UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation Into Using Electricity Harvesting Elliptical Machines As A Renewable Energy Source

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APSC261

November 30, 2010

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ABSTRACT

This report investigates the feasibility of installing electricity harvesting elliptical machines in the University of British Columbia's new Student Union Building (SUB). These machines convert the kinetic energy exerted by those exercising into electrical energy which can be used to power the SUB. The ReRev system achieves this by retrofitting elliptical machines with a small electrical generator.

A triple bottom line assessment was performed which analyzed the environmental, social and economic impacts of installing this system. After investigation, it was concluded that installing the ReRev system would promote energy conservation, encourage healthy living and would enlighten students about creative ways to generate energy. In addition, the electricity generated would offset the cost of purchasing the machines. Finally, the use of these machines over their lifetime would cause a net reduction of greenhouse gas emissions. This report recommends installing 15 ReRev machines in the space already allocated for Alma Mater Society Recreation Facilities in the new SUB.

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LIST OF ABBREVIATIONS

AC - Alternating Current

AMS - Alma Mater Society

DC - Direct Current

GHG - Greenhouse Gas

LEED - Leadership in Energy and Environmental Design

MRES - Micro Renewable Energy System

SUB - Student Union Building

UBC - University of British Columbia

1.0 INTRODUCTION

This report evaluates the installation of 15 ReRev elliptical-training units within the University of British Columbia's new Student Union Building whose construction is slated to begin in 2012. This proposal consists of a triple-bottom line assessment evaluating the environmental impacts of manufacturing and disposing of this technology, its energy output, and the resulting financial and social benefits it incurs.

This technology qualifies as a Micro Renewable Energy System (MRES). It harvests kinetic energy from the Precor EFX546i elliptical machine (Figure 1) retrofitted by ReRev. The company was started by engineering-entrepreneur Hudson Harr, and is based out of Clearwater Florida. Such 'green' gyms have been installed in a multitude of universities with great success. The list of participants is made available in [1]. The exercise room suggested in this paper would be based out of area within the AMS Recreation Facilities and would be central to student activity.

Figure 1: Precor EFX546i Elliptical Machine

Retrieved from: http://www.precor.com/comm/en/efx-com/546i

After discussing the environmental impacts of these machines during their lifecycles, a social evaluation of the student population is conducted. This deals primarily with health and educational benefits as well as general willingness of students to take part in such an idea. Much of the data used was collected from other educational institutions, mostly universities in the United States, having installed green gyms.

A financial assessment, including recovering a portion of capital costs in terms of savings in BC-hydro energy, is conducted alongside a broader analysis of MRESs in our society.

The concept of having an open-to-all energy-producing gym would be a visible demonstration of the AMS's Leadership in Energy and Environmental Design (LEED) goals for the building and offer the students a chance to both give back and make use of an innovative facility.

2.0 ENVIRONMENTAL IMPACT

In this section, the environmental impacts of the ReRev system are discussed. In particular, the environmental repercussions of the construction and disposal of the ReRev system, its electrical energy output, and its potential for environmental education are considered.

2.1 ENERGY OUTPUT

When someone exercises on an elliptical machine, they are burning calories; converting the potential energy stored in their bodies into kinetic energy. This kinetic energy is dissipated as heat inside the machine by a power resistor. Essentially, this human generated energy is wasted--the heat dissipated increases the temperature in the room. Instead, using the ReRev system, elliptical machines can be retrofitted with generators that harvest the kinetic energy, converting it to DC power. The DC electricity can then be sent to an inverter that will convert it into the AC electricity suitable for powering the building.

An average 30 minute workout can create 50 watt hours (Wh) of electricity: this is enough energy to charge 6 cell phones or run a laptop for 1 hour [1]. One unit does not produce much energy; however, when put together, the energy output is more substantial. For example, if 10 machines are used for 8 hours per day, the energy production jumps to 12 kWh--enough to power 240 laptops for an hour. According to BCHydro [2], 25 tons of CO_2 are released per GWh of power consumed. Using this figure, one ReRev machine would save 0.2 kg of CO_2 per day. Over the entire lifetime of the machine, this translates to 730 kg of CO_2.

The ReRev machines can also have displays on them on which the user can see how much electricity they are generating during their workout. This aligns with the new SUB project's goal of "[providing] advanced building systems visibility and visible systems monitoring" [3].

2.2 MANUFACTURING

It is not possible to avoid the fact that the manufacturing processes for elliptical machines has negative environmental impacts. The steel required to construct each machine requires on a large amount of energy to be processed from the ore, purified and formed. The Precor EFX546i elliptical machine has a mass of 144 kg [4], so assuming that it has 125 kg of steel in it, the production of that quantity of steel would release on average 312.5 kg of CO_2 using data from [5]. Furthermore, plastic used in the machine's construction produces waste and hazardous materials during the manufacturing process. However, over the machine's entire lifetime, approximately 730 fewer kilograms of CO_2 enter the atmosphere. Which means, that despite the large amount of green house gasses (GHGs) that are released during construction, the machine still creates a net reduction in GHG emissions over its projected lifetime.

2.3 ENVIRONMENTAL AWARENESS

Compared to other renewable energy sources, the ReRev system does not provide as much energy as other technologies such as solar power. However, the main goal of installing the ReRev system is not the production of energy – rather it is to promote sustainability and environmental awareness. Energy harvesting is just the by-product of this. People should be informed about other novel ways of producing renewable energy such as energy harvesting from gym equipment. When students use the ReRev system, it will entice them to think creatively about renewable energy production.

2.4 DISPOSAL

At the end of their lifetime, ReRev machines can be recycled in the same way as other large appliances such as stoves and dishwashers. The old ReRev machines can be taken to businesses such as Happy Stan's Recycling here in Vancouver where the steel frame can be turned into scrap metal, the plastic components can be recycled, and the E-waste can be dealt with in a sustainable manner.

3.0 SOCIAL IMPACT

The building of a new energy-efficient SUB at UBC provides a unique opportunity for further education outside of the classroom. A renewable energy-generating gym, in particular, takes full advantage of this opportunity by increasing awareness of health and fitness, sustainability, and energy consumption and conservation.

3.1 HEALTH

The gyms on the UBC campus are often very busy. A new gym in the SUB will not only attend to these issues of limited gym space and time on the machines, but it will also encourage more people to use the gym [6]. An energy-generating gym will attract many people not otherwise inclined to exercise. If more gym space is available, more apprehensive users—who might otherwise be intimidated by the volume of people at a gym—might be inspired to take advantage of the UBC facilities.

It is well know that setting goals increases one's success rate [7]. An energy-generating gym provides many goals for people looking to save energy and people looking to get fit. With a user-friendly display showing energy saved, a user can set a goal of generating a certain amount of energy, to save a certain amount of money, or to burn a certain amount of calories. They receive not only the satisfaction of knowing that they are getting healthier, but also the knowledge that they helped save energy and are contributing to reducing CO_2 emissions.

3.2 EDUCATION

A study undertaken by the *National Centre for Environmental Research* on the educational benefits of an energy-generating gym showed "significant increases… in the area of identifying renewable energy resources from nonrenewable energy resources" and “trends towards environmentally consciousness decision-making.” Participants in the study also showed an interest in conserving energy to delay global warming, while saving money was the least important reason [8]. An energy-generating gym was found to “[increase] percentages of participants engaging in positive environmental behavior.” Thus an energy-generating gym educates and promotes energy conservation, as well as sustainability in general [8]. It presents a green lifestyle to some who may not otherwise be exposed to it, or who may not care for it. It shows quantitatively how much energy a single person can generate and what effect creating this renewable energy can have; it increases one’s energy consciousness. Instead of energy being something unquantifiable, it becomes something calculable, finite and crucial—something to be saved and not forgotten or wasted.

3.3 INTEREST

At the University of Maryland, a study was undertaken to assess the general appeal of an energy generating gym to students. Six hundred students, mostly between the ages of 18 and 21, participated. The data below represents their findings [6]:

- An average cardio workout is 30 to 35 minutes in length
- Four hundred and forty-three of the 600 students currently workout 2.9 days/week
- Half of the people surveyed who do not currently workout plan to start soon
- Seventy-five per cent of students gave a score of at least 8 out of 10 (1 being not likely to, 10 being very likely to) when asked about their willingness to use an energy-generating gym (Figure 2)
- Twenty-nine per cent of 180 students who do not plan to join a gym said that they would be more likely to join a gym if it offered this technology—this number became 50 per cent if incentives were offered
- Twenty-eight per cent of people who gave a score of 7 or higher in regards to their willingness to join an energy-generating gym were also willing to pay higher prices for this technology

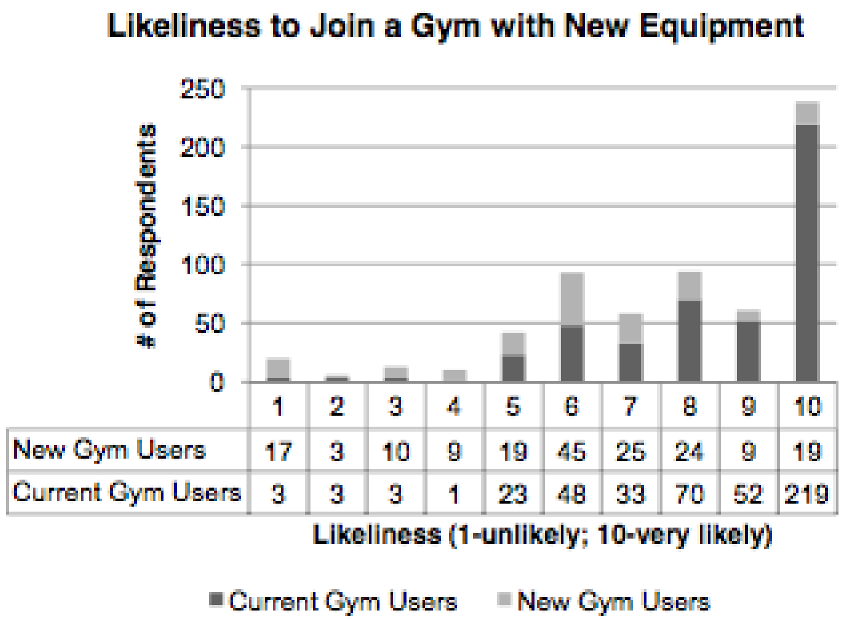

Figure 2: The willingness of study participants to join a gym with the ReRev system. Retrieved from: *A study of the benefits of retrofitting cardiovascular exercise equipment of a gym with human energy harvesting technology*.

These statistics provide encouraging feedback to the receptiveness of students towards this technology. While this data was taken from a different university, one can expect to find similar results at UBC. This study should therefore be considered in the decision to implement an energy generating gym.

An energy-generating gym strongly advocates a well-rounded lifestyle. It creates a community with a healthier heart, mind, outlook, and planet—all things that UBC is looking to achieve in its SUB renewal project.

4.0 ECONOMIC IMPACT

4.1 INTRODUCING THE CONCEPT OF MICRO RENEWABLE ENERGY SYSTEMS

Electricity-generating gym equipment falls under the category of Micro Renewable Energy Systems (MRES). Any technology with a power output per unit less than 5 kWh classifies as such. These methods of energy harvesting or production are more prevalent in the homes as they do not provide a viable source of energy for a commercial endeavor. Thus the goal of such human-kinetic power is not primarily to cut down costs but rather to provide alternate methods of energy generation. While the term ‘alternate’ is for now synonymous with ‘costly’ in the case of human powered MRES, the trade off is their applications and concept advancement: portability, eventual energy independence, and reduction of cyclic power-grid strain.

While rural areas may greatly benefit from investment in MRESs, the fact is that residents situated in such locations do not usually possess the time or the funds to invest into a low-yield power generating method for producing their own energy. At the moment, only an elite, curious, or deeply invested demographic composes the market. This trend, caused by the general lack of availability (and by consequence, high cost) of MRES systems, can be attributed to the lack of funding in the research sector. While many MRES devices have been developed for the US army, including energy generating backpack frames and micro hydraulic transducers in the heel of combat boots [6], these portable methods are not geared to household applications but are rather designed for the field and are inherently low-yielding in terms of power. The search, then, is for a middle ground: a strain of systems geared to urban application that passively acts as energy generators, albeit not on a large scale.

The lack of commercial applications, due to demand size and thus the need for more efficient methods of power generation [9][6], in conjunction with the lack of tax credits, research funding, and general incentives (items which are applicable to larger alternative energy projects), makes the MRES drastically under supported.

The United States' Department of Energy (DOE) requested in 2009 that $2.3 billion be allotted in the following fiscal year to support renewable energies and to develop more efficient transmission infrastructure [10]. If 1% of the approximately 300 million people living in the United States invested $300 into a MRES, that would produce enough to cover 40% of DOE's requested budget [6]. In other words, the marketing strategy at the present is to target the residential demographic that would otherwise not be contributing to renewable energies research funding. To put it plainly, the push required for this technology to be fully developed and increase its efficiency needs to come from individuals' purchasing power rather than sporadic grants and purchases: "If micro renewable energy devices become popular enough for people to buy, the effect on energy independence can be dramatic" [9].

While MRES are perhaps not yet a viable source of energy, long term financial commitment through the form of investment and consumer interest is necessary to continue the push for more efficient, versatile, renewable, and independent sources of power generating system. As such, installing a few of these units in the Student Union Building, we would be doing our part as consumers to bring awareness to the concept and support the product in question: in this case, the ReRev system.

4.2 PROJECTED FIGURES

The following section will outline a financial plan behind the purchase of 15 ReRev converted Precor elliptical trainers. While the cost of retro-fitting one machine ranges well over $1000, the large-scale purchase order would qualify for a client discount. In personal communication with Mr. Glen Johansen, a representative from ReRev, he supplied us with a further estimate of $14,000 to $16,000 CAN as a cost to retro-fit 15 machines and install a specialized panel transformer. This is on par with the large-order cost of [11] and [6]. Taxes and shipping costs would have to be added. Mr. Johansen further mentioned that cable lengths and the availability of a three-phase-to-208V-single-phase power converter would slightly alter installation costs. Correspondence with him can be found in Appendix A. He also provided a general facility assessment form which can be found in Appendix B.

Given that the gym tailors to a student population, the variety of schedules would justify opening the gym early and closing late; say for a total operational time of 16 hours each day.

While the energy savings to the Student Union building are of interest, it is also important to compare these to BC hydro-electricity savings. Given the 2011 rates, the Student Union building would presumably qualify as "Zone 1 commercial"—a facility using 35KW-h or more per month—and would be charged $0.0816 per kWh (for the first 14,800 kWh) and all additional kWh at $0.0393 per kWh [13].

The following takes into account the purchase of 15 Precor EFX546i trainers with a unit price of $2899 to $5995 (depending on whether it has been previously used) and an installation cost of $14,000 to $16,000. Mr. Johansen stated that the fully retrofitted models could be purchased directly from ReRev.com. The capital cost, then, would range between $105,925 and $57,485.

Assuming the following:

- The capital cost is amortized over 10 years
- The gym is open for 5280 hours a year
- On average, 33% of machines (ie: 5) are in use at a time
- The average output per machine in operation is 100W
- Hydro-cost is valued at $0.0816 per kWh

Repair, disposal and recycling costs as well as maintenance and database administration costs have not been figured into the calculations. In other words, the fact that the gym encompasses ReRev machines is saving around $215 a year. The cost per year in terms of amortized capital, taking into account energy savings, ranges from $5534 to $10,378.
In the larger picture, if the equipment is functional for 10 years, it is simultaneously providing a service to the students at slightly reduced cost to the establishment and promoting MRES technology.

An additional economical benefit of slightly decreasing day-time energy expenditures includes reducing the amplitude of the cyclic day-night power draw for a region. It is costly and inefficient to have fluctuations in a power grid. Human kinetic generating equipment, presumably used during the day, would reduce power consumption during a time of high demand.

The cost of display programs for ReRev systems to show gym-users how much energy they were producing was directed by [14]. There are a few viable options that interface well with the micro-inverter inside the elliptical machine to then process the data and display it within the gym.

5.0 LOCATION

The space required for the proposed energy-generating gym is roughly 1600 sq. ft. There needs to be adequate space for 15 Precor machines retrofitted with ReRev and the other gym essentials (weights, etc.). To fully reap the educational benefits offered by an energy-generating gym system, the gym would ideally be located in an area of high traffic throughout the SUB. A large display outside the gym showing the total amount of saved energy or saved dollars would also attract students.

Following these requirements and the information outlined in [15], the best location for the gym is the AMS Recreation Facilities. This space is slated "to support a select range of AMS clubs and related large movement activity [15]." Its main function is to facilitate movement and exercise of all kinds.

A climbing wall has been proposed that will rise up through many levels. This will attract the attention of many students, and would provide an excellent partner for the proposed gym. The space currently allocated for a pocket lounge opposite the climbing wall would house the gym nicely and provide exercisers with an interesting view of the climbing wall. The recreation facilities will also have change and shower rooms which are essential to a fully functioning gym.

6.0 CONCLUSION & RECOMMENDATIONS

The final recommendation—after reviewing environmental, social, and economic impacts, and weighing both the pros and cons of each—is to suggest the installation of 15 Precor machines retrofitted with ReRev in an energy-generating gym in the AMS Recreation Facilities.

A ReRev system implemented in a gym in the new UBC SUB will save over 700kg of CO_2 per machine from being emitted into the atmosphere over its entire lifetime. It will also save the UBC community $215 dollars a year and demonstrate the feasibility of MRES.

This gym, paired with the great climbing wall, will form a centerpiece in the new SUB that champions the commitment from the UBC community towards a healthy and prosperous planet. While the environmental or economic savings may not overwhelm, they are surely neither detrimental to the overall goal of achieving LEED certification. Furthermore, the social benefits—in education and awareness nonetheless—certainly do more towards long-term achievements: this gym is designed for social reform with regards to environmental cognizance and appreciation.

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APPENDIX A

This is personal email correspondence with a representative from ReRev.

Hello,

I'm inquiring on behalf of an Applied Science class that I am a part of this term at the University of British Columbia, Canada. We are engineering students within the Engineering Physics program who have been working on a proposal that would recommend the installation 15 ReRev elliptical trainers. This would be a feature of the new Student Union Building at UBC slated to begin construction in 2012 and aiming at LEED platinum certification.

We are interested in obtaining a quote for an inverter panel and 15 of your kits able to retrofit Precor EFX546i elliptical machines (or a model similar). We are also curious as to how the installation process usually occurs. As the project still has a few months to mature, a ball-park estimate is all that is for now required.

We hope to hear from your soon,

Rémy Barois

Hello Mr. Barois.

ReRev system was developed to harness the human kinetic energy in the cardio room. It was designed for the commercial GYM with multiple pieces of self-powered cardio machines that can be connected to the the array. Similar to a micro-wind farm.   We can retro fit the existing equipment, but have compatibility with Precor Ellipticals and Woodway's new Echomill Treadmill.
http://www.precor.com/comm/en/efx-com
http://www.woodway.com/commercialtreadmills/ecomill.html

We can provide you with new Precor Ellipticals or Woodway's treadmill if needed.

Attached is an assessment form we use to prepare a proposal.
I would like to give you a specific proposal and cost. An estimate for a system that would accommodate 15 machines would be $14 - 16,000.

There are a number of variables that will determine the cost, distance, wire runs, conduit or wire tray. We ask that the facility provide a 208v (single phase) electrical drop in the room where we mount the converter.

I look forward to hearing from you soon.

Best Regards, Glen
www.rerev.com
--
Glen Johansen
SunQuest Energy
13620 49th Street North
Clearwater, FL 33762
727-556-0804

APPENDIX B

ReRev™

Facility Assessment

In order to better evaluate your opportunity as a ReRev™ energy generating facility, we need some specific site information regarding your gym.

PLEASE RETURN FORM TO:

FAX (727) 556-0360 **PH** (727) 556-0804

MAIL 13620 49th St. N | Clearwater FL 33762

We look forward to hearing from you!

This information is used to determine the feasibility of installing & operating a **ReRev™** energy-harnessing system that will send power back to the grid in the form of KWHs which are used throughout the building. **Please provide as much information as possible.**

Facility Name ____________________ **Contact Name** ____________________

Facility Address ____

Phone ____________________ **Mobile** ____________________

Fax ____________________ **Email** ____________________

Please provide the following information about the self-powered cardio machines (i.e. elliptical) in your facility:

Type of Equipment	Manufacturer#	Machines

Is your facility EXISTING or UNDER CONSTRUCTION? *(Please circle one)*
If under construction, please indicate completion date. Your cost per Kwh ____________________

____

Are you planning an equipment purchase in the future? *If so, indicate equipment type, manufacturer,& timeframe:*

____

Location of self-powered cardio machines: Please provide a brief diagram illustrating the layout of your machines (for example, are they banked together in one location, spread across several stories, show spacing,, etc.)

Note: We assume 4 feet from center line to center line of each piece of equipment unless otherwise indicated.