Human Power Generation at the Recreational Sports Facility at UC Berkeley

Jodi Loo, Danny Namkyu Chang, Rajith Jayaratne, Eric Mao, Matthew Roeschke, Jennifer Wang, Kyle Zampaglione, Prof. Alice Agogino

University of California, Berkeley
Department of Mechanical Engineering
Berkeley, CA, USA

rsfenergy@gmail.com
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I. Introduction

As energy usage across the world continues to rise, there is a strong need to develop new methods for energy conservation and power generation, particularly with approaches that have less environmental impacts. There is an untapped potential for harnessing human power at most fitness facilities. The Human Power Generation (HPG) in Fitness Facilities research project studied the technical feasibility and social benefit of harnessing human power at the University of California, Berkeley Recreational Sports Facility (RSF), which averages over 2,800 patrons per day.

The overall goal of our project was to create a human power generation center at the RSF by retrofitting an elliptical machine such that it can generate usable energy. Additionally, our project aims to educate members of the RSF on the energy usage of various machines, the potentials of human power, and additional ways to lead more sustainable lifestyles. This goal was accomplished by creating a charging station out of an elliptical exercise machine that allows users to charge their electronic devices directly through the energy they produce while exercising and retrofitting a recumbent bicycle with a pedal-powered display station that teaches users about alternative energy and sustainability as they exercise. In addition to these two prototypes, we have created screen slides to be displayed on RSF television screens that contain facts and information on energy usage and conservation to inform RSF users about energy sustainability and the HPG project.
II. Sponsors

The work of Human Powered Generation has been performed under the auspices of The Green Initiative Fund (TGIF) at the University of California, Berkeley in addition to Sigma Xi, the Scientific Research Society, the Green Fund Grant by the Chancellor’s Advisory Committee on Sustainability, UC Leadership Excellence through Advanced Degrees (UC LEADS), and New Experiences for Research at Diversity in Science (NERDS) Program.

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III. About the Project

While working out in the gym, burning unwanted calories, many of us wonder what could be done with all this excess energy. Is there a way in which it could be harnessed instead of dissipated as heat? With this question in mind, the Human Power Generation in Fitness Facilities research project was born. This project is part of the Community Assessment of Renewable Energy and Sustainability (CARES) research being conducted in the Berkeley Energy and Sustainability Technologies (BEST) laboratory in the Mechanical Engineering department at the University of California, Berkeley.

Over the Summer of 2009, a feasibility study was conducted on the Recreational Sports Facility (RSF) at the University of California, Berkeley to determine how energy efficient the facility was and to estimate the amount of energy that could be harnessed from gym patrons. The study was conducted for an energy harnessing system that involves retrofitting elliptical machines so that their built-in resistance mechanism is replaced with a micro-inverter. Not only does this micro-inverter provide the resistance for the patron's workout, but it also converts the patron's direct current electricity into usable alternating current electricity.

With 28 elliptical machines in mind for retrofitting at the RSF, it was calculated that approximately 10,000 kWh could be generated from such an installation. A further energy audit determined that this would produce less than 1% of the RSF's energy needs.

However, looking in to the RSF's overall energy usage, it was determined that the facility has already done a great deal to be energy efficient. Replacement of the majority of the lights in the facility over the past year has decreased the facility's energy consumption by over 150,000 kWh, while also increasing hours. Comparing the RSF to other gyms across the nation further the conclusion that the RSF is very energy efficient, mainly because of the facility's lack of air conditioning.

During Fall of 2009, a user survey was sent out to all the members of the RSF to gauge how the members of the RSF perceive the energy usage of different machines as well as determine how gym members would react to such an installation of energy generating elliptical machines.

The responses to the user survey demonstrated that many members could be educated on the energy usage of various machines in the hopes that they choose to use cardio machines that use less energy. For example, not many people realize that an elliptical machine only uses about 15 W to provide a sufficient work-out, while a treadmill may use up to 2.2 kW for the same 1 hour work-out. At the same time, the survey also demonstrated the great deal of enthusiasm the campus community has for this project.

Goals
At the University of California Berkeley, the Recreational Sports Facility (RSF) is the main gym for students, faculty, and community members seeing an average of 2800 patrons on a given day. As of now the RSF contains over 20 bikes and 20 elliptical machines that produce energy as users workout on them, however, this energy is untapped and often dumped as heat.

Human Power Generation is a research team whose main goal is to not only retrofit elliptical and bike machines to generate power from users, but also to educate the entire campus community about sustainable energy sources, such as human power, and how to conserve and reduce the energy that they use. The main implementation technique is to develop a system that can be simply attached to an elliptical or bike machine that will convert the energy that is being produced by the user into a steady source of usable energy.

Alongside the retrofit to harvest energy, our education campaign would implement a poster campaign, as well as an interactive methods, to teach all RSF users about conserving energy in their lives and about different forms of sustainable energies.

**Accomplishments**

By the end of 2013, we have successfully installed a retrofitted elliptical and bike trainer at the RSF. These machines were modified to turn kinetic to electrical energy and step it down in order to charge the users phone. We have successfully implemented these two machines into the RSF as an initial step to retrofit all the machines at the RSF and to serve as an educational tool to show RSF members about different forms of sustainable energy, as well as the amount of tangible work it takes to charge ones phone.

We have also implemented the educational campaign at the RSF. By utilizing the numerous television screens at the RSF, we have implemented a series of slides with information about sustainable energy, energy usage in the United States, and our project.

**Challenges**

For the pedal powered charging station, there were many obstacles that prevented us from achieving what we laid out in the original application submission. The primary obstacle what that adding resistance to the system that would positively benefit the power generation was difficult and out of reach for the team. Because the bike was designed simply using an electric motor as a generator, increased effort would only reduce the amount of resistance across the coils. This in turn creates less resistance and the user attempts to pedal faster. Adding resistance into the system given this setup would have to be of physical means; unfortunately implying that the increased effort of the user would not generate more electricity.

Some of the other obstacles included: creating a theft-proof solution for the iPad, fitting the casing back
onto the bike, and finding correct chargers. Creating a theft-proof solution for the iPad was not originally considered at the beginning of the project. As it became more of an issue, the team ended up doing several iterations of display setups before finally settling on a purchased solution with key and lock. Fitting the casing was a challenge as the internal mechanical system to increase motor RPM was much wider than the original bike drivetrain. The team solved this issue by modifying the casing. Finally, finding correct chargers was difficult as tablets require a higher charging amperage. This fact is often not advertised on 12V car adapters and many were purchased that could not charge the tablet.

On the elliptical side, the main challenge we faced was converting electricity generated from the elliptical’s DC motor directly into AC power. Our original design was to use existing solar panel AC/DC converters to convert the DC output from the motor into AC power which could be sent directly to the grid. However, when we connected the Enphase M215 Microinverter to our system we realized our elliptical motor was not generating enough current to power the microinverter. Hence we were left with no choice but to abandon the plan of sending electricity directly back into the grid until future technical improvements are discovered. Due to time constraints we decided to instead use the DC power from the motor to charge batteries which would in turn charge patrons’ cell phones. This would provide a more direct sense of converting human power to electricity as user’s could see their cell phone's battery meter increase as they were using the elliptical machine. Had we started over we wish we had more expertise in solar arrays since our system has very direct parallels with solar energy conversion. The Precor elliptical is a very complex system and with more time and effort we could have understood the system better leading to a more optimized design. Future work will definitely explore these areas. The design to move to charging people’s cell phones was two fold. First, to turn this into more of an educational campaign illustrating the amount of effort it takes to generate electricity. Secondly, to implement a human energy converter as soon as possible given the funding and time we had already invested in the project. From the feedback we’ve received, we feel this was the right decision as students are excited to be using the machines turning their hard work into more talk time on their cell phones.

Both teams experienced an obstacle in that the systems would continually drain their storage batteries. The electrical system on both bike and elliptical requires a solar charge controller that draws a small current from the storage battery. When the system is left on, the controller eventually drains the battery. Users on the bike did not know to shut off the charger after they were finish, hence depleting the storage battery. The elliptical did not have a shut off switch and drains from the small current draw. This issue causes both systems to require frequent storage battery changes so that the systems will continue to charge devices.

**What Would We Change**

If the bike team were to go through the process again, they would choose to create a custom casing from the outset to allow for more room for electronics and mechanical system. The current casing looks
scrapped together as the team had difficulty integrating the custom casing with the existing case. The team would also change the wiring implementation to run internally or at least have more coverings for a cleaner, safer design.

In addition to being able to send electricity from the elliptical back to the grid, improvements to the elliptical add on housing can be made more compact and robust. Currently the technology we’ve implemented to convert the power from the elliptical into power for people’s cell phones lie in a plexiglass box under the elliptical. Though it does not obstruct the user, we could make it smaller and seem more integrated with the existing elliptical casing. In addition, we would make it more modular so that our add on can be mass produced and easily installed by customers of our system.

Both teams would implement a more robust circuitry specification if they were to do it again. The problem of draining from the charge controllers nominal current draw could easily be solved with some circuitry design and would mean the bike and elliptical would last much longer in the RSF setting. With some careful modifications (IE: quick shut off and solar charger for energy stabilization when not in use) the systems could be made to run indefinitely on a single storage battery.

**Feedback to TGIF**

Overall, TGIF has been very supportive of the HPG project for the past few years. In concept, the HPG project retrofit seemed to be a straightforward task. But as more research and implementation took place, we realized that there were significant challenges that prevented us from implementing our machines sooner. The implementation the original design of putting power back to the RSF power grid would require much more effort in terms of time, finance, coordination with various agencies (PG&E, the RSF, UC Berkeley), and a lot more technical expertise. We hope that future work done to expand our project will be given these resources. For now, TGIF would continue to be beneficial for our project in helping to publicize and promote our project to the Berkeley campus and at various campus events.

**Timeline**

**Summer/Fall 2009**
- Feasibility study conducted on the Recreational Sports Facility (RSF) at the University of California, Berkeley (RSF) to determine how energy efficient the facility was and to estimate the amount of energy that could be harnessed from gym patrons
- User survey sent out to members of the RSF which demonstrated that many members could be educated on the energy usage of various machines in the hopes that they choose to use cardio machines that use less energy

**Fall 2010 - Spring 2011**
- The project team expanded to approximately fourteen students to complete the project.
The students were divided into two teams: one to work on the pedal-powered laptop system and one to work on the elliptical energy-harnessing system. The project team completed 80% of the pedal-powered laptop station and the elliptical trainer energy-harnessing system is underway in the prototyping stages.

- The project team received an elliptical donation from a professor in the Electrical Engineering and Computer Science department; unfortunately, its internal mechanisms were too different from those within the RSF machines and therefore could not be used for the prototype.
- The project team received an elliptical donation from RSF by the end of spring semester; this machine will be used starting fall 2011 for the elliptical prototype.
- Human Powered Gym was able to offer course credit up to 4 units to students for assistance with the project; this offer will be carried over into 2011-2012.

**Fall 2011 - Spring 2012**

- Recruited a new student intern to head the creation of an energy education campaign for the RSF.
- Created a team of 15 undergraduates who received course credit for their research work and documentation of meeting minutes, design review presentations, and final reports.
- Converted a stationary recumbent bicycle into a pedal powered laptop station- the team had some technical difficulties in its original design and had to make many modifications. The team also decided to purchase a discounted iPad rather than use a laptop to create a more interactive experience for an educational kiosk.
- The team began working in spring 2012 to convert a donated elliptical machine into a working prototype of an energy harnessing system; the team hopes to have the model completed by the end of summer 2012

**Fall 2012 - Spring 2013**

- Prototype educational kiosk (pedal powered laptop)- Convert stationary recumbent bicycle into a pedal powered laptop station. The team is fine tuning the casing and how to demonstrate the output power of the machine and the effectiveness of generating/saving energy as an educational opportunity for future display in the RSF.
- Prototype human power harnessing system- Convert elliptical machine into energy harnessing system. We completed putting together the parts, but still need to design proper casing for the parts.
- Test prototyped energy harnessing system and try to improve energy efficiency- We are currently awaiting the RSF's resources to transport the machine to the RSF in order to do testing, since the machine must be plugged into the grid to work/test.
- Prepare to retrofit 14 elliptical machines at the RSF with protoyped technology- This
semester we hope to have at least 5 completed. Need to test the prototypes and present to RSF.

- Work on energy education campaign for the RSF and the human power gym installation- We currently have two undergraduates working on this campaign. They will send out surveys and create apps for RSF user feedback on green exercise technology. We are also in the process of creating an app for RSF users to use to access usage. We are coordinating such efforts with the Pedal and Elliptical team.

Fall 2013

- The Human Powered Gym team presented the project at Engineering for Kids (E4K) Day, Cal Day, and at the 2013 CACS summit. The project had the ME110 and ME290H class groups work on a prototype for a user interface system for the machines.
- Human Powered Gym was mentioned in Ecopedia's May article “Human Powered Gyms Make Watts from Your Workout.”
- Completed the first version of the elliptical and housing for the retrofit parts. The team is planning on building another, more finalized, housing design as the final design.
- Tested the energy harnessing system and calculated data. The team is not optimizing for efficiency.
- Currently awaiting RSF and Precor's approvals on the retrofit in order to progress with the project.
- Posters have been made by the education team with plans for collaborating with the RSF to display them. Posters are ready to be printed to display in the RSF.

Nov 6, 2013 - Project launches at the RSF
**IV. Impact**

This project’s educational component had a large sustainability impact on the students at the RSF. By using our machines, students were able to physically understand how much energy is required to charge their electronic goods, hence gaining a greater appreciation for the energy expenditures of such products.

Furthermore, the educational campaign included informational signage throughout the RSF, on and near the machines, and on TV screens in the workout areas. The signage included facts about the retrofitted machines and a breakdown of the RSF’s energy usage to understand how the users of various machines impact the RSF’s energy climate. Signage also provided general facts about energy to provide gym users with a deeper understanding of what energy means, where it comes from, and how energy is used not only locally, but globally.

The elliptical team has added a data acquisition device using a custom programmed Arduino to capture statistics on power generation. Quantitative sustainability metrics we’re looking at are the number of Watts our system produces. Since we have just launched, we do not have enough data points but are looking forward to receiving metrics on the impact of our system when students come back from winter break and begin using our machine.

A generous estimate of energy benefits would be 1 to 2 full cell phone charges per day or approximately 30-60Wh. Due to the battery draining problems mentioned in the project summary, the systems require constant external energy inputs to keep the storage batteries functioning.

Based on the steady state current draw from the charge controllers, the systems will require a battery change every 3 days. This means that if no users use the systems, each charge controller will waste 8amp-hours of energy. This is equivalent to approximately 3 charges of an average smartphone, or 3 days worth of charges. From this rough metric it can be assumed that the machines waste the equivalent energy of approximately 1 cell phone charge per day.

Although the machine is consuming energy, over the course of the day, several users will charge their phones or tablets. These users will not charge their devices completely though; most will do ⅛ to ⅕ of a total charge of their phone. So from this reasoning, as little as 5 users a day will produce the equivalent of the energy expended by the machine. While no data has been taken on the number of users per day who use these machines, 5 users is a safe estimate.

A more generous, though still reasonable estimate, of 10 users per day would produce 1 fully charged cell phone’s worth of energy on top of the machine’s expenditures. If 10 users were to use one of the machines for an entire year, a total of 900Ah or 10.8kWh would be produced. This is enough energy to
power a laptop computer for 9 days straight.

Using data from Outlier, the average cell phone costs approximately $0.45 cents to charge for a year. So by charging the equivalent of 1-2 phones every day on top of the machine’s expenditures via the exercise of 10-15 users and assuming that a cell phone is charged every day, each machine will save $0.45 to $0.90 a year.
V. Visibility

HPG has participated in various outreach events in order to promote science and engineering to students as well as to publicize our project to the Berkeley community. We have participated in the UC Berkeley College of Engineering’s Engineering for Kids (E4K) Day and UC Berkeley Cal Day. In addition, we have presented posters at the Chancellor’s Advisory Committee on Sustainability (CACS) Summit and at the UC Berkeley Mechanical Engineering department External Advisory Committee poster session.

Copies of our poster designs and photographs of HPG events as well as our project milestones can be found in our Dropbox folder.
(Dropbox folder link: https://www.dropbox.com/sh/ke5l9bhpaoak6gj/Ox-R9ZeuZ5)

Our project has also generated a great deal of media. The following lists all of the major publications in which HPG has been featured. Please find copies of the actual articles in our Dropbox folder.

- The Human Powered Elliptical is now in the RSF! - TGIF Blog
- Cal Engineering Creates “Human-Powered Gym” - The Black Sheep
- Gym Twofer: Get Fit, Charge Your Phone - Earth Techling
- HPG team installs ellipticals at the RSF - berkeleyByte
- Work out to charge up - Innovations - UC Berkeley College of Engineering
- Charge Your Electronics As You Work-out - Recreational Sports, UC Berkeley
- The Human-Powered Gym Set to Deploy at RSF - UC Berkeley Department of Mechanical Engineering
- Video Feature: A low-wattage workout - UC Berkeley College of Engineering Webzine
- CACS Recognizes Innovation and Achievement and 2010 The Green Initiative Fund Grantees - UC Berkeley Office of Sustainability Bright Green News
- Dec 2009 Sustainability Forum - UC Berkeley Office of Sustainability Bright Green News
- Green Machines - Campus Issues: Retrofitting exercise machines to generate power furthers the campus's green agenda and applies student knowledge. - The Daily Californian
- Exercise Machines May Supply Power for RSF - The Daily Californian

In addition, we also have a few publications in journals and conference proceedings.
Harnessing Human Power for Alternative Energy in Fitness Facilities: A Case Study - Proceedings of AASHE 2010 Conference on Campus Initiatives to Catalyze a Just and Sustainable World October 10-12, 2010
VI. Conclusion

Our machines will be mechanically maintained by the RSF staff and the remaining HPG members will help maintain the electrical and retrofitted aspects of the machines. The next steps in this project is to retrofit the other elliptical trainers at the RSF and possibly expand our concept into other campuses or privately owned gyms. Also, changes can be made to the elliptical machine to make the energy conversion process more efficient. The current system implemented on the elliptical machine takes the energy created by the user to charge a 12V battery, which is then used to charge the users phone. However, by implementing a system consisting of a rectifying diode, a capacitor and a voltage regulator the AC current produced by the elliptical machine can be directly converted to energy that can charge the users phone. This change can be made to the bike machine as well.

Since most of the current HPG team are graduating seniors, we want to bring in new members and teach them the basics about the project so that they can continue maintenance and also continue research on how to improve our system. The new team can come with fresh and innovative ideas as to send power generated by the elliptical into the RSF power grids rather than simply charging electronic devices.

Though the project deviated from the original plan of sending generated power back into the gyms power grid, we succeeded in showing that renewable energy can be generated from these machines. The next significant step of the project involves expanding the work of our educational campaign throughout the UC Berkeley campus and to other schools in order to teach more people about sustainable energy and energy conservation.
VII. Expenditures

Please see our Dropbox folder, which contains files from the UC Berkeley Mechanical Engineering Financial Department that delineates the budget and expenditures of this project by fiscal year. (See Budget folder)