The Energy Contest Cover Page
Rutgers New Brunswick Undergraduate Students

Sponsored by The Rutgers Energy Institute

Cover pages should be submitted along with the proposals **on or before April 1, 2014** to via email to bea@marine.rutgers.edu.

Proposal Title: Energy Recycling

Total number of pages (not counting cover pages): 10

Student Name: Rachit Mehta
Email Address: rmehta4@gmail.com
Major(s): Materials Science and Engineering
Minor(s): Economics
Planned graduation Month and Year: May 2016
Contact phone number: (732) 698-8659

Student Name: Timothy Yong
Email Address: timothy.yong@rutgers.edu
Major(s): Computer Engineering & Computer Science
Planned graduation Month and Year: May 2016
Contact phone number: (732) 208-7217

Faculty Advisor Name: Dr. Dunbar Birnie
Title: Professor
Email Address: dbirnie@ rutgers.edu
Department: Materials Science and Engineering
Campus phone number: (848) 445-5605

200 word (maximum) summary of the proposal or video:
Our proposal is to harvest energy from three basic forms of energy: thermal, light, and kinetic. We plan to harvest this energy through devices developed that can convert these three forms of energy to electrical energy (which we call ‘energy recycling’). We also plan on using autonomous feedback to have users monitor their own electronic energy consumption. The goal of this proposal is to reach self-sufficiency in energy costs where Rutgers University can save more than half of their current energy costs and generate enough to become optimal. The proposal remarks the costs to benefits analysis where the benefits outweigh the costs as well extra energy left for storage. In addition, there is a social impact analysis of what the potential social benefits are. The proposal is comprised of a comprehensive twelve-step strategic plan to implement the proposal which will take place in three stages.

Introduction

A basic property of energy is that it cannot be created or destroyed, that energy itself can only be converted from one form to another. However, although we constantly use this energy to power our appliances and heating, we seldom reuse this energy, instead exerting it into the environment and never containing this energy. This paper explains a plan to contain and recycle this wasted energy in order to decrease the amount that we consume directly from the source.

When planning our design, our goals were based around four human motivations:

(1) The average person will attempt to optimize effort.

(2) The average person will try to manage their money optimally, and therefore would like a more efficient piece of technology than one that is not.

(3) When people are more aware of their surroundings, they tend to control themselves in order to optimize their actions for time or money.

(4) Self-sufficiency is a trait desired amongst independent individuals.

Therefore, we needed a design that was autonomous, where people would not realize that they were saving energy just by implementing technology, and therefore did not need to be managed by a third party. It also needs to be reasonably efficient, where the benefits outweigh the costs. It would further need to give feedback to the user, to raise awareness of how much they were actually using. These actions would lead them to becoming more self-sufficient energy-wise, reducing costs up to the point where they could potentially feed this energy back to the grid.

In order to recycle energy, we explain a system of devices that harvest thermal, kinetic, and solar energy and convert them into electrical energy to be reused. We also explain how autonomous feedback from low voltage devices promotes self-awareness of energy consumption.

Thermal Energy

The largest consumption of thermal energy is dedicated to spatial heating. This is the result of inefficiency due to the nature of insulation. If the room is not insulated properly, then the room will lose heat over time, and therefore more energy will be used to keep the room at equilibrium. In order to save energy, the rate at which energy leaves the room must decrease.

The most common solution to this problem is to improve the insulation of the building to decrease the rate of thermal energy release (keep the heat inside). This includes adding plastic insulation on the glass panes of windows, which are often conductive and let heat out more easily. It also involves sealing leaks and other holes in which heat might escape. However, the more leaks that are sealed, the more the bacteria concentration in the air increases due to lack of ventilation.

In order to solve this problem, a heat recovery ventilation (HRV) system can be implemented in order to provide ventilation while maintaining a somewhat steady temperature. HRV systems allow the building to release stale air while using a heat sink to maintain a constant room temperature, with up to 85% efficiency. Therefore, HRV's are most effective in extreme weather, such as the summer or winter, where air conditioners and heaters make the most impact.

Another significant use of thermal energy and potential reusable source of energy is the usage of hot water. Since used hot water has to exit the building to maintain sanitation, one way to recover this thermal energy is to use a grey-water heat recovery system on the outgoing stream. It is does not have a high efficiency rating in comparison to combining insulation with HRV's, however it allows the system to reuse energy that was spent on heating the water that flows through faucets, shower heads, and washing machines. In combination, using insulation and HRV's with grey-water heat recovery systems are able to reuse overall spent thermal energy.

Kinetic Energy

The most common form of transportation is walking, whether it is to or from the entrance of a building or just between the hallways in order to go to the classes. Although walking theoretically takes no work, in reality it is actually quite the opposite. This can be explained through the acceleration caused by your feet - whenever you take a step, you exert a small amount of force downward with your foot. This force is absorbed by the ground and converted from kinetic energy into other forms of energy, which has the potential to be reused.

At Georgia Institute of Technology, they have developed something called a triboelectric generator, which harvests energy by stepping on it. Every square meter has the capability of producing up to 300 watts. Given that the average person in the United States consumes approximately 30kWh per day, the amount of power that triboelectric generators harvest would be enough to power up to 20% of their current consumption (based on average calculation).

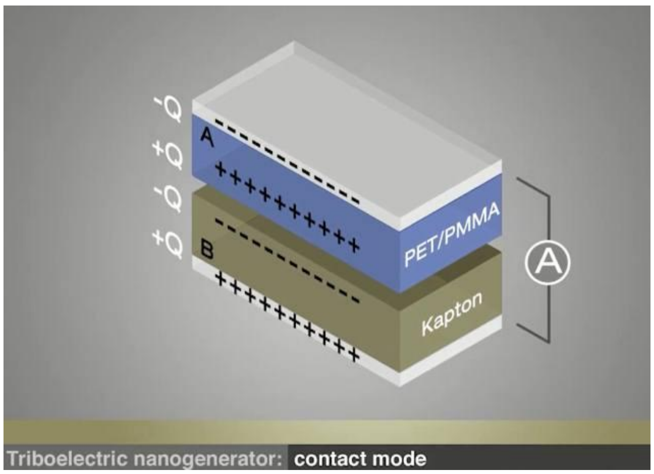

Figure 1. Triboelectric Generator

Since the layer of triboelectric generators will absorb the force exerted by the recipient to the ground, the layer will act like any other material that absorbs force, such as carpet or foam, or even in extreme cases, dry sand. Since work is absorbed by the device to be converted into energy, people who walk on this device are more likely to gain a higher degree of exercise. The device also gathers energy from oscillations, so even partial amounts of energy from waves (such as sound) will be able to become absorbed.

Light Energy and Energy Storage

Light energy has already been proven to be an abundant and reliable source of energy. The devices that gather light energy from on top of our rooftops and over the Livingston parking lot are the commonly seen photovoltaic solar cells, which only gather light. However, there are also other types of solar cells, such as thermoelectric and photovoltaic solar cells which (in addition to absorbing light energy from the sun) absorb heat energy as well, therefore increasing the energy harvesting efficiency of the device.

This has potential to be extremely useful for long term energy storage. For instance, consider the difference between the summer and winter energy levels. In places where this difference is extreme, a large amount of energy harvested during the summer could actually be used in order to help keep the winter warm. The only question is how to store this energy other than using batteries, since batteries do not have the potential to hold large amounts of energy for long periods of time. One particular solution is to use gas compression - the extra energy harvested during the summer could be used to compress vaults of gas such as hydrogen. This compressed gas energy could then be used for the wintertime or in cases of extreme energy usage, such as during an emergency.

Low Voltage Feedback

Feedback is essential in the Information Age. Humans today self-monitor everything: money, time, grades, homework, and even responses from their peers. By creating a system where users can easily access their energy usage and energy generation, they will be able to see immediately how their actions can be optimized and become more aware of their surroundings.

In the Rutgers University dormitories, where the bathrooms are shared and the hallways are heated and cooled, this energy usage monitoring would only monitor the energy usage of lighting, appliances, and electronics, which compose around ⅓ of today's energy costs. ⅙ of today's costs actually go to water heating, and other other ½ go to spatial heating and cooling:

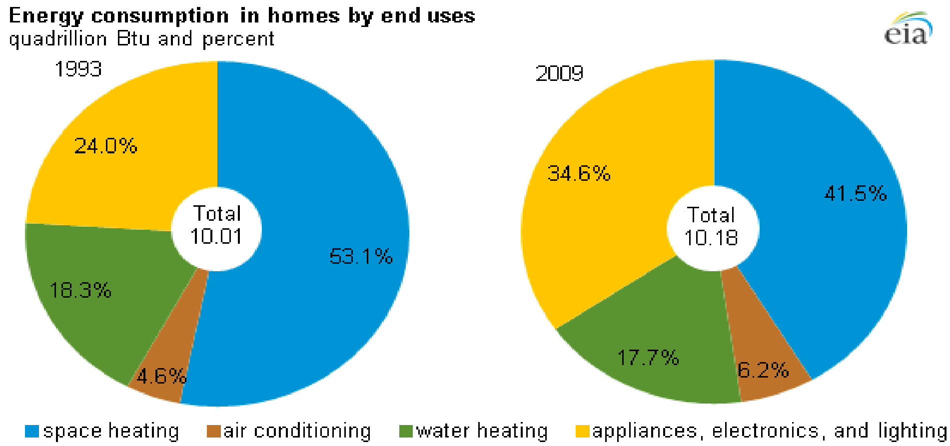

Figure 2. End Use of Energy Consumption

However, as shown above, the amount of energy devoted to lighting and electronics has risen by almost 50% within 15 years, which raises a glaring red flag. Should that particular trend keep rising, the amount of energy used by electronics and lighting might even surpass the total amount of energy using for spatial heating/cooling and water heating.

The ability for humans to monitor themselves will be able to not only save energy, but also teach them the value of energy saving in general. Implementing this as an autonomous system allows them to view data discretely and independently, allowing them a sense of privacy and self-sufficiency. In addition, if coupled with non-monetary attached achievements, users such as students will not feel obligated, but think about energy saving as something fun and desirable. In order to implement such a system, the information for personal room consumption can displayed directly to a Sakai tab where students can look at their achievements.

Strategic Plan

The comprehensive twelve-step strategic plan is broken into three main stages: initial installation of necessary hardware and programming the software, monitoring the efficiency and energy usage of individual energy categories during on and off peak hours, and continuous positive reinforcement with long term installation so that people can get more exercise and continue saving energy.

Stage 1: Initial Installation (Short term)

(1) Install low voltage room-per-room energy monitoring systems

(2) Program server/client code for Sakai page and set up achievements database

(3) Install window plastic insulation to recover wasted heat

(4) Install photovoltaic thermoelectric solar panels throughout campuses

Step 2: Monitoring and Evaluation of Data (Post Short term)

(5) Cluster dormitory energy usage based off electronics and thermal consumption, and calculate total energy generated from light and kinetic energy generation

(6) Gauge the performance of student energy consumption over time

Stage 3: Continuous Reinforcement and Installation (Long term)

(7) Install grey-water heat recovery system to recycle thermal energy from water

(8) Install triboelectric generators to harvest mechanical energy

(9) Install a heat recovery ventilation system calibrated for dormitories

(10) Further eliminate fossil fuel consumption and send this energy generation back to the grid

(11) Promotion of exercise to harvest mechanical energy and allow students to stay healthy

(12) Possible installation of hydrogen energy storage units (optional and only with extra energy)

Cost Analysis

Although there are no known case studies yet on this proposal, we have developed a theoretical case study that would exemplify the costs in one floor that consists of 45 students in 25 rooms with 4 communal bathrooms (based on the Ernest Lynton South Tower dorms for 1 floor).

Items	**Initial Costs (USD)**	**Percentage of Energy Generated**
Energy monitoring system: $100 each, 25 units (1 per room)	*$2,500*	*14.3%*
Plastic Window Insulation Film: $12.50 per 10 windows, 5x	*$62.50*	*12%*
Triboelectric Generators: Cost relative to material used (for now Kapton and Polyester [PET]); Approx. dorm room size: 200 sq ft, Total area (non-optimized): 5000 sq ft Kapton HN Film: $13.35 per 0.002 x 24" x 24", 50 tiles per room, 25x Polyester Film (Type A Frosted): $66.50 per 0.002 x 48" x 100', 15x	Kapton HN Film : $16,700 Polyester Film (Type A Frosted): $1,000 Total (non-optimized) Cost of Triboelectric Generators: *$17,700*	*20%*
Grey Water Heat Recovery System	*$500*	*7.5%*
Heat Recovery Ventilation System	*$1,200*	*35%*
Server Setup, Analysis, and Maintenance	*$500*	(omit)
Current PV systems with hybrid water based thermoelectric generation	*$2,500*	*20%*
Total theoretical cost vs. theoretical amount generated in comparison to average energy use	**$25,000**	**108%**

This means we can theoretically generate enough power to not only be self-sustaining, but also have some small amount left over to both send back to the grid and generate revenue.

This extra energy could also be stored in a hydrogen energy recovery system. Given that the triboelectric generator is still in research and development, the price is expected to go down dramatically. A majority of these calculations were in calculated on current costs of the average unit being sold in the market and the percentage of energy generated is determined by the average amount of the energy produced in each individual unit. In the long run, this proposal would essentially allow Rutgers University to be self-sustaining and nearly eliminating all energy costs Rutgers University currently has. Although the initial costs would be somewhat high if implemented throughout four campuses in Rutgers University in New Brunswick, the long term benefits give Rutgers University a higher yield to the initial investment.

Social Effects Analysis

The social impacts of energy recycling are substantial. Among various energy efficiency solutions, energy recycling comes out as the most practical. It does not require any consumer involvement other than the normal routine of physical activity such as walking and running as it will be self-sustaining once set up. This will also allow further impacts in promoting more cardiovascular exercise to create more energy. Another major impact would be conservation of natural resources such as fossil-fuels. Considering a large amount of our energy costs come from natural resources that are being depleted every day, energy recycling could potentially eliminate the need for fossil fuel usage.

These three types of energies allow Rutgers to be essentially self-sustaining and keep energy costs astronomically low. Not only would Rutgers be able to use these funds for other projects such as funding to other research and educational tools, it would create a eco-friendly environment that would in turn cause other universities to closely examine their energy costs and rethink their energy distributions used via fossil fuels in order to reduce their ecological footprint and costs in energy usage. This would allow the overall dependence on fossil fuels to dramatically decrease and keep universities more considerate on other funding.

In addition, using energy recycling and low power feedback, the general student body would become more aware of everyday activity and how much energy they use. They would also be able to identify which electronics use the most energy based on comparisons with other students, and they would be able to develop habits that lead to better usage. Over time, they would be able to make better decisions when choosing what installations are necessary at work and home, and as technology evolves, possibly use that energy for other things such as transportation.

Conclusion

Renewable energy technology offers a favorable solution for rising energy concerns. Large universities such as Rutgers should consider methods such as energy recycling as it is an attractive method to implement. The benefits of energy recycling are endless from being cost effective to promoting good physical activity. As fossil fuels are becoming harder to come by, alternative methods to using our large consumption of electricity as a university should not be shortchanged. The proposed twelve-step strategic plan allows Rutgers to take action in three stages and enact all steps in a favorable manner. The harvested energy results in savings for Rutgers and creates room for other spending such as more infrastructure and more resources at hand. Technology has transformed humanity's productivity and lifestyle. The energy needed to power this technology is becoming more and more expensive to maintain; however, the alternative methods to creating electrical energy allows promising results that save the university more than half of their current energy costs.

References

[1] http://www.eia.gov/consumption/residential/index.cfm

[2] http://www.energyharvestingjournal.com/articles/phonon-map-offers-direction-for-engineering-new-thermoelectric-devices-00006152.asp

[3] http://www.news.gatech.edu/2013/12/07/harvesting-electricity-triboelectric-generators-capture-wasted-power

[4] http://www.epa.gov/greenbuilding/pubs/gbstats.pdf

[5] http://corporate.efergy.com/Customers/Public-Sector

[6] http://www.greentechmedia.com/articles/read/the-long-term-storage-challenge-batteries-not-included

[7] http://www.ecobroker.com/misc/articleview.aspx?ArticleID=60

[8] http://energy.gov/energysaver/articles/tips-windows

[9] http://www.toolbase.org/Technology-Inventory/HVAC/energy-recovery-ventilators