Preliminary Design Report Energy Generating Cardio Machines

Date: April 26th, 2013
Client: Campus Fitness Centers & Siemens
Engineering Design 100
Section 11
Team 5

Zach Santos, Austin Zelko, Steven Griffel, and Kenny Fuhrman

This design project's goal is to design or redesign an aspect of University Park to make it more sustainable. It is proposed in this project that this be accomplished by conserving energy in addition to promoting fitness. The design utilizes human's mechanical energy to produce renewable energy that can reduce the amount of electricity a building, specifically the IM building, has to use. This will be done by connecting both cycling machines and ellipticals to an inverter that can convert the energy and then send the energy to a generator for storage. A typical twenty minute workout can generate 50-150 watts. Each inverter, which easily fits inside the cardio machines, can generate up to 2,000 watts per hour, so having one inverter for every five machines will optimize the design to reach its full potential.

Contents

Introduction 3
Concept of Operations.....3
Design Principles.....6
Project Schedule.....6
Concept Development 7
Detailed Concept Development.....9
Calculations.....9
Conclusion.....10
Lessons Learned.....11
References.....12
Appendix A.....13
Pairwise Comparison Chart.....13
Appendix B.....14
Weighted Selection Matrix.....14
Appendix C.....15
Survey Question One.....15
Appendix D.....16
Survey Question Two.....16
Appendix E.....17
Survey Question Three.....17
Appendix F.....18
Survey Question Four.....18
Appendix G.....19
Survey Question Five.....19
Appendix H.....20
Survey Question Six.....20
Appendix I.....21
Flowchart for Energy Generating Cardio Machines.....21

Introduction

SIEMENS Corporation, an international company that specializes in engineering and electronics, proposed a project in making the University Park campus of Penn State more sustainable. The solution must enhance economic, social, environmental sustainability, and/or use appropriate technology. Therefore, it must improve some attribute of the campus to make it cleaner functioning.

Team 5 researched different aspects of the campus such as energy, transportation, and water treatment. When doing this, the team noticed that Penn State University (PSU) purchased 88.75% of its electricity from the grid. Penn State University can be considered a small city in itself, so the opportunity for this project was to reduce the amount of energy that the campus purchases from the grid. Therefore, the solution must either add more energy production or redesign a part of campus to consume less energy.

Concept of Operations

During the brainstorming process, the goal was to come up with an idea to reduce energy obtained from the grid. In this process, we came up with six different solutions to reducing the large amount of power used by the campus. These included wind and solar power, heat and light regulating sensors, and power generated from exercise machines. For one of these projects to be considered, it must be sustainable, which is an ecological balance between human behavior and the environment. The harm to the environment can be reduced while working with human behavior.

Our first idea was to include wind turbines into the campus due to the high amounts of wind that state college has year round. After doing research, we found that even though it is highly efficient and would generate a lot of electricity, it would be hard to gather all the wind due to the location. The size of the wind turbines also makes wind turbines hard to place among the campus without conflicting with current buildings and the student body. Overall, the durability of the wind turbines is fairly high, but they run the risk of having birds colliding with them which would reduce the lifespan of them and would also increase the number of repairs needed. Safety isn't really a problem for the wind turbines other than for birds that live in the area. The main issue with wind turbines is their aesthetic appeal as well as sound. They create an eyesore over time for the students and visitors. Relative to the other proposed designs, wind turbines cost a much larger amount than most of the other ideas, making it much harder to implement into the campus.

Solar panels were the next idea we had for the campus. While highly efficient during most times of the year, the winter months will show a large decrease in energy produced due to less sunlight. Even though each individual solar panel is relatively small and flat, a large number of them would be require which would take up a substantial area. Durability would be similar in length to the wind turbines due to them constantly being subjected to weathering and constant use. Safety isn't an issue for solar panels. Solar panels have no downside to likeability, but they lack the aspect of engagement to the population. Cost for solar panels is quite high. This is a major downside to them, thus making them harder to implement.

Another idea to make the campus more sustainable was to install either heat or light regulating sensors. The idea of using sensors to save energy sounds appealing, but in reality, this technology is inefficient compared to our other ideas. This technology is very small in size and barely noticeable after it is installed. The sensors can withstand reasonable temperatures and other room conditions, but they are very fragile, which are not ideal for a college dorm. They also cannot be exposed to direct sunlight. In terms of safety, the sensors bring some risks. The sensors cannot come into contact with water or else they will short out and create a fire hazard. The technology does not have any protective circuits implemented. The likeability of having a sensor is almost non existent because they are not appealing and there is no want from college students to have these in their rooms. The costs associated with installing these sensors into dorm rooms are rather high. Although the cost of the sensor alone is relatively low, the sensors can only cover a small area, so there will have to be multiple sensors throughout the room. Also, the utilities that can be used with the sensors must be purchased and installed with the sensors in order for the technology to work. This all adds up to a really high cost for something that is rather inefficient.

The last idea was utilizing cardio machines to generate electricity. The efficiency rate is relatively low, but can create a high output with many machines in addition to promoting fitness. In terms of size, the technology can easily be installed into the machines that are already in place without altering its original structure. The projected durability of the technology is approximately ten years. Having said that, this ten year period will minimize maintenance and repairs on the system. All of the wiring and the technology can be harnessed on the inside of the machine, so safety is high. There is very little risk in

harming the users of the cardio machines. The cost of this technology is fairly high per unit, with each unit being a combination of five bikes and a battery.

Design Principles

The design must produce energy to power some of the gym's utilities such as lights, air conditioning, and heating. It must fit within the current dimensions of the bikes and ellipticals (3.5 feet by 2 feet by 4 feet). It must be cost under $1,000 dollars per bike/elliptical. It must have a system to record the energy produced from the design. The design must increase gym attendance by at least 20% and increase overall gym usage by 20%. It must be able to last at least 10 years before repairs or replacements are necessary. The design must maintain the current level of safety in the premises. In addition, the buyback period for the machines must be under 17 years to be considered efficient.

Project Schedule

The project's development took place over the period of seven weeks. Once the project was assigned, the problem statement was determined, and the design criteria for it was laid out. The first week was used to define the problem and brainstorm ideas. The next week was used to gather information about both the specifications for the proposed idea, as well as gather information on related activities of the campus residents through surveys. We then spent time analyzing the possible solutions to the problem and determining which one would provide the best results. Below is a picture of our overall schedule in a Gantt Chart (shown on next page).

Schedule for Project

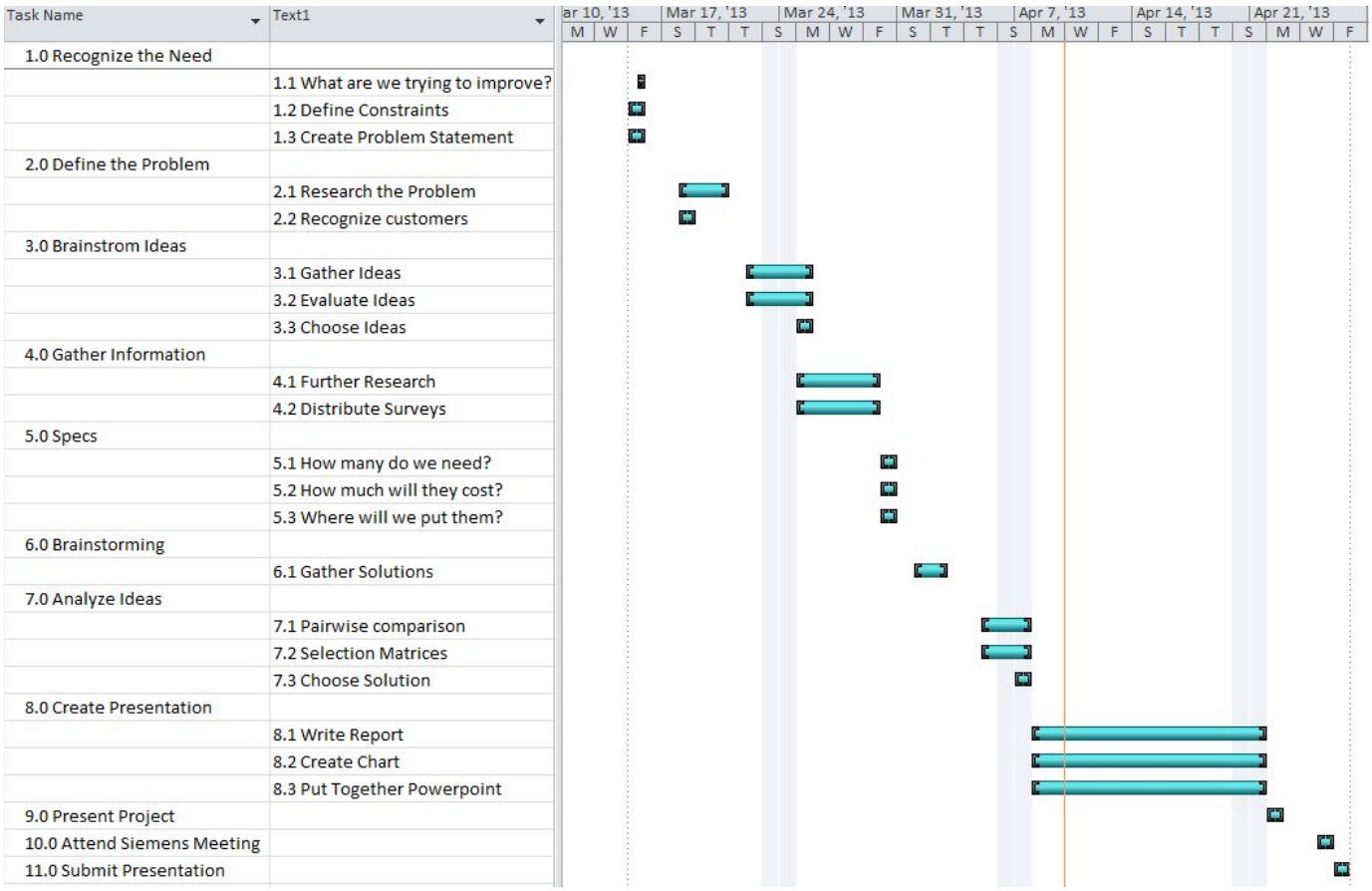


Figure 1 - This chart shows the time frame for our energy generating cardio machines. It maps out how many days were devoted to a given part of the design process.

Concept Development

The solutions evaluated to accomplish the goal of this project were implementing the use of wind turbines, solar panels, heat regulating sensors, light regulating sensors, ellipticals, and cycling machines to produce usable energy for the campus. After evaluating these ideas with the use of selection matrices like a pairwise comparison chart (See Appendix A) and a weighted selection matrix (See Appendix B), we came to a conclusion that the best solution to move forward with would be the use of the two cardio machines as sources of energy for the campus. Since we chose to implement cardio machines as the

source of energy, we decided that the energy should be used to power the same room that it is coming from. Therefore, the energy created from our solution will be used to power the lights in the gym.

During our researching phase we conducted a survey to determine how people would react and be accepting to the implementation of the energy generating cardio machines (See Appendix C-H). The first question we asked was how many hours a week do you exercise. The responses averaged over five hours which show that many people exercise and the implementation of an exercising device would be used. The next question, "Do you do cardio," is used to determine if people would actually be using the technology we plan to implement. With an almost 90% positive response to the question, it is clear that our project would be in high demand. Next we asked which machines were used most often to further gauge how much they would be in use. The next question is part of the promoting fitness on campus part. There was about a fifty fifty split between people being more motivated to work out if they could compare themselves to each other, so those who wish could participate, and those who were not interested could opt out of comparing themselves to each other. For the second to last question, we asked how energy conscious people were throughout their day to day activities. Our goal is to increase general awareness of energy consumption/production, by displaying how much is produced in a workout, so the question was used to gauge how much people pay attention already. Lastly, we asked if people would be more inclined to work out if they could see how much energy they are producing. This had a majority yes response which would be helpful in increasing fitness as well as energy production.

Detailed Concept Development

Electricity is generated in the bikes and ellipticals through a simple process (See Appendix I). The bikes and ellipticals act as a turbine that when spun and hooked up to an inverter, generate electricity. Instead of the turbine being spun by water or steam, like in dams and coal power plants, it is spun by human mechanical energy through the act of spinning the pedals. The inverter will then be connected to a system of batteries to store the electricity in order to be used whenever needed. This process is found to be about 45% efficient since there is a lot of energy lost to friction of the spinning bike and escaped heat.

Calculations

14% of the IM building's electricity usage is lighting. Gym light is about 10% of the total light in the IM building, so it is 1.4% of the total electricity. The Intramural Building uses 1,500,000 kwh in one year, so our goal is to produce 21,000 Kwh/year. In a 30 minute workout, a person burns about 300 food calories (FC), so one hour will equal 600 FC. Since one FC is equal to 1,000 calories, a total of 600,000 calories will be burned in an hour. By using basic stoichiometry to convert the calories to Kilowatt hours, a total of .7Kwh will be produced. Then by multiplying the .7 Kwh by the 45% efficiency, then by 8 hours a day and 365 day in the year, a total of 919.8 Kwh per year will be produced. If 23 machines are used, this will produce 21,155.4 Kwh a year, which, at $0.07 a Kwh, the machines will produce around $1,480 per year. At this rate, they will have a 15.5 year buyback period (See calculations below).

600FC x 1,000 calories (1FC is equal to 1,000 calories) = 600,000 calories

600,000 calories x 4.186J/calorie x 1W-s/1J x 1hr/3600s = 700Wh = .7Kwh

.7Kwh x 45% efficient x 8hrs/day x 365day/year = 919.8 Kwh/year (1 machine)

919.8 Kwh x 23 machines = 21,155.4 Kwh/year

21,155.4 x $.07 (1 Kwh cost 7 cents from the grid) = $1,480/year

$23,000 (cost of all machines) / $1,480 = 15.5 years to make money back

Conclusion

Overall, our new and upcoming design would be very successful in the near future in terms of technology and innovation. Our energy generating cardio machines use simple physics and friction to produce electricity, have the energy produced forwarded to an inverter, and then from there, distributed throughout the gym for appropriate consumption. If the energy is on overload, the energy is simply stored in a battery and then tapped into when needed. The design satisfies our environment in a positive manner by using people's natural power through exercise to produce electricity. Our design satisfies the economy because even though the buy back is 15.5 years, it will pay off in the long run and ultimately save the university a sizeable amount of money. With the money saved, it may be distributed for general maintenance purposes, for new and decrepit machines, or for salary and bonuses for the workers in the gym. Our leading point in sustainability is that our energy generating cardio machines promotes fitness throughout our Penn State community. It motivates people to work out, makes the users aware of how much energy they are producing, and it ultimately saves their life by making their hearts stronger and healthier as well as saving money for the prestigious Penn State University.

Lessons Learned

There were many lessons learned while planning, executing, and finalizing our project. We as a group learned that through communication and combining our human capital, innovation and advancement in technology can be achieved. Therefore, with our brain power and leadership skills, we came up with a revolutionizing idea of energy generating cardio machines. First, we learned with our similar personality types, we meshed together very well as a group. Even from the first day of working together as a team, we knew what each other were thinking and were always on the same page. We had our disputes and conflicts but after simple agreements, we came to a consensus. Next, we learned how truly important time management really is when planning and developing an idea with team members. Through our Gantt Chart and mapping out our eight week period of creating this design, we understood and utilized staying on track and never going down the wrong path. Our Gantt Chart provided us with guidelines and a goal to follow, and we learned and figured out how to achieve them. Lastly, we educated ourselves with the new idea of figuring out how to make any system or piece of technology sustainable. We have learned throughout the year that to make something sustainable, one has to satisfy the community economically, socially, and environmentally through the use of appropriate technology. We firmly believe our idea and concept of energy generating cardio machines satisfy our Penn State community only for the better. It was proven that our concept saves money in the long run, satisfies our customer needs and wants, and promotes fitness to the student body. In conclusion, our energy generating cardio machines are a new and upcoming piece of technology that will revolutionize the pre existing gym technologies and benefit them for the better.

References

1. Bloyd, Stephanie. "Green Gym Equipment Gaining Popularity." (n.d.): 1-3. *Penton Media, Inc*. Web. <http://rerev.com/downloads/Articles/Dawn_Green.pdf>.
2. Craig, Patricia. "What We're Doing." *Green: What We're Doing*. N.p., 2009 Aug. 2009. Web. 24 Apr. 2013. <http://www.green.psu.edu/psuDoing/energy.asp>.
3. "Fitness and Energy Awareness." Interview. *Survey Monkey*. Kenny Fuhrman, Austin Zelko, Zach Santos, Steven Griffel, 27 Mar. 2013. Web. <http://www.surveymonkey.com/analyze/?survey_id=39634030&OPT=NEW>.
4. "Fitness Equipment Helps Facilities Harness User-Generated Energy." *Athletic Business*. Ed. Michael Popke. Athletic Business, 8 July 2011. Web. 24 Apr. 2013. <http://www.athleticbusiness.com/articles/article.aspx?articleid=3764>.
5. "TeensHealth." *Getting Exercise in College*. N.p., n.d. Web. <http://kidshealth.org/teen/school_jobs/college/exercise.html>.

Appendix A

Pairwise Comparison Chart

Pairwise Comparisons								
	A	B	C	D	E	F	Row Totals	Row Total/Total
A	1	6	1 1/2	2	3	1 1/2	15.00	30%
B	1/6	1	1/4	1/3	1/2	1/4	2.50	5%
C	2/3	4	1	1 1/3	2	1	10.00	20%
D	1/2	3	3/4	1	1 1/2	3/4	7.50	15%
E	1/3	2	1/2	2/3	1	1/2	5.00	10%
F	2/3	4	1	1 1/3	2	1	10.00	20%
					Total		50.00	
A - Efficiency								
B - Size								
C - Durability								
D - Safety								
E - Likeability								
F - Cost								

The pairwise comparison was determined by considering how important each characteristic compared to the other. This allowed for a better understanding on what the solution needed to accomplish. Certain characteristics have a higher weight in value, making them more important, while others have low weight in value, making them less important. Efficiency has the highest weighted value because the whole goal of the project is to generate electricity for campus, which correlates to our results. Durability and cost are the next most important characteristics because the solution must last a while and allow for a buy back period to successfully be considered sustainable. Size, safety, and likeability are lower than the other characteristics, but that does not mean that these should not be considered. All in all, everything must be considered when implementing a solution, but there will always be a chance that sacrifices must be made in order for a solution to become real.

Appendix B

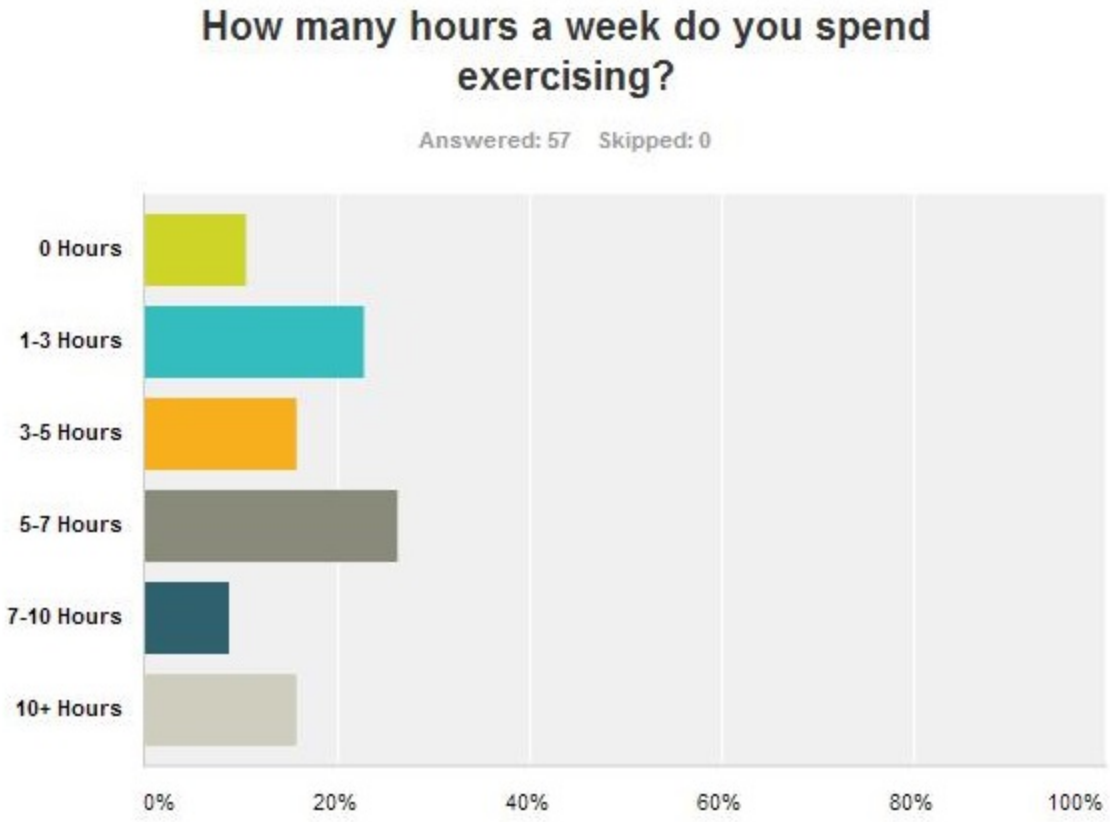
Weighted Selection Matrix

Weighted Selection Matrix for Ideas													
Concepts													
		Bike		Elliptical		Wind Turbines		Solar Panels		Heat Regulating Sensors		Light Regulating Sensors	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Efficiency	30%	2	0.6	2	0.6	4	1.2	4	1.2	1	0.3	1	0.3
Size	5%	5	0.25	5	0.25	1	0.05	1	0.05	6	0.3	6	0.3
Durability	20%	3	0.6	3	0.6	3	0.6	2	0.4	2	0.4	2	0.4
Safety	15%	2	0.3	2	0.3	2	0.3	2	0.3	2	0.3	2	0.3
Likeability	10%	7	0.7	7	0.7	3	0.3	3	0.3	2	0.2	2	0.3
Cost	20%	3	0.6	3	0.6	2	0.4	1	0.2	2	0.4	2	0.2
Total Score		3.05		3.05		2.85		2.45		1.9		1.9	
Rank		1		1		2		3		4		4	
Continue?		Develop		Develop		No		No		No		No	

After obtaining the percentages from the pairwise comparison to weight the different selection criteria, the six possible design solutions were compared. They were given a score between 1 and 10 with 1 being the least appealing, and 10 being the most appealing for the solution. Once each was scored, the rating for each category was multiplied by the weight, and then added to the other weighted scores for a total. The total scores were then compared to each other to determine which project would be the most likely to implement.

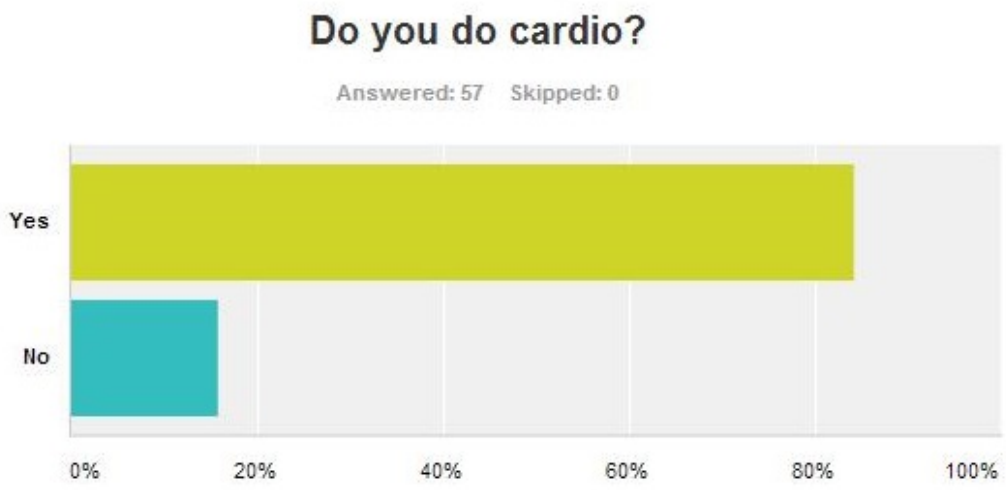
Appendix C

Survey Question 1



Appendix D

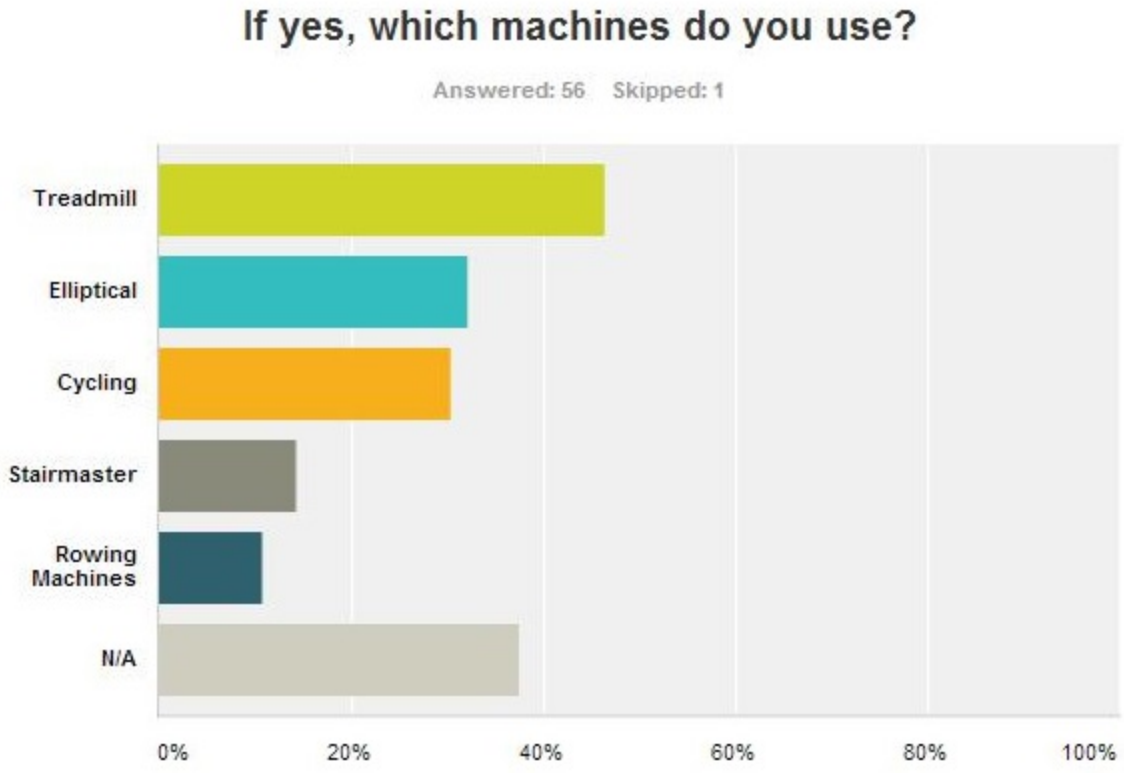
Survey Question 2



Answer Choices	Responses	
Yes	84.21%	48
No	15.79%	9
Total		57

Appendix E

Survey Question 3

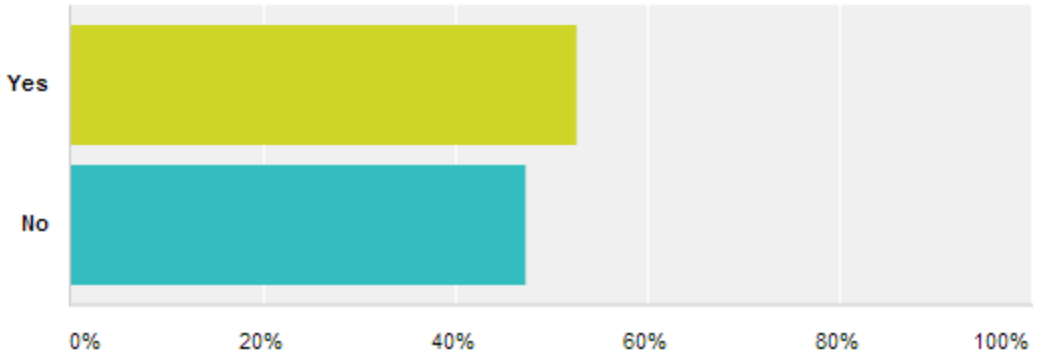


Appendix F

Question Survey 4

Would you be more motivated to work out if you could compare your results to other people?

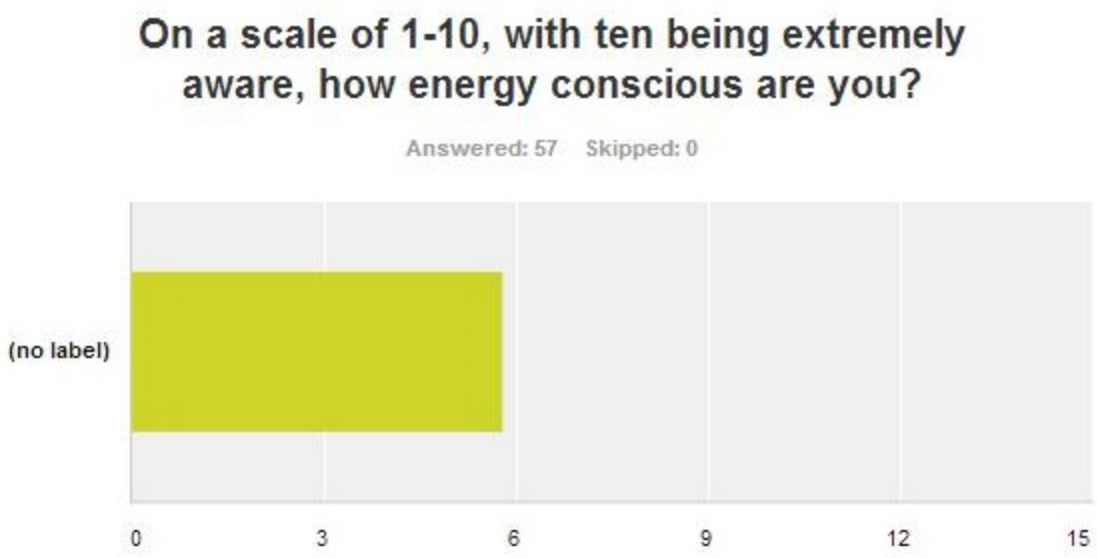
Answered: 57 Skipped: 0



Answer Choices	Responses	
Yes	**52.63%**	30
No	**47.37%**	27
Total		57

Appendix G

Question Survey 5

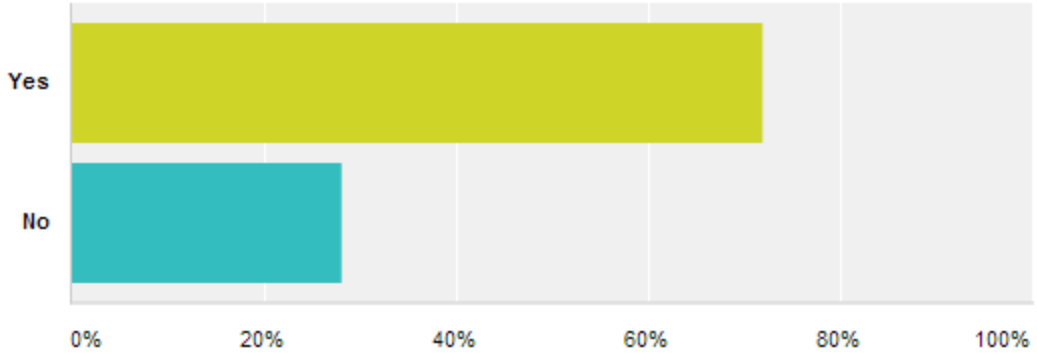


Appendix H

Question Survey 6

If you could produce usable energy while working out and see that amount, would you be more inclined to exercise?

Answered: 57 Skipped: 0



Answer Choices	Responses	
Yes	**71.93%**	41
No	**28.07%**	16
Total		57

Appendix I

Flowchart for Energy Generating Cardio Machines

This diagram shows how the entire system would work by linking a number of the bikes together, then using the power generated from them to charge a battery. The energy then be immediately used to power the gym's lights, or stored for later use.