanical strain on the material induces an electric gradient across the material. When these materials are integrated into a circuit, the voltage drop across them can be used to create an electric current. Pavegen claims that each tile is able to generate 4-8 watts of electricity per footstep, with 5% used to power the tiles LED lighting and 95% left over as useable electricity (Pavegen Systems, 2011). The cost of the eight Pavegen tiles is $30,800, and does not include installation, shipping, maintenance and disposal.

Figure 2: Installed Pavegen Tile

This report is a triple bottom-line assessment investigating the feasibility of implementing the eight Pavegen tiles in the new SUB. The assessment is based on the social, environmental and economic impacts of the tiles over their expected lifespan of 5 years (Pavegen Systems, 2011). An environmental assessment of the product was conducted, which looked into the impacts of the Pavegen tiles from manufacture to disposal, including CO_2 emissions and recyclability. The social impacts of the tiles were also gauged through the use of an online survey, and finally, a financial evaluation was performed which looks into recovering capital costs, as well as costs of shipping, installation, maintenance and disposal by comparing the electricity generated by the tiles with the cost of purchasing that amount of power from BC Hydro.

2.0 ENVIRONMENTAL IMPACT

An environmental analysis of the Pavegen tile is presented in this section. Factors considered include the electrical output, the materials used, and the disposal of the tiles.

2.1 ENERGY OUTPUT

The Pavegen tile makes use of the property of piezoelectric materials that, when compressed, an electric field is generated that can be used to either charge a battery or power a system. The Pavegen floor tiles, during peak hours will be stepped on 926-1889 times per hour during peak hours, 12pm to 2pm, and 0-719 times during off hours, 8am to 12pm and 2pm 5pm (as seen in Appendix B), which works out to about 56 kWh per weekday. This is about how much energy is required to power 560 100W light bulbs for one hour. The environmental cost of replacing that electricity from BC Hydro is approximately 23 tonnes of carbon dioxide (CO_2) per gigawatt hour (BC Hydro, 2011). This means that if the tiles produce 0.000056 GWh, the tiles will save 1.28kg of CO_2 from being produced by BC Hydro per weekday. Based on the expected 5 year lifespan of the Pavegen tile, this translates to reducing CO_2 emmisions by about 1664 kilograms. Note that these calculations are based on the assumption that the tiles will be used to replace power provided by BC Hydro. If this is not the case then they save no CO_2.

2.2 MATERIALS

The top surface of the Pavegen tile is made up of 100% recycled car tires and the frame is made up of 80% recycled materials, consisting mostly of aluminum (Pavegen Systems, 2011). The piezoelectric material used in the construction of the Pavegen tile is not provided, but the most common material used in these types of applications is Lead Zirconate Titanate (PZT). PZT is considered a hazardous material due to the presence of lead (U.S. National Library of Medicine, 2011), so we assume this is not the piezoelectric material used in Pavegen tiles. However since no information is provided and no lead warning is given, we will assume that quartz is the piezoelectric material used.

2.3 DISPOSAL

After their 5 year lifespan, the Pavegen tile can be recycled in sections. The top surface, which is predominately made of recycled car tires, can be re-recycled and converted into playground surfacing, colored mulch, athletic tracks, commercial flooring, and fuel supplements by the BC Tire Stewardship (Tired Stewardship BC, 2011). The frame, which is mostly made of Aluminum, can be recycled at the nearest recycling plant or sold for scrap metal. Finally, the quartz can be recycled using methods similar to those required to recycle glass.

3.0 SOCIAL IMPACT

The social criteria, the most difficult to quantify as it is very abstract, may prove to be the most promising of the three criterion. The most efficient way to obtain concrete data to build a thesis upon was through a survey, directed towards current SUB visitors. The survey was conducted using the online tool SurveyMonkey, "the world's leading provider of web-based survey solutions" (SurveyMonkey, 2011).

3.1 SURVEY RESULTS

The survey mostly consisted of current UBC students that are regular SUB attendants. The results of the survey are graphically represented in Appendix A. Six questions were asked to gage the attitude toward the SUB's pro-sustainability initiative. The questions ranged from the view toward power generation through human kinetic energy using piezoelectricity to frequency of SUB visits. However, the most important question was whether being part of this social and interactive technology would invoke a sustainability-based change beyond the SUB.

From the results, an overwhelming 79% of the survey population would go out of their way to generate green power. This indicates the rich spirit present in the current SUB visitors that will hopefully carry down to the next generation of new SUB visitors. 62% believe that the SUB's initiative will alter their behavior elsewhere, increasing their awareness of sustainability in general. Some suggested changes were decreasing consumption of electricity at home/work and spending less time in the shower to conserve water and thermal energy. A few mentioned bragging rights over other academic institutions that are not as supportive of the sustainability initiative as UBC, citing school pride and character. This is the most important result obtained from the survey. Social change toward increasing awareness is the most beneficial factor of the Pavegen tile.

Ultimately, Pavegen may not be the most efficient source of energy generation, but survey takers chose Pavegen tiles and solar panels (~40% each) over BC Hydro (~20%) as the most efficient technology for the new SUB. This is an indicator of the importance allocated to sustainability by the survey population. This may not be realistic, but it definitely shows drive, motivation and enthusiasm in supporting UBC's sustainability agenda.

3.2 PROFESSIONAL RECOGNITION

Pavegen's numerous awards is the next indicator taken into consideration. A small idea, turned big company, Pavegen was set into motion in 2009 by then 22-year-old Laurence Kimball-Cook. It seemed the only place for this company to go was up. The company received many awards from professional technological cooperation, such as Loughborough University and The Observer (Anonymous, 2011) leading to acclaim from respectable media outlets such as BBC, CNN, the guardian and The Daily Telegraph (Pavegen Systems, 2011). A few of these awards are outlined in the figure below.

Figure 2: List of Honors Awarded to Pavegen

The essence of this indicator is that professional acclaim gives rise to well-deserved branding power, which implies complete devotion to the task at hand by the recipient. In this scenario, professional reputable scientific corporations give Pavegen a nod for their achievements in making the best and most regarded piezoelectric tile on the market. Reputation plays an extremely crucial role in product appreciation. Pavegen tile users would be pleased to know that this is the very same tile that has been discussed and appraised across the board of famous media outlets. Conformity carries an important function as well. The average person would think that if everyone, especially unbiased professionals, believes in the Pavegen tile then public regard would increase dramatically. Basic instinctive human curiosity dictates social interactions. This new technology must be experienced to see what all the excitement is about and to not feel excluded.

3.3 CASE STUDY – SIMON LANGTON GRAMMAR SCHOOL

Laurence Kimball-Cook, 24, was a former pupil of the Simon Langton Grammar School in Kent, United Kingdom. He grew up watching the music video of Michael Jackson's hit, Billie Jean, revolving around a tile that lights up when stepped upon. Little did Pavegen director Kimball-Cook know, it would be the source of inspiration for the Pavegen tile design (Halverson, 2011). He returned home with his invention in January 2011 "determined to have Langton be the first school to benefit from a Pavegen installation"(Frontier PR, 2011). Pavegen installed an energy generating walkway in a busy-1100 student-corridor of Langton, while monitoring the results (Pavegen, 2011). This field test led to the Ethical Business Award for the 'Big Idea Category' shown earlier in Figure 1 (Webster, 2011).

A display board was implemented nearby to light up every time a student stepped on a tile (Frontier PR, 2011). This would provide visual confirmation to a young impressionable student-body that they have personally contributed to reduction of power dependence. It explains important values like involvement, responsibility, participation and awareness of environmental and social impacts by society. Pavegen aims to introduce a new generation of potential entrepreneurs to a socially conscious and aware mechanism of energy generation. It provides a starting point and sparks ingenuity for much needed development in the sustainable technology department.

This assessment aims to impart wisdom in some small yet substantial form to the current UBC student body. Applying the Pavegen tile and other pro-sustainability technologies in the SUB would ignite a rich social presence. Involving students in the energy generation process and delegating responsibility increases awareness of the energy crisis. Also, it provides the right-pathway to finding a well-developed technological solution. In conclusion, the many beneficial social impacts on the SUB visitors provided by implementation of the Pavegen tiles are a strong factor in favor of application.

4.0 ECONOMIC IMPACT

A financial evaluation was performed which looked into recovering capital costs, as well as costs of shipping, installation, maintenance, insurance and disposal by comparing the electricity generated by the tiles with the cost of purchasing that amount of power from BC Hydro.

4.1 COSTS

Our financial evaluation looks into capital costs, as well as additional costs such as maintenance and disposal involved with the Pavegen tiles. The total cost of the eight Pavegen slabs is $30,800 CAD, and requires a down payment of $15,000, with the remaining $15,800 to be paid over three years (Personal Communication, 18 October, 2011). This does not seem costly for a newly innovated technology; however, this does not include the costs of shipping, installation, maintenance, insurance and disposal fees. The products size and weight could be problematic, meaning extra shipping fees may be added. Pavegen, known for its durability, has a lifespan of about five years (Halverson, 2011). The maintenance of the tiles could be a problem since the manufacturer is located in the other side of the globe. Sending these slabs for repair would not only take quite a lot of time, but it also is expensive. Not only that, but to install the tiles a designated professional technician must travel from London to UBC. The initial cost quoted does not include any of these additional fees.

4.2 SAVINGS

Pavegen's innovative technology can convert human kinetic energy into green electrical energy. 5% of this green energy is used to light up the tiles LED's and rest of the harvested energy is stored in lithium cells to be used for lighting at night or other applications such as a display board (Pavegen Systems, 2011). In British Columbia, BC Hydro is the main electricity provider throughout the province and their main power is produced hydroelectrically. Hydroelectric energy is considered green energy compared to coal or gas power plants and its efficiency is already high enough to provide electricity to millions of households (Government of British Columbia). Pavegen is simply bringing the process of harvesting green electricity to a place where it will affect the way people view green energy and sustainability. The financial

investigation focuses on determining the amount of green energy produced by the Pavegen tiles and comparing it to the cost of green energy purchased from BC Hydro.

Important information was provided by our project stakeholder, Chris Karu, as well as by the Pavegen website. The most important information is that each Pavegen tile produces 4 to 8 watts per step (Pavegen, 2011). This means that it is possible to measure how much human kinetic energy could be converted to electricity if numbers of steps are counted. In order to calculate the amount of steps the Pavegen tiles would receive, the traffic through the current SUB was measured at peak hours and off hours. The current SUB has many entrances and due to shortage of team members research was only able to cover the main entrance, which is where the Pavegen tiles would be located in the new SUB.

Before the data was collected, it was important to discuss the nature of population traffic in the SUB. The SUB is part of the University and consists of commercial markets that target students and staff. Since it is a mostly commercial based building, the steps will be greatly influenced by the day of the week and time of the day. It was, therefore, suggested to collect data on peak hours and off hours to show that number of steps is time variant. In addition, it was assumed that there will most likely be less traffic through the SUB on weekends and during winter/summer breaks. Data was collected over three days. The peak time started at noon, when most regular classes end, and lasted until about 2pm. Off hours were considered to be from 8am to noon and 2pm to 5pm. The numbers fluctuate due to time of the day, and day of a week as previously mentioned. When the data was collected, it was during the midterm examinations, so it was assumed that students are more likely to stay inside to study rather than going to the SUB building. These numbers represents an ideal situation. During the off hours and at night, traffic numbers could go down to zero. The data collected is located in Appendix B.

Using 8 watts for each step and using numbers from Appendix B, the amount of energy generated during the peak hours and off hours was calculated. Because Pavegen tiles produce DC electricity, it is necessary to convert this energy to AC, because BC Hydro electricity is AC. In this conversion, there is a 20% loss in energy. The maximum steps in peak/off hours times the 8 watt rating would result in maximum DC energy output, so only 80% should be accounted for

once converted to AC. It was calculated that during peak hours, one tile produces 12kWh ideally. During the off hours, it produces 5kWh ideally. These results can be compared to the price of BC Hydro electricity, which is $0.0861 per kilowatt hour (Manitoba Hydro, 2011).

Using the above price of BC Hydro electricity, considering two peak hours and seven off hours in a day, five days in a week, and thirty-nine school weeks in a year, UBC could save approximately $37,608.48 over the tiles 5 year lifespan. Since in total, the eight tiles cost $30,800, UBC could save $6808.48, which could be used to cover some of the additional fees involved with the Pavegen tiles.

5.0 CONCLUSION

Upon investigation of the environmental, social and economic impacts of implementing eight Pavegen piezoelectric tiles in the new SUB building, the following conclusions were drawn:

- Over their 5 year lifespan, the Pavegen tiles could reduce CO2 emissions caused by the production of non-green electricity by 1664kg.
- The Pavegen tiles are almost 100% re-recyclable.
- Based on results from the survey, the Pavegen tiles will promote involvement, responsibility and participation in UBC's sustainability initiative.
- Based on the Simon Langton Grammar School case study, implementation of the Pavegen tile has been proven successful.
- Over their 5 years lifespan, the energy produced by the Pavegen tiles will save UBC approximately $38,000 in purchased BC-Hydro power. This money can be used to recover the capital costs of the tiles, as well as cover maintenance and disposal fees.

In conclusion, our research team recommends that the eight Pavegen piezoelectric floor tiles be installed in the new SUB.

REFERENCES

Alma Mater Society of UBC (2010). *My New Sub*.
Retrieved from http://mynewsub.com/site/

Anonymous. (2011). *Pavegen floor tiles recognised at ethical business awards*.
Retrieved from http://ezproxy.library.ubc.ca/login?url=
http://search.proquest.com/docview/872087267?accountid=14656

BC Hydro. (2011). *Climate Action & Greenhouse Gases*
Retrieved from
http://www.bchydro.com/about/our_commitment/sustainability/greenhouse_gases.html

Frontier PR, (2011). *One Step Beyond for Kent*.
Retrieved from http://www.frontierpr.co.uk/news/press_releases/
onestep_beyond_for_kent_grammar_school/

Government of British Columbia. (no date). *The BC Energy Plan: A Vision for Clean Energy Leadership*. Retrieved November 23rd, 2011, from the Government of British Columbia: Energy plan: www.energyplan.gov.bc.ca

Halverson, N. (2011). *Tiles Harvest Energy of Your Footsteps (Or Dance Moves)*. Retrieved from http://news.discovery.com/tech/harvesting-foot-energy-111021.html

Manitoba Hydro. (2011). *Utility Rate Comparisons*.
Retrieved from http://www.hydro.mb.ca/regulatory_affairs/energy_rates/electricity/
utility_rate_comp.shtml

Pavegen, (2011). *Pavegen: Generating energy from footsteps at a busy school*.
Retrieved from http://www.youtube.com/watch?v=-Sp2QiKATwY

Pavegen Systems. (2011). *Product Specification Document PG/006* .
Retrieved from DropBox on Oct. 25th, 2011.
http://dl.dropbox.com/u/42742762/New%20SUB/Pavegen%20Overview.pdf

Pavegen Systems. (2011).
Retrieved from http://www.pavegen.com/

SuveyMonkey. (2011).
Retrieved from http://www.surveymonkey.com/mp/aboutus/

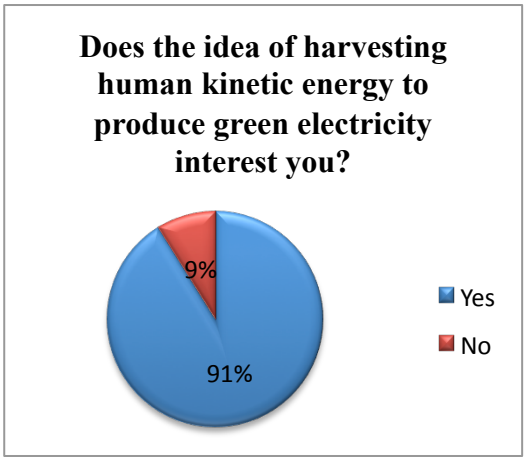
Tire Stewardship BC. (2011).
Retrieved from http://www.tirestewardshipbc.ca/

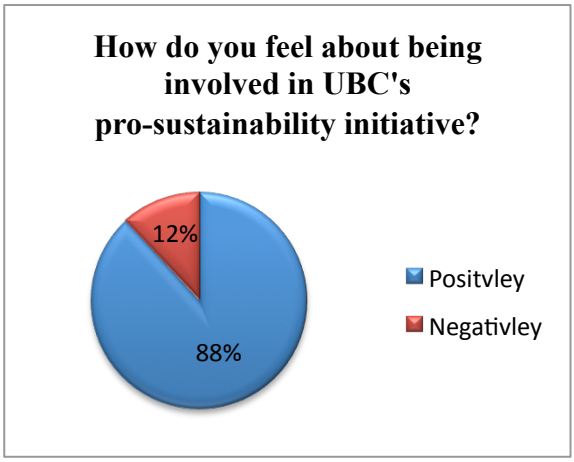
UBC (2011). *CIRS*.
Retrieved from http://sustain.ubc.ca/hubs/cirs

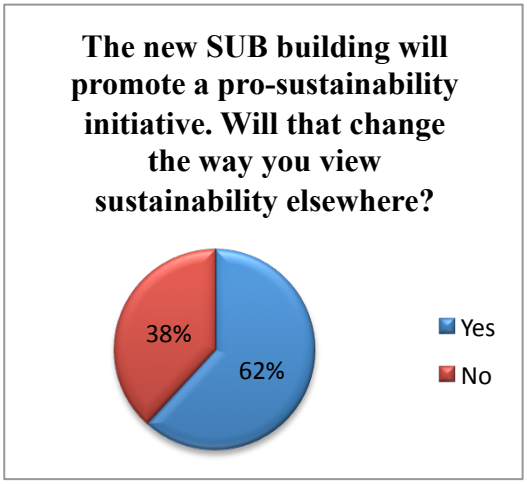
U.S. National Library of Medicine. (2011). *Haz-Map*.
Retrieved from http://hazmap.nlm.nih.gov/cgi-bin/hazmap_search?queryx=12626-81-2&tbl=TblAgents

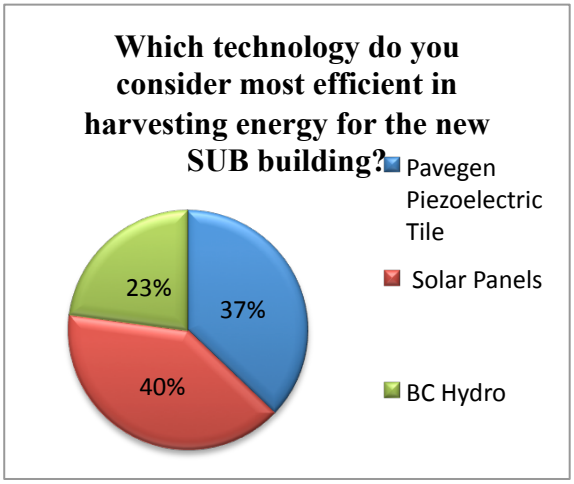
Webster, G. (2011). *Green sidewalk makes electricity -- one footstep at a time*.
Retrieved from http://www.cnn.com/2011/10/13/tech/innovation/pavegen-kinetic-pavements/index.html

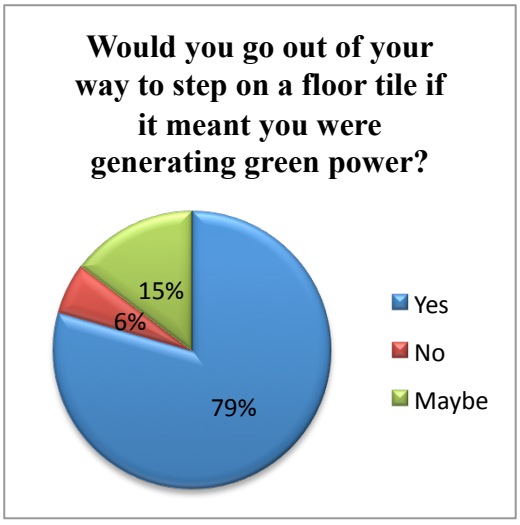
APPENDIX A – SURVEY RESULTS

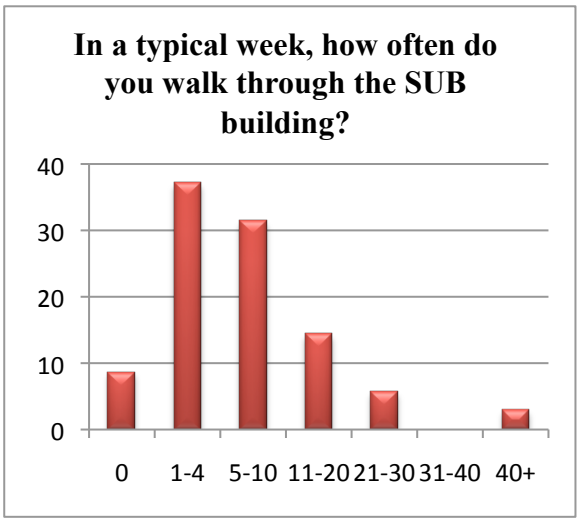












APPENDIX B – STEP COUNT

	Day 1	Day 2	Day 3
Number of steps taken in a peak hour	1756	1889	926
Number of steps taken an off hour	841	800	719