UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into Pavegen Energy Generating Steps at the New Student Union Building

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APSC 261

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ABSTRACT

"An Investigation into Pavegen-Energy Generating Steps at the New Student Union Building"

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The purpose of this report is to evaluate the feasibility of installing Pavegen energy generating steps in the second level entrance of the new Student Union Building (SUB) at the University of British Columbia (UBC). After researching academic papers, peer review articles, and consulting online public opinion, a triple bottom line assessment is performed in order to assess the potential short and long term social, environmental, and economic implications of the proposed project.

Pavegen steps harvest kinetic energy from people walking on a slab, and convert it into electricity that can be stored or used for a variety of different applications. The fundamental component of a Pavegen slab is a piezoelectric material that generates electricity when it is compressed. Potential social impacts are predominately positive, among which include the strong possibility of creating awareness of sustainable energy usage. In addition, installing the steps would be the only known installation of piezoelectric slabs in the lower mainland, the technology would significantly stand out as unique for the local geographical area, and thus creating more social awareness of UBC's efforts to reach its green initiative. Subsequently, there are no foreseeable significant environmental problems with installing the steps, as manufacturing is done with recycled materials, and transportation is done through lower carbon footprint methods. However, evaluating the installation cost shows that the steps are not economically viable, but at the same time, there is not enough information or in depth calculations to provide a sufficiently strong reason to rule out the installation of the steps based on issues of associated costs.

Based on the triple bottom line assessment, it is recommended that the Pavegen steps be installed at the new SUB, as the potential positive social and environmental impacts outweigh the foreseeable costs associated with purchasing and maintaining the product.

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GLOSSARY

Piezoelectric Effect	An external stress generates an electric polarization in piezoelectric materials leading to surface charges.
Piezoelectric Materials	Capable of holding and creating charge inside crystal structure occur naturally and can be manufactured (i.e. Quartz).
Poling	Required for not naturally poled piezoelectric materials, heating the material above the Curie temperature and applying high electric field.

LIST OF ABBREVIATIONS

UBC - University of British Columbia point grey campus

SUB – Student Union Building

AMS- Alma Masters Society operates and manages services for students campus wide

1.0 INTRODUCTION

The Pavegen-energy generating steps proposed for the new SUB are to be installed in the new SUB atrium. The steps generate electricity utilizing the piezoelectric affect converting kinetic energy into electrical energy to power a display board to demonstrate the sustainable features of the new SUB. In order to evaluate the proposed Pavegen steps for the New SUB a triple bottom line assessment is performed, examining the social, environmental, and economic impacts of the Pavegen energy generating steps.

1.1 THE PIEZOELECTRIC EFFECT

The Piezoelectric Effect was first discovered by Jacques and Pierre Curie in 1880, any external stress created on a piezoelectric material generates an electric polarization in the piezoelectric material leading to surface charges. If the surface of the material has metallic electrodes, these can take on surface charges of opposite sign with respect to the polarization of the piezoelectric material. This can be applied to generate electrical charges when force is applied to the material (Stoeber, 2011).

1.2 PIEZOELECTRIC MATERIALS

Piezoelectric materials are specialized materials with the charges distributed asymmetrically within the crystal structure, the piezoelectric effects within the material are strongly orientation dependent (Stoeber, 2011). The materials occur naturally but can also be manufactured; some common natural materials are Quartz (SiO_2), Triglycine sulfate (TGS) and Lithiumtantalat ($LiTaO_3$) (Stoeber, 2011).

1.3 PAVEGEN ENERGRY GENERATING STEPS

The Pavegen-energy generating steps were developed by Laurence Kemball-Cook a 25 year old engineering graduate student who developed a prototype step in his final year of school in 2009. The step generates transforms kinetic energy depressing approximately 5 millimeters and converting the kinetic energy into electrical energy (Webster, 2011).

The Pavegen System could power lights, computers, automatic doors and ticket machines at tube stations information displays, street lighting, shop frontages, train and bus timetables and way finding solutions. The slab glows when being stepped on indicating to the user it is creating electricity the rest of the energy is stored in Lithium

Polymer batteries. With the energy generated 5% is used to illuminate the step and 95% is stored in the on board batteries. Each slab is able generates 2.1 watts per hour when located in an area with high footfall and is stepped on with a footstep every 4-10 seconds. The steps are mad of various recycled materials with minimal environmental impact the top surface is recycled rubber car tires and toughened glass, internal components are recycled aluminum and the exterior housing is marine grade 316 stainless steel. The system requires annual servicing and is designed to withstand 5 years of use equating to 20 million steps in indoor and outdoor environments. The system can be retrofitted into existing interior or existing environments and depending on the application the buyback period is approximately 1 year or less (Specified, 2010) .

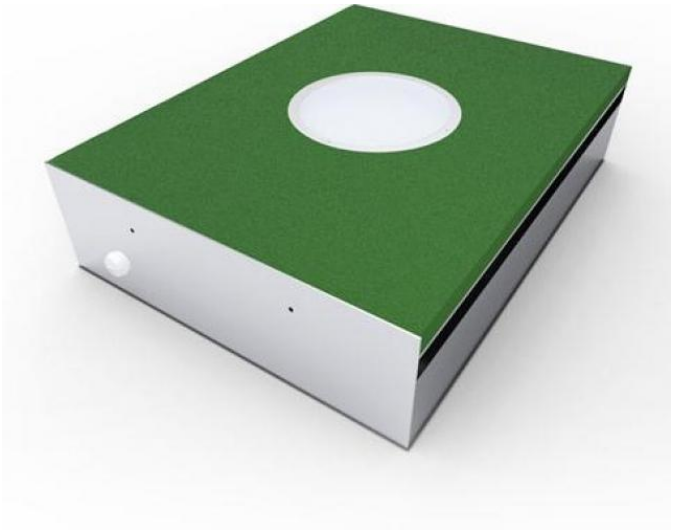

Figure 1: Pavegen Energy generating steps (Pauw, 2011)

The first commercial application of the steps is 20 tiles will be scattered along the central crossing between London's Olympic stadium and the recently opened Westfield Stratford City mall with an estimated footfall of 30 million people in the first year. This will provide enough power to supply half of the malls outdoor lighting needs. Initial testing is already ongoing at a school in Kent (southeast England) where 1100 kids have been stepping on the slabs (Webster, 2011).

The Pavegen slabs are currently manufactured in the United Kingdom on a per order basis. The cost of the slab is not specified yet since the current price will drop substantially once the step goes into mass production (Webster, 2011). The steps

proposed for the new SUB atrium will consist of a total of 8 steps with approximate purchase price of $30,800 CDN excluding instillation, the steps will come from the United Kingdom and installed by a firm determined by Pavegen. .

2.0 NEW SUB PAVEGEN-ENERGY GENERATING STEPS IMPLEMENTATION

2.1 PAVEGEN-ENERGY GENERATING STEPS DETAILS

The Pavegen steps proposed for the New SUB are a relatively new technology, many of the details of the actual mechanism that produces electricity is closely held by Pavegen, but other details of the steps are available.

2.1.1 DETAILS

The Pavegen system can be installed into new or existing spaces, in the New Sub it will be a new instillation, but the slabs can be retro-fitted into pavement and flooring in either interior or exterior spaces. The light that glows when the step is depressed creates a strong visual link between the slab and a sustainable attitude allowing the public to actively take part in the energy saving process. The possible buyback period depending on the project application can be 1 year or less (Specified, 2010).

2.1.2 POWER

Each Pavegen step is capable of generating 2.1 watts per hour when located in an area such as the New SUB in an area with high footfall. In order to achieve 2.1 watts per hour the slab must stepped on with a footstep every 4-10 seconds. During testing at trial sites 5 hours of walking at this rate will generate enough power to illuminate a bus stop light of over 12 hours (Specified, 2010). This energy generation rate should be sufficient to power the proposed display board the steps are intended to power but since the SUB footfall rate is not constant during the year this could propose a challenge for the system. With the energy generated from each footstep 5% of the energy illuminates the low energy LED lamp and the other 95% of the energy is stored within Lithium Polymer batteries either in each Pavegen step or in a cluster of 5 (Specified, 2010).

2.1.3 MATERIALS & DURABILITY

The Pavegen slabs are manufactured utilizing as many recycled products as possible. The top stepping surface is constructed from recycled rubber and car tires. The internal components excluding the mechanism that generates the electricity it is composed of recycled aluminum and the exterior housing is marine grade 316 stainless steel. The low energy LED is covered by toughened clear glass with an optical film. (Pavegen, 2011). The Pavegen steps require annual servicing and are designed to withstand 5 years or 20 million steps in indoor and outdoor environments. The steps are engineered to withstand harsh winter conditions without corrosion and the removable gear tray allows for hassle free servicing (Specified, 2010). The Pavegen step proposed for the New Sub would require servicing every year and possible replacement of the steps during the life time of the building depending on usage.

2.1.4 MISCILLANEOUS

The Pavegen slabs are designed with anti-tamper stainless steel bolts to prevent unauthorized personnel accessing unit. Shock absorbing dampers have been implemented into the steps to prevent damage to the mechanism when large vehicles or high impacts are placed on the Pavegen slab. The top surface of the Pavegen slab is available in a variety of colors grey, red, blue and other mixes. Custom branding logs can be added to the central lamp (Specified, 2010).

2.2 PAVEGEN LOCATION NEW SUB

The Pavegen Step will be located in the New SUB atrium on level 2 adjacent to the pi r squared outlet with two slabs side-by-side on each step landing space with a total of 8 Pavegen steps. This location will have a significant amount of traffic help to maximize step usage and bring awareness to the Pavegen tiles.

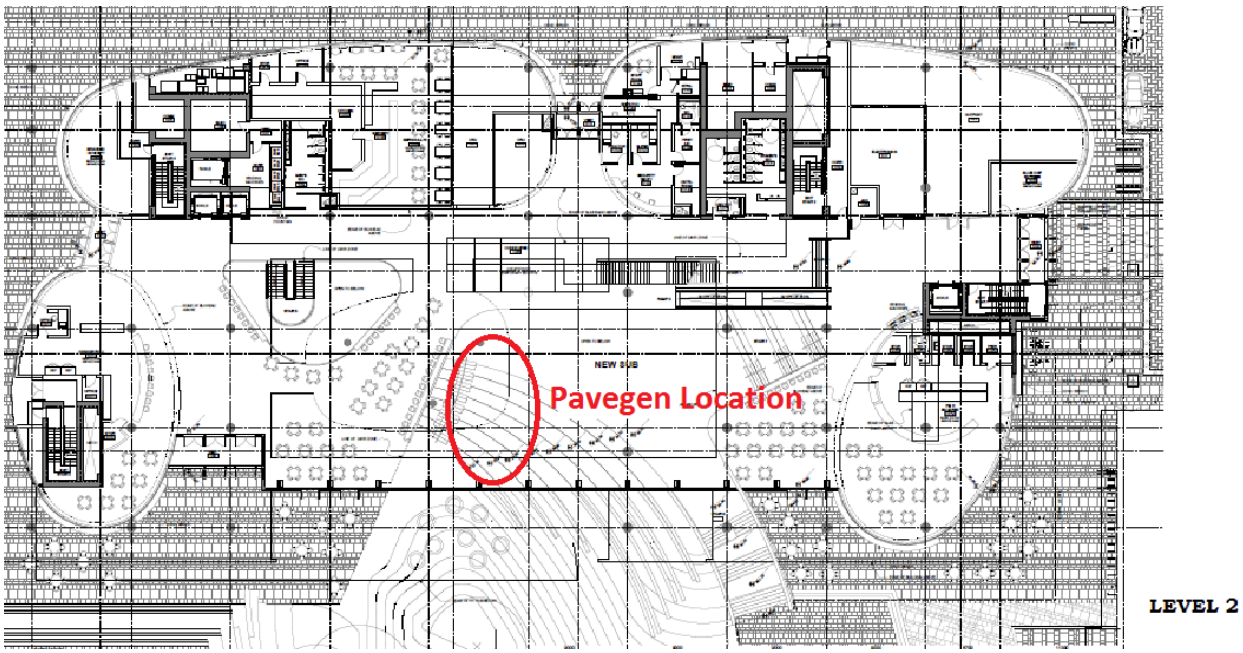

Figure 2: New SUB Level 2 Pavegen Location

This area will provide the maximum amount of exposure for the steps and also incorporate the knoll as part of the Pavegen project. This space will also allow for space for events to be held showcasing the Pavegen steps as part of the New SUB atrium.

3.0 SOCIAL IMPACT

With up to five thousand people entering the current SUB each day, it is clear that there will be a high level of foot traffic though the entrance of the new SUB once it is built (Kreitzman, 2008). For this reason, it is important to analyze and consider possible long term social implications that Pavegen steps may have on the population of UBC. The following sub-sections outline and discus such implications in further detail.

3.1 POSITIVE IMPACTS

The fact that an individual can generate electricity with virtually no extra effort on their part will help people understand that sustainability is not something that will make people's lives more difficult. It can be as easy as walking over a soft pad on the ground. Graemer (2010) states that the slab only needs to compress 5 mm to achieve energy harvesting. It can even be suggested that a small amount of compression can make a slab more comfortable to walk on.

An advantage to having a block on the ground that lights up when a person steps on it is that not much effort needs to be put into creating awareness about the technology. In contrast to something such as building walls made from reclaimed pine beetle wood (Drexhage, 2011), as done in the CIRS building at UBC's Vancouver campus, brightly lit Pavegen steps will stand out and will easily attract attention. Furthermore, glowing steps can be visually appealing, and should add to the sustainable and futuristic atmosphere of the new SUB. *Imagination of the People* (2011) claims that a Pavegen step "... informs the passerby of their contribution, but also reinforces a sustainable attitude..." Subsequently, they claim that the steps will result in "... an increased awareness of the energy that is continually created and expended by each individual." By installing the steps, UBC can contribute further towards helping shape the way people view sustainable change.

Pavegen steps have been installed in various places in Europe, mainly in the UK. According to *Imagination of the People* (2011), the technology may be implemented in famous, high traffic places across the world in the near future. For instance, there are plans to equip Time Square in New York, the Eiffel Tower, and Disney Land with energy harvesting steps. If this technology is implemented and showcased in the new SUB, it

may, assuming it is received well by the people using it, spark the interest of local researchers and investors. With further investment into energy generating steps, it is possible for Vancouver to rise to the forefront of this new emerging area of technology, and help the city remain as one of the lowest carbon footprint cities in North America (Cole, 2011). In essence, the steps have the potential to have significant positive impacts not just on the users who use the technology on a daily basis, but for people who invest in and are involved in the research and development of creating more efficient, cheaper, and visually appealing steps in the future.

3.2 NEGATIVE IMPACTS

In addition to the various social advantages of installing Pavegen steps at the entrance of the new SUB, there are some potential negative effects that must be considered. An initial question that may come to mind when seeing the steps for the first time is that of how much they cost to implement. Considering the high cost of installation, people may develop a bias against the steps and may feel that the economic cost outweighs the potential social benefit. Furthermore, a high number of students are against increases in AMS, potentially impelling one's bias against Pavegen steps (Krietzman, 2008).

In an extreme case, an individual may have ethical issues with regards to using human power to generate electricity. Further research should be done into what people think about the idea, in addition to analyzing public opinions on the matter.

3.3 POTENTIAL IMPLEMENTATIONS

There are many ways Pavegen steps could be used to promote sustainable energy usage. The energy harvested by the steps can be counted and displayed on the proposed display boards. A suitable location would be near the entrance where the proposed steps may be placed. When a person walks into the building, they can see a running total on the screen of how much energy they have saved. However, since the general public may have a difficult time understanding the magnitude of their energy generation, a simple, effective measure of the energy must be decided upon. For example, if the display boards could display how many light bulbs the captured energy can power over a given time, the impact of the collective effort of the people using the steps could be easily comprehended.

Graemer (2010) outlines how only 5 percent of the total energy harvested goes towards lighting the slab, leaving 95 percent to power an external load. Considering this, one plan might store the energy harvested throughout the day, and at night, to use the energy to light a set of lights near the entrance of the building. If people were to see that they could essentially power such lights at night with no running utility costs, they might be more willing to accept the idea of the potential constructive effects energy capturing can have.

4.0 ENVIRONMENTAL IMPACT

The proposed Pavegen tiles for the new SUB will create an environmental impact during their manufacturing, transportation, instillation, operation and end of life. During the life cycle of the product the steps will be helping to generate electrical energy and increase awareness of sustainability. We will be examining the environmental impact of the Pavegen steps during all phases of its life cycle.

4.1 MANUFACTURING

The Pavegen steps are a relatively new technology with only a few commercial instillations and the company has not begun mass production of the steps. The steps are produced on order, and the factory is located in the United Kingdom (Webster, 2011). Few details are known about the manufacturing processes and some of the details are not given on the mechanism that converts kinetic energy into electrical energy. The major materials being used in the steps are recycled aluminum and rubber, stainless steel, glass and lithium polymer batteries (Specified, 2010). The recycled materials will have minimal environmental impact since the materials are being reformed not created, and the rubber is from car tires helping to eliminate other environmental issues. The other components stainless steel, glass, and batteries would have to be created using energy intensive processes but these materials can be recovered at the end of life reducing the environmental impact. Without any specifics on the assembly of the steps we cannot determine the environmental impact (Pavegen, 2011). The steps Pavegen steps are attempting to produce a low environmental impact during manufacturing making use of recyclable materials.

4.2 TRANSPORTATION

The Pavegen steps for the New SUB will need to be transported overseas from the United Kingdom to Canada. Depending on the selected transportation method this will generate a different environmental impact. Since the New SUB project is still in the design stage and completion is not expected till 2014 we will be able to use slower more environmentally friendly options to transport the steps. Shipping the steps by ship and overland railway will have a significant reduction in carbon footprint compared to shipping by air.

4.3 INSTILLATION

The steps instillation is will to be determined by Pavegen and this has not been determined. A local firm to install the steps is preferred and will be sourced by Pavegen if a suitable firm is not found Pavegen will install the steps. It greatly reduces the environmental impact if a local firm installs the steps, instead of flying several Pavegen installers to UBC.

4.4 OPERATION

During operation the Pavegen steps will have a positive impact on the environment generating small amounts of electricity. The steps generate 2.1 joules of electrical energy with every step (Specified, 2010). The current SUB has an estimated foot fall of 8000 people entering and exiting the current SUB (Limkhuntham, Ma, Quach, & Yutuc, 2010). We predict that half of the people entering the SUB will step on one of the 8 steps will produce 8400 joules of electricity per day.

4.5 END OF LIFE

The steps will last 5 years of 20 million steps before needing to be replaced; the steps will need to be recycled at that point. The rubber and the aluminum can once again be recycled to produce other products or new Pavegen steps. The stainless steel can also be recycled and used to create new products. The lithium ion batteries are also able to be recycled with some of the various mechanical and chemical techniques available to recover some of the materials (Xu, 2008). Other than the components we do not know about in the steps the end of life for Pavegen will possible be able to be recycled.

5.0 ECONOMIC IMPACT

In this section the economic analysis of the energy generating steps is performed. Various aspects are taken into consideration, such as deployments, cost, and maintenance in order to determine the benefits of the energy generating steps. UBC, as any other organization, needs to make decisions based on firm economic footing and as such an in depth analysis of the technology is needed.

5.1 DEPLOYMENTS

Prior to considering the deployment of a new technology, it is important to put that technology into context with the rest of the world as well as the society it is being deployed in. This will allow for a better view of the status of the technology from a perspective of the other investors.

At Club Surya in London, England deploys the Pavegen steps in order to work towards sustainability. Club Surya estimates that the energy generated by this floor with be enough to cover 60 percent of the club's energy requirements (Henderson, 2009). Although

The Sustainable Dance Club in Rotterdam, Netherlands makes use of gears attached to the dance floor instead of piezoelectric materials to generate electricity. A tile of the 65 cm by 65 cm dance floor can be displaced approximately 1 cm and can generate anywhere from 2 to 20 W of electricity (Sustainable Dance Club, 2007).

During September 2011, Pavegen received an order from the London 2012 Olympics Site to install their energy generating steps in a crossing between the Olympic stadium and the Westfield Stratford Shopping Centre. The current progress appears to be successful, as the Olympics brings foot traffic of hundreds of thousands of people from around the world. Showcasing the steps on such an occasion will give rise to tremendous amounts of energy being generated.

More locally, Translink, a public transportation company in Vancouver, Canada conducted a study in 2003 at the Metrotown Station, estimating that a peak of 13,100 persons board the skytrain on an average Sunday. This study was helpful in their consideration towards the deployment of the piezoelectric tiles (Creative Transportation Solutions, 2003).

5.2 COST

In order to implement the piezoelectric steps, an initial investment of $30,800 is required. Such a substantial initial cost is something to be cautious of, especially due to the infantile nature of the technology. According to Elin Tayyar, AMS VP Finance, the cost would amount to approximately three quarters of a dollar per student, and he is not convinced that everyone will agree to contribute.

Since the technology is still fairly new, there have not been any financial figures outlining a return on investment from other investors. However, there have not been any negative responses to the technology which suggests that the outcomes may simply be en-route. The fact that the steps can output 2.1 watts of electricity per hour given that they are stepped on at least once every 10 seconds is something that needs to be considered.

The SUB on the UBC campus is not a source of constantly heavy footfall, in contrast to places such as the bus loop. The next thing to consider is the placement of these steps, as if the places to buy food in the SUB, where most of the foot traffic normally lies, are located away from the stairs, the use of Pavegen steps will be substantially decreased.

5.3 MAINTAINENCE

The maintenance of these steps is another factor to consider before coming to a decision. The design of the steps and the material involved allow the steps to be quite durable. According to Pavegen, one step will require replacement or refurbishment every five years, during which time it is expected to work without major failures. Another feature of these steps is their tamper proofing. The development company has installed safety mechanisms that prevent others from tampering with the step.

6.0 CONCULSION AND RECOMMENDATIONS

The Pavegen energy generating steps are slabs made from piezoelectric material, that convert kinetic energy, harvested by a person stepping on and compressing the piezoelectric material, into electricity, which can be stored or used for various purposes. In order to determine whether or not these steps should be installed in the new SUB, a triple bottom line assessment is conducted. A triple bottom line assessment considers the economic, environmental, and social impacts of a project, in order to assess its value, ultimately to determine whether or not a recommendation should be made to pursue the project. From a social point of view, Pavegen steps are an excellent way to increase awareness and to showcase new technology to the local population. It can provide a trial run to demonstrate to outside investors whether or not such technology is viable and practical, potentially sparking their interest if the project is a success. However, more data on public opinion should be collected before a final decision is to be made. Furthermore, since the slabs are made from recycled material, and transportation is done in ways that have a smaller carbon footprint than most transportation methods, there are no major environmental concerns regarding the manufacturing and transporting of the product. As an economic consideration, there is a $30 000 dollar cost to acquiring and installing the steps, which does not include the recurring, periodic maintenance costs. However, considering that the total budget of the SUB is over $100 million dollars, the cost to be the first organization to bring Pavegen to Vancouver is small. Hence, after conducting a triple bottom line assessment of the Pavegen energy generating steps, it is recommended that, despite the financial investment and potentially long payback period, the project should be considered by the design committee and stakeholders of the new SUB, due to the strong potential for social benefit and the unforeseeable negative impacts on the environment.

REFERENCES

Absolute Astronomy. 2010. *Metrotown.* www.absoluteastronomy.com/topics/Metrotown (accessed 10 Jun 2010).

Cole, G. (2011, October 28). Local initiatives: cities take big steps to trim carbon footprints. *Financial Times*. Retrieved November 3, 2011, from http://dubaipropertyforsale.net/tourism/news/PaveGen.html

Creative Transporation Solutions. 2003. *2003 SKYTRAIN SYSTEM MONITORING PROGRAM – SUMMARY REPORT.* http://www.skytrain.info/retail/2003_SkyTrain_System_Monitoring_Program_Summary_Report.pdf (accessed 11 May 2010).

Drexhage, G. (2011, February 20). Vol. 56 | No. 2 Â« UBC Public Affairs. *UBC Public Affairs*. Retrieved November 10, 2011, from http://www.publicaffairs.ubc.ca/2010/02/08/vol-56-no-2

Graemer, J. (2010, February 25). Pedestrian footsteps, converted into energy | Springwise. *Springwise | New business ideas, trends and innovation*. Retrieved October 18, 2011, from http://www.springwise.com/eco_sustainability/pavegen/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%253A+springwise+

Henderson, Tessa. 2009. *Energy harvesting dance floors.* Energy Harvesting Journal. http://www.energyharvestingjournal.com/articles/energy-harvesting-dance-floors-00001613.asp?sessionid=1 (accessed 14 May 2010).

Imagination for People. (n.d.). *Imagination for People | Identify and support imaginative social projects*. Retrieved October 20, 2011, from

http://www.imaginationforpeople.org/en/project/pavegen/

M. Kreitzman, “March 2008 AMS Referendum Results,” UBC Insider, 2008.

Pavegen. (2011, October 20). *Pavegen*. Retrieved Novemeber 11, 2011, from Pavegen Systems: http://www.pavegen.com/

Specified, N. (2010, October 26). *Pavement Power*. Retrieved October 15, 2011, from Architecture World News: http://www.worldarchitecturenews.com/index.php?fuseaction=wanappln.projectview&upload_id=12560

Stoeber, B. (2011, October 26). Mech 420 Sensors and Actuators. Vancouver, British Columbia, Canada.

Sustainable Dance Club. 2007. *Sustainable Dance Floor*. http://www.sustainabledanceclub.com (accessed 14 May 2010).

Webster, G. (2011, October 13th). Retrieved October 15th, 2011, from CNN: http://www.cnn.com/2011/10/13/tech/innovation/pavegen-kinetic-pavements/

Xu, J. (2008). A review of processes and technologies for the recycling of lithium-ion secondary batteries. *Journal of power sources*, 512-526.