Greening Kirby Fitness

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The purpose of this project was to explore the possibility of making Kirby Sports Center a more sustainable building while engaging the campus community in Lafayette College's sustainability efforts.

Kirby Sports Center

INTRODUCTION

Our group, Ben DeForest, John Ludington, Adam Iglehart, and Owen McCann, developed the "Greening Kirby" project to address sustainability issues in the Twenty-first Century. We feel that Lafayette College has a responsibility and opportunity, as a higher-education institution, to serve as a leader in addressing global issues such as over-consumption and sustainability. While Lafayette College has declared sustainability as one of its core values, their efforts have not yet transpired into actual change (Lafayette College, 2015). The "Greening Kirby" project seeks to address this issue by reducing the Kirby Sports Center net electricity usage and emphasizing the over- consumption of electricity at Lafayette College.

RESEARCH QUESTION: *Can power generation in the Kirby Sports Center workout facility be used to strengthen discussions at Lafayette College about energy over-consumption in everyday life?*

FINAL OUTCOMES:

1. Determine the technical feasibility of using regenerative workout machines.
2. Serve as a foundation for future sustainability projects at Lafayette College.

"Greening Kirby" is designed to serve as much an educational tool as it is anything else. While regenerative workout equipment has the potential to be cost benefiting in the long term, the motivations for the project originate with the opportunity to strengthen the school's sustainability effort by raising awareness through student and community engagement. It is our hope that the final design, installation, application, and maintenance of the equipment will incorporate student projects and learning exercises. This directly aligns with the college's initiative to foster projects that bring students from various academic backgrounds to work on complex issues that fall outside the boundaries of traditional disciplines (Lafayette College, Interdisciplinary, 2015). For more information regarding spreading awareness for sustainability on campus, visit our Social Context page.

For this project, we aim to make the equipment in the Kirby Fitness Center regenerative. This will either involve retrofitting existing machines with energy converters or replacing the machines with ones that have built in energy conversion systems. The technology required for both of these options is already available and we have consulted with several companies that offer these services. For more information about how the energy is converted and what each company offers, visit our Technical Analysis page.

The main challenges our project faces are raising awareness, understanding the technical solution, and navigating through the heavily bureaucratic capital budgeting application process at Lafayette College. This is, in large part, due to the lack of a unified sustainability outlet at Lafayette. In 2007, the college created the

Campus Sustainability Committee to devise and implement environmental initiatives. Unfortunately, this committee has been ineffective in facilitating change, as well as educating and engaging the student body (Lafayette College, Climate, 2015). Members of the committee have primary jobs and numerous commitments outside of the committee, which has led to a slow system with little accountability (Last, 2015). Our group has experienced these hurdles first-hand and emphasize that it is a major obstacle in process for student- and faculty-led projects. Fortunately, after adamant lobbying from the Lafayette Environmental Awareness and Protection group (LEAP), the administration has recently recognized the shortcoming of the organizational structure and has decided to hire a sustainability coordinator. This full-time coordinator will work to facilitate communication among clubs, assist in marketing campaigns and events to the entire campus, and increase follow-through on student- and faculty-led projects (Last, 2015). While this outlet will not exist during the scope of our project, it highlights the college's efforts to bridge the gap between the administration and the campus community. For more information on the application process and administrative feasibility please view our Policy Analysis Page.

Our group recognizes that the final decision for the approval of a project ultimately depends on its economic value. In the case of the "Greening Kirby" project, which has little financial value, this represents a significant obstacle to overcome. However, we feel that the existing environmental social movements and administrative support on Lafayette's campus can overcome this barrier (Last, 2015). Projects are consistently undertaken at colleges to highlight research or issues that frequently will not have financial kickback, but are still considered excellent uses of resources. Additionally, we advocate that the "Greening Kirby" project has an intrinsic educational value that cannot be accounted for in the economic analysis and will serve as an influential force during the application process. As a private, higher-educational institution, Lafayette College has the ability and experience to incorporate externalities such as education in their analysis. For more information on our plan to finance this project please view our Economic Feasibility Page.

The Kirby Sports Center was chosen because it is one of the focal points of life on Lafayette's campus. The vast facilities it provides bring together students, faculty members, and community members to engage in activities ranging from dance classes to the infamous Lafayette vs Lehigh rivalry game. Consequently, the facility receives a high volume of people and hosts a wide variety of events on a daily basis. Recently, Lafayette College has renewed their interest in pushing for sustainable solutions on campus, and to bring environmental sustainability to the forefront of campus conversation. Our group feels the regenerative workout equipment and informative dashboard present an opportunity to demonstrate the college's commitment to their sustainability initiatives. Looking forward, we believe the dashboard can serve as a medium to broadcast the school's sustainability effort by centralizing all data and information related to energy use and projects directed towards progressing the Lafayette Community.

SOCIAL CONTEXT

The aspiration to make Lafayette's fitness center more energy efficient has come about as a result of a conglomerate of social forces. Developments in climatology research have led to an overwhelming consensus amongst the scientific community that anthropogenic produced greenhouse gasses are the main driver of climate change. The increase of the average global temperature and frequency of severe weather events have led to a rise in public awareness of greenhouse gas emissions. Since the United States is recognized as a global leader, there is an inherent pressure to set a precedent by reducing emissions. Additionally, it is commonly known that the United States has historically been and remain today, one of the largest contributors to the climate change problem. Many academic institutions across the globe are actively seeking to successfully reduce the carbon footprint of their facilities. Such institutions are more attractive to prospective students and potential employees. There is no reason why Lafayette should be any different.

This raises the questions: why should Lafayette College be concerned and why does the problem focus on Kirby Sports Center?

Lafayette College and similar institutions invest a great deal of time and money into developing and maintaining their reputation. As the climate change debate has matured and its reality has become more widely accepted, there has been a social movement to act responsibly by reducing greenhouse gas emissions. This has presented companies and institutions alike with an incentive to frame themselves as environmentally conscious and morally responsible. At this point in time, there already is a movement within the Lafayette Community to do so. In fact, the social impulse is so strong that President Byerly and the administration deemed sustainability one of Lafayette's three core values. (Lafayette College. 2015) Additionally, climate change is a topic on the student's agenda. Recently, the student run environmental group, LEAP (Lafayette Environmental Awareness and Protection), held a rally to raise awareness to environmental issues and try to establish a campus sustainability representative to spearhead the school's sustainability efforts. (Hayet. 2015) This proves that there is a clear consensus among Lafayette's community that the administration should continue to make the school's facilities greener.

Students at Lafayette are generally aware of their carbon footprint. However in order for students to actually make a difference, they need to make lifestyle changes which can be easier said than done when balancing schoolwork with extracurricular activities. The school needs to aim to make it easy and fun for students to develop energy saving habits by integrating sustainable systems in various facilities on campus. The school should focus on the most commonly used facilities because they generally require the most energy to run. The Kirby Fitness Center is constantly in use, whether it be by student athletes, locals, or the school's faculty. The building plays a key role in the daily lives of many people in the surrounding area which is why it is the perfect place to integrate new sustainability practices.

The people who use the proposed regenerative equipment will be playing a direct role in saving energy on campus without having to make a huge change in their lifestyles. They will also feel a sense of accomplishment because not only are they staying fit but they are doing so in a way that benefits the environment. We want to provide the users of this new equipment with as much information as possible regarding how they are contributing to energy generation. This will make students more aware of their individual energy consumption habits. The equipment will have a visual display that does this in a user friendly way. This element may have the effect of encouraging friendly competition among users to see how much energy each individual can produce in a given time period. In 2009, students at both the University of Oregon and Oregon State University hired a company called ReRev to retrofit their elliptical machines with a system that converted the user's input to usable energy. A pre-existing sports rivalry between the two schools inspired exercise competitions among students to see who could generate the most energy. (Lovgren. 2011) This could happen between Lafayette and Lehigh as the rivalry between the two institutions could fuel a similar competition that would ultimately benefit both schools. In addition, it's possible that students will use social media to share how much energy they have saved with their friends and family which could help increase student interest in sustainability.

One of the overarching goals of this project is to successfully capture the attention of both Lafayette's community and other institutions as well. Successfully making the gym's exercise equipment regenerative would capture the attention of other organizations which would help Lafayette establish itself as a leading institution on the sustainability front. Lafayette has the potential to be a model for sustainable achievement in the greater Lehigh Valley. Outside organizations that read about the college's increased sustainability efforts may work to achieve similar goals in local communities. Additionally, Lafayette can work together with Easton on sustainability projects off campus which would allow students to have a direct impact on the community while learning a great deal in the process. Easton has already begun to ramp up their efforts through several sustainability projects that aim to increase the city's energy efficiency and reduce pollution. One of these projects involves building a facility called the Easton Sustainability Complex that "combines innovative energy technology with Easton's state-of-the-art wastewater treatment technology". The new facility aims to reduce the town's dependency on purchasing electricity from the power grid. (Bollinger. 2015) If Lafayette students were to participate in projects such as this one, they would gain valuable experience which could then be applied to future sustainability projects on campus.

Drexel University implemented regenerative fitness equipment back in 2010. We reached out to Drexel University and were put into contact with Bryan Ford, who is the Director of Recreation in the Department of Athletics. During the conversation we were informed that they have twelve precor elliptical machines that have been retrofitted to work with ReRev technology. (Ford. 2015)

ReRev in Action at Drexel University

These machines are connected to a display as well as a light up sign. When the machines are being used, the display shows the amount of energy the user is generating and a sign lights up. Bryan informed us that these elliptical machines are the most popular pieces of equipment in the gym. They are used primarily for an awareness campaign on Drexel's campus and their Drexel Green movement. However, they do not use the equipment to generate power for the gym, nor do they plan to advance the program to do that in the future. Drexel will only use the gym equipment for educational purposes. (Ford. 2015) The sign that reads "I am a dragon.", is particularly effective because it gives users the ability to see power generation take effect. This shows that installing regenerative fitness equipment can help to strengthen sustainability awareness on campus through education.

Increased interest in the school's sustainability efforts could lead to the development of additional research opportunities for students who are interested in this field. This would encourage innovation by providing students with opportunities to actively make an impact on campus while learning a great deal during the process. New York State University has added a School of Sustainability Student Research allowing students to work collaboratively across disciplines on sustainability projects that have real-world applications. (Redden. 2009) This program is similar to Lafayette's Engineering Studies B.A. degree in that it teaches students how to work with people from a wide variety of academic backgrounds. The development of a separate sustainability major may not be too far away in Lafayette's future as sustainability is becoming an increasingly relevant topic in today's world.

Administrative support of student-led sustainability projects is essential for allowing students to play a central role in making important changes on campus.

Why hire a sustainability consultant when you can rely on the bright minds of Lafayette's academic community? It is important that Lafayette addresses campus sustainability issues by having the college community drive change instead of simply throwing money at the problem by hiring outside experts to do the job for them. Members of the college community understand the different contexts involved when considering certain projects because they spend so much time on campus. Students often find flaws in the school's infrastructure that are overlooked by the administration. The ultimate goal is to make people care more about living a sustainable lifestyle.

POLICY ANALYSIS

The policy analysis section of our report focuses on the laws and regulations that the regenerative workout equipment must comply by, as well as the stakeholders that will be affected and how they will influence the implementation of the project. As thoroughly developed by the coursework and class discussions in Engineering and Society, it is imperative to recognize the interconnected relationship that technology and society have. By influencing the development of the other, the two entities, technology and society, exist together within a greater socio-technical system. As interdisciplinary engineers at Lafayette College, our group uses this section to not only explain the approval process, but to emphasize the politics behind the technology.

As explained in the social context section, the regenerative workout equipment and the informative display screen are developed solutions to sustainability issues on campus. It is important to revisit the underlying assumptions that went into defining the problem and developing its solutions. This presents the question, why sustainability? In tackling this question, our group was tasked with analyzing why sustainability matters to the broader population at Lafayette, as well as if and why policy actors will be motivated by the issue. Given the nature of the globalized world we live in today, it is fair to state that sustainability is a universal issue, and is fundamentally linked to environmental and social justice issues. Knowing the college's vowed efforts to diversify its demographics with regards to ethnicity, socioeconomic status, and place of origin (among other classifications), it is critical for the college to also acknowledge that these same groups of people are the ones being disproportionately affected by global issues like sustainability (Lafayette College, Diversity, 2015). As a well funded, leading higher-institution in the United States, it is imperative that Lafayette College is conscious of the implications of its actions and/or inactions. To address sustainability the college needs to first recognize the consequences of its over-consumption of energy, and then move forward by researching and implementing policies that effectively work to solve the problem.

After evaluating the economic and technical contexts influencing energy use at Lafayette College, with respect to the limitations shaped by the scope of our project, our group concluded that awareness and education are the most effective methods of addressing sustainability at Lafayette. The interactive environment produced by the regenerative workout equipment and the informative interface are designed to do just this; raise awareness and increase education concerning energy consumption at Lafayette College by creating a platform that facilitates community engagement. Following our analysis of the problem and alternative solutions, our group focused on the federal, state, and local regulatory measures restricting the implementation of our project.

Policy constraints that need to be overcome for the approval of the "Greening Kirby" project include a variety of regulatory standards and administrative approval. Due

to the dangers inherent with electricity production and conversion, our project must comply with local, state, and federal codes. These codes include:

Federal:

- Underwriters Laboratories 1741
    - Governs inverters, converters, change controllers, and interconnection system equipment (ISE) intended for stand-alone and utility-interactive power systems
    - Used in conjunction with IEEE 1547 for utility-interactive systems
    - Covers AC modules that combine flat-plate photovoltaic modules and inverters that provide AC output power for both stand-alone and utility-interactive systems. The requirements also cover alternative energy sources combined with inverters, converters, charge controllers, and ISE in system specific combinations.
    - Requirements cover power systems that combine independent power sources with inverters, converters, charge controllers, and ISE in system specific combinations
    - Products covered by these requirements are intended to be installed under the National Electrical Code (Underwriters Laboratories. n.d.)
- National Fire Protection Association 70
    - Benchmark for all safe electrical design, installation, and inspection
    - National Electrical Code addresses installation of electrical conductors, equipment, and raceways; signalling conductors, equipment, and raceways; and optical fibers conductors, equipment, and raceways in commercial, residential, and industrial occupancies (National Fire Protection Association. 2015.)
- IEEE 1547: Standard for Interconnecting Distributed Resources and Electrical Power Systems
    - Establishes criteria and requirements for interconnection of distributed resources with electrical power systems
    - Requirements relevant to performance, operation, testing, safety considerations, and maintenance of the interconnection (IEEE Standards Association. 2015.)

State/Local:

- No local codes governing the electrical equipment
- Building codes possibly applicable for any adjustments to the gym facilities itself
    - Not a necessity if installation of equipment doesn't change the building (Xiques. 2015.)

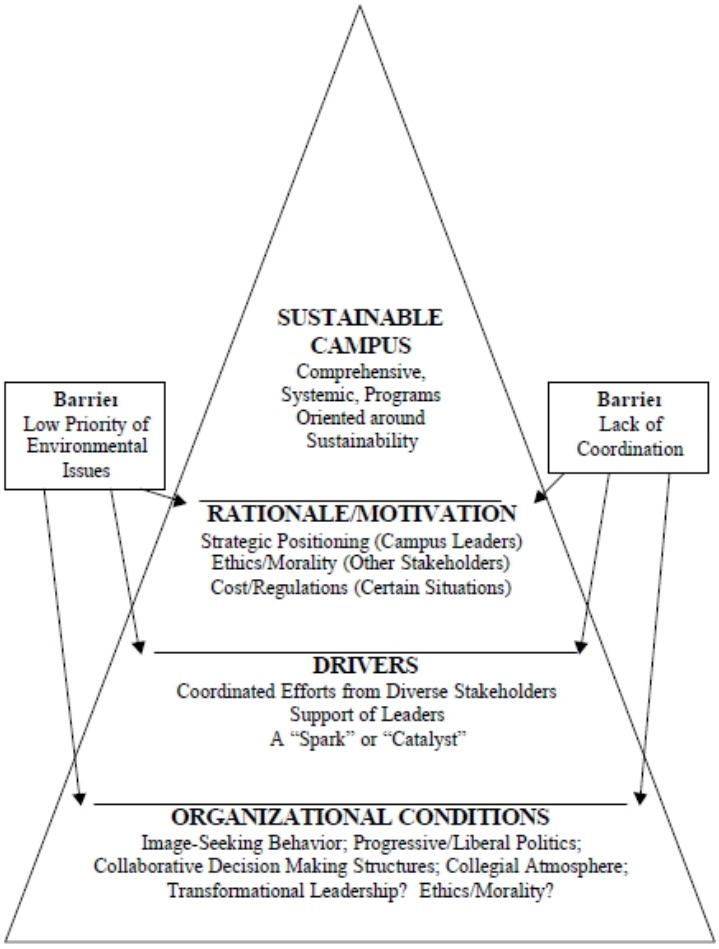


Figure 1: Campus Sustainability Model (Shriberg, 2002)

Following compliance with regulatory bodies, all sizable projects at Lafayette College inevitably need the approval of the 'decision makers'. In the case of the Greening Kirby Project, these decision makers will ultimately be: the Director of Facilities Planning and Construction, Mary Wilford-Hunt, the Director of Plant Operations, Bruce Ferretti, the relevant Division Heads, VP for Finance and Administration and Treasurer, and potentially the Board of Trustees and President Byerly. While our report cannot predict nor anticipate their final decision, we can and have focused on evaluating and gaining the approval of other campus leaders that can influence the board's decision. In *Institutional Assessment tools for sustainability in higher education: Strengths, weaknesses, and implications for practice and theory*, Michael Shriberg found that in addition to moral motivations and support from campus leadership, successful sustainability initiatives require a coordinated effort from a diverse group of stakeholders (Shriberg, 2002). Essentially, sustainability is only possible when you have a broad range of support and transparency. For student led projects like "Greening Kirby", our group recommends clearly identifying all decision makers and stakeholders across the Lafayette Community. In the case of installing regenerative workout equipment in the Kirby Sports Center, these groups are: the general student body, student &

faculty organizations, gym employees, community members, prospective students, alumni, and administrators. Our group feels the best way to build support for the "Greening Kirby" project will be by educating the general student body, engaging with activist groups such as the Lafayette Environmental Awareness and Protection (LEAP), reaching out to cultivate alumni support, and working alongside capital budgeting administrators. Thus, as demonstrated in Figure 2, active communication between students, faculty, and all other players is essential for the success of this project.

As outlined in the social context section, the Lafayette College Board of Trustees and President Byerly have made sustainability one of the college's core values. Therefore, there is existing support from the top for initiatives that fall under the umbrella of sustainability. Further supporting the initiative, the college has decided to hire a sustainability chair to spearhead Lafayette's sustainability efforts. This marks a significant progression in Lafayette's efforts and the centralization of information will drastically increase the likelihood of implementing projects similar to ours in the future. In addition to administrative support, it is important to recognize the existing support across the student body. The hiring of a sustainability chair is in large part a result of a student protest organized by LEAP and other community members concerned with issues related to sustainability. Our group is currently in contact with LEAP and plans to utilize their resources to raise awareness and support for our project. Since college campuses are viewed as potential hubs for forward thinking and social progress, our group feels we can utilize the current environment at Lafayette and across similar institutions to provide the impetus for approval and ultimately implementation.

Formally, the approval of the "Greening Kirby" project would begin with a "Capital Project Request Form", which can be found on the Lafayette College's website. Our group will not specifically be engaged in this process because it is outside the scope of our project. However, it is the essential step for any project to be approved on campus. The request form would require the project description, an outline of its cost estimates, department and division approvals, and a proposed funding source. As outlined in the economic analysis, the cost estimates would be clearly articulated by quotes developed by the companies we are working with ReRev, Green Revolution, and SportsArt, as well as a cost benefit analysis compared. Key players in the capital request process include: the Director of Facilities Planning and Construction, Mary Wilford-Hunt, the Director of Plant Operations, Bruce Ferretti, the VP for Finance and Administration and Treasurer, Roger Demareski, and finally President Byerly and the Board of Trustees. If this project is continued in the future by other students, it is imperative that they maintain consistent and effective communication with these players during the process.

While the capital budgeting request process introduces serious administrative obstacles for the implementation of the regenerative workout equipment, our group feels the "Greening Kirby" project is politically feasible. We hope that the administration will recognize that the long-term social benefits of sustainability

projects often outweigh the economic negatives. The purpose of an educational institution is to foster learning that is relevant to current events. Sustainability is a crucial theme in today's world, so Lafayette's administration is responsible for strengthening their sustainability initiative through policy action by acting as a role model for students. Current social movements, the commitments of Lafayette leadership, and increased communication between the student body and administration (with the introduction of the sustainability officer), will make it possible for future groups to overcome the economic challenges of future projects.

TECHNICAL ANALYSIS

For a sometime people have been harnessing human power on bicycles to power lights at night while they ride. Power generating workout equipment use similar techniques to harness the energy a person generates while on an aerobic machine, such as a stationary bike or elliptical. Using inverters and controllers, much like ones developed for solar or wind energy, current machines are able to be retrofitted to become green aerobic machines. It is also possible, using the same technology, for companies to design and manufacture their own machines from scratch. (Gibson. 2011)

There are two options available to us when it comes to harvesting energy from exercise equipment. We have looked at several manufacturers that specialize in doing this and we have compared the different services that they provide. In particular, three companies stood out as being especially feasible both technically and economically: SportsArt , ReRev, and Green Revolution.

SportsArt provides the client with a selection of new ellipticals and bikes that have a built in energy conversion system. A section of the company, called ECO-POWR, offers 14 different regenerative bike and elliptical models. These machines plug directly into a 120-V outlet and the excess energy that is produced goes back into the facility's power grid which offsets energy costs. They also have a visual interface that shows the user how much energy they are producing over time. This interface also has a variety of different fitness games that keep the user entertained during an exercise session. (gosportsart)

SportsArt Equipment Interface

We would lean towards this option if the majority of the machines in the facility were outdated or in need of repair. If so, it would be more feasible to completely replace the aged equipment by consulting with SportsArt. According to Lafayette's director of facilities operations, the typical turnover rate for the exercise equipment is 5-10 years. (Xiques. 2015)

In contrast, ReRev and The Green Revolution retrofit existing exercise equipment with this system so that the client does not have to pay for a completely new set of machines. (Gibson. 2011) As seen in the figure below, an external energy converter would be attached to the equipment.

Equipment Retrofitted by The Green Revolution

A thorough inspection of the quality of each individual bike and elliptical would need to be performed before choosing a specific manufacturer. This process would also involve filling out a facility assessment form with information regarding the size of the facility, how often it is used, and the models of each bike and elliptical. (ReRev)

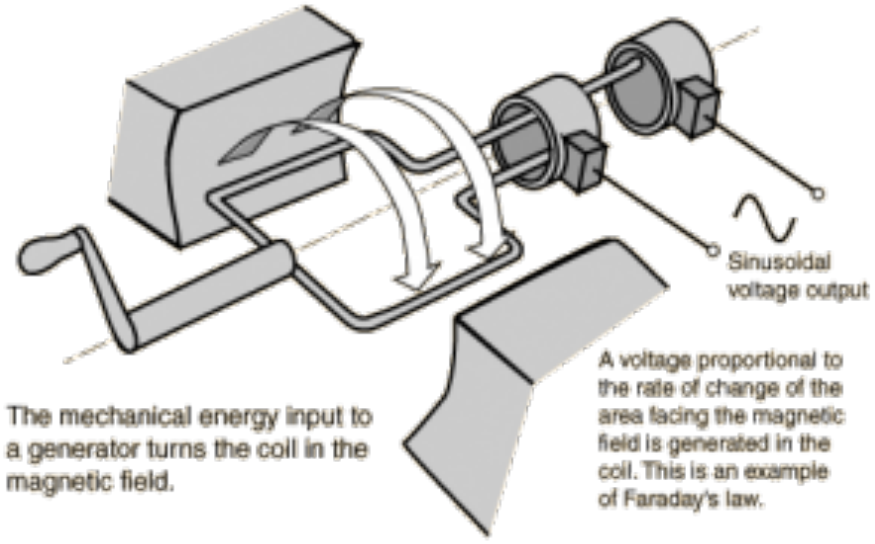
How Does This Energy Conversion Technology Work?

Most types of cardiovascular exercise equipment have an internal wheel that rotates when the user exerts physical energy. It is possible to capture this rotational energy by capitalizing on the piezoelectric effect. The piezoelectric effect is present in materials that generate electric potential in response to a mechanical load. (Kofinas.

2009) A simplified example would be a microphone. The user sends sound waves that exert pressure on the internal microphone system which changes its internal electrical response and results in an acoustic signal. (comsol) We considered applying this same idea to rowing machines, however there are complications due to the fact that this particular type of equipment does not have the ability to produce energy at a continuous rate. A rowing machine operates based on a series of physical pulses that are produced when the user performs each stroke. It may still be possible to harness short bursts of energy but this 'pulse' effect would adversely affect energy generation. (Kofinas. 2009)

Many of today's workout equipment are already fitted with generators. These generators supply the power for the equipment's display screens by converting mechanical energy into AC power. These display screens do not require much power for operation, and typically the user generates more electrical power than the machine needs. This excess energy is fed through resistors that dissipate it as heat. A retrofitted system would send this excess energy to the building's electrical grid. (Lovgren. 2011)

As seen in the figure below, the rotational mechanical energy turns a coil that produces a voltage proportional to the rate of change of the area between the two magnets. This results in a sinusoidal voltage output. (Generators)



How a Generator Works

DC Generator Animation

This voltage output (anywhere from 20-280V) is sent to a rectifier that converts AC to DC power. This is necessary because sometimes AC (alternating current) power can switch directions and DC (direct current) power only flows in one direction. (techopedia) This DC power is sent to a a high-frequency sine-wave inverter that

converts DC into 3-phase AC power. (Freitas. 2010) Inside this inverter, there are two types of transistors: field effect transistors that control the voltage flow and bipolar junction transistors that amplify the voltage which maximizes energy output. (learningaboutelectronics) The energy travels to an output filter that reduces the frequency of the sine wave to 60 Hz so that the energy can travel through a typical AC outlet. (hyperphysics)

Energy Conversion Process

How Much Energy Can Be Produced?

A person who is in decent shape can generate anywhere from 60 to 120 watts during an hour of strenuous exercise. Comparatively, an elite cyclist can average about 300-400 watts. If, in an hour long workout, the person using the machine is averaging approximately 75 watts they are producing 75 watt-hours of energy. ReRev has figured out that 50 watt-hours of electricity can power a compact fluorescent light bulb for two and a half hours, a cell phone charger for six full charges, a laptop for one hour, and a desktop computer for thirty minutes. (Gibson. 2011) Additionally, we have taken a look at several case studies involving schools that have planned and executed similar projects. In 2009, the University of Maryland performed a study that sought to identify the benefits of implementing human energy harvesting technology in gym exercise equipment. They performed a number of surveys that kept track of peoples exercising habits as well as the potential energy that can be produced. They discovered that most people go to the gym 2-3 times a week and use cardiovascular workout equipment for 25-30 minutes per session. They also found that retrofitted elliptical trainers generate approximately 0.1 kW of power each per day. This would only decrease grid dependence by a small fraction. (Kofinas. 2009) According to Lafayette's director of facilities operations, the fitness center's annual energy consumption is 214,500 kWh. (Xiques. 2015) If 10 machines were used 8 hours per day for a year, approximately 2,900 kW would be saved. This means that only 1.35% of the facility's annual energy consumption would be saved.

ECONOMIC ANALYSIS

There are a few different goals that the economic analysis should achieve for this project. The first is to detail the up-front costs to the college for a set of market alternatives to introduce regenerative fitness machines to Kirby Sports Center. It will also review which avenues are possible for finding funding for this type of project and recommending a plan of action on the best option for the college to keep this project running beyond its initial installation. The economic analysis will also look at a present worth analysis of the lifespan of a possible option, and how these machines could eventually pay for themselves given a reasonable use case scenario. Finally it will relate this information back to the project as a whole, showing its relationship to the project and how it affects our intended goal.

Upfront Costs

Upcycle Flywheel

One option for implementing this type of system in Kirby Sports Center is to use the Green Revolution UpCycle Ecocharger. This is a Do-It-Yourself solution and would only be applicable to workout bikes in the gym. the UpCycle components replace the back wheel of a bicycle, or attach to the flywheel on a spinning bike. There is a 600 watt inverter as well that converts the electricity to a usable output to the house. Interestingly Chevrolet used this system in a display at the 2015 Pan-Am games in Toronto. They did extensive testing and proved that it could be used for extensive periods of time in high heat, which should give some comfort that this is durable

enough for daily use in Kirby Fitness Center (Boesel, July 13) . These Kits cost $1,150 to buy, and this includes everything for it to be set up correctly. However with this solution there will be outside wires, and it is not a cohesive system that has been rated for commercial use.

Another option we have explored is the solutions from Re-Rev. They are a consulting company that will retrofit existing equipment and suggest new equipment to use in this system. This would allow Kirby Fitness Center to be more flexible in the types of machines they included in the system. Unfortunately they want a considerable amount of information from the customer before installing a system, which makes it tough to recommend as a viable economic solution. Additionally, the company itself is based in Florida, with no affiliates in the areas nearby area which means any maintenance would either have to be completed by Kirby Fitness Center staff, or would have to wait until the company could come do the maintenance themselves.

Finally there is a commercial option through the Green MicroGym. They sell ellipticals, reclining bikes and spin bikes made by SportsArt that include the inverter in the systems themselves. These machines are on the premium end of the aerobic fitness machines, but they are not unreasonably out of price range. They offer premium quality machines that existing users are familiar with and come with the company's warranties, as well as with the latest updates and designs from SportsArt.

Based on the availability, ease of use and cost, we believe that the SportsArt option is the best option going forward for the gym to implement a system for regeneration in the Kirby Fitness Center. These are commercially ready machines that have been tested in many gyms already. The machines are reasonably priced, and work exactly like the machines they would be replacing, as the college replaces machines. finally they come from a large enough supplier that there will be ample support, and the ability to buy more if the initial project is effective (Boesel, December 5). Figure 1: Cost Estimates is a cost breakdown of the SportsArt Eco line vs. their regular line, as well as a comparison of both to a competitor's machines of similar quality based on price.

Type	Cost/ Machine	Number of Machines	
Sports Art Eco Elliptical	$ 5,795	8	
Sports Art Elliptical	$ 5,295	8	
Competitor commercial Elliptical	$ 5,195	8	(Precor EFX 532i Elliptical Crosstrainer)
SportsArt Vertical EcoBike	$ 2,995	4	
SportsArt Vertical Bike	$ 2,595	4	
Competitor Vertical Bike	$ 3,255	4	(Precor UBK Upright Bike)
SportsArt Spin EcoBike	$ 2,795	5	
SportsArt Spin Bike	$ 1,299	5	
Competitor Spin Bike	$ 999	5	(Diamondback 9101c Indoor Cycle Trainer)
Total Cost Sports Art Eco	$ 72,315		
Total Cost Sports Art	$ 59,235		
Total Cost Competitor	$ 59,575		

Figure 1: Cost Estimates. Unit Cost links below.

Analysis of Cost Recuperation

One of the primary goals of Lafayette College when selecting sustainability projects is for them to be economically sustainable as well. That is, they will cover the cost of installation and operation over the course of their expected lifetime. When determining whether or not this project will do this, we have to look at a couple of different factors. First, using Figure 1 we determine that there is about a $12,700 premium for fully outfitting the gym with regenerative fitness machines. We will use this as the price to cover in terms of installation cost because the regular cost for replacing the aerobic machines is already factored into the budget for the gym.

Weekday			
Capacity (%)	Machines In Use	Hours In Use	Kwh produced
100	17	2	6.8
75	13	4	10.4
50	8	7	11.2
25	4	4	3.2
Totals:		17	31.6

Weekend			
Capacity (%)	Machines In Use	Hours In Use	Kwh produced
100	17	1	3.4
75	13	2	5.2
50	8	7	11.2
25	4	4	3.2
Totals:		14	23

Figure 2. Usage Case Scenario for Kirby Fitness Center

Based on literature from the Green MicroGym we estimate that the average user will produce about 200 watts when using the equipment. For this analysis we will assume that we are using all suggested 17 machines. We have to estimate how often and how many of the machines are being used during the day. Based on observations there are times each day where every single machine will be in use, and there are other times during the day where there will be only a percentage of machines used. Figure 2 describes the distribution of machines in use, and hours of that many machines in use. We end up with about 32 Kilowatt-Hours produced during the average weekday and 23 Kilowatt-Hours during weekends.

According to George Xiques, Assistant Director and Sustainability Planning for Lafayette College, Lafayette pays 0.08 cents per Kwh of electricity they use (G. Xiques, personal communication, December 1, 2015) . Multiply this by the projected production and we get approximately $2.50 per weekday and $3.68 per weekend (Saturday and Sunday). There are 140 weekdays in our school year and 28 weekends, so the estimated total payback for weekdays during the semester is approximately $457. If we divide this by the $12,700 premium we said we need to cover then it would take about 28 years for Lafayette to see a return on its investment. This only includes information pulled on times when students are in session as this is when the machines will be in regular use.

Based on these numbers, this project will not currently be able to cover even its capital cost in a reasonable amount of time. This is a major hurdle for Lafayette and will have to be taken into consideration as the college decides on different alternatives in energy generation experimentation and production for the college.

Capital Budget and Grant Considerations

July is the start of the college's fiscal year. October is when we would submit an expenditure request to the college. We have looked through the college's commitment to sustainability and have found sections that say that they will be financially committed to the growth of the cause as well as physical solutions to reduce energy, water and fuel usage on the college campus. Lafayette College, under the Climate Action Plan (November 2011) has pledged to spend $400,000 per year for ten years to reduce campus emissions by 20%. This project could fall under this grant as an educational tool and as a way the campus is reducing its electricity usage.

From the project prospective, this could actually fall under a couple of different budgets. The capital request is the most broad area of budgeting that the college could consider this project under. We could also try and fit it in through the Sports Center Budget, under the premise that Kirby Sports Center has a budget to periodically replace and renew its aerobic athletic machines. We would have to prove that the extra expense incurred with buying upscale machines is offset by the educational opportunity and the small amount of energy savings that can be achieved through using these athetic machines.

Present Worth Analysis

	Economic Dimension	Monetary Estimate
1	Cost of Machines	$72,315
2	Estimated Cost of Original Machines	$50,000
3	Maintenance	n/a
4	Estimated Premium on Using SportsArt Eco Machines (Fig.1)	$12,740
5	Energy Savings	$457/Year

A present worth (PW) analysis will allow us to look at the actual cost to the college over a predetermined number of years, given the cash flows that we know we have. It will give a more accurate idea of how much this project will cost Lafayette College. The present value will be less than the amount of the future value because we must take the interest rate into account (Blank, L., & Tarquin, A., 2012, p. 129). For this project we are using an interest rate of 3% because that is the national average at this time. (Todays Interest Rates, December 2015).

There are two cash flows in this model: that of the initial cost and that of the annual amount that the college will save because the energy generation. For the initial cost we will use the premium of using SportsArt Eco machines over a competitor's option, which is $12,740. This allows us to see whether or not we have a positive present worth, meaning that the SportsArt Eco machines cost less in the long run because of their ability to generate energy for Lafayette College. The annual cash flow will be $457 per year based off of earlier calculations about the efficiency and use of the machines. The life of the project will be ten years. This is extremely optimistic, considering the warranty of parts is five years, although the frame and display have a lifetime warranty. Our equation then will look like this:

$$PW = -12{,}740 + 457(P/A, 3\%, 10)$$

Our annual cash flow needs to be turned into a present worth, so we use the Uniform Series Present Worth Formula:

$$\frac{(1+i)^n - 1}{i(1+i)^n}$$

Combining these we get the formula for our projects Present Worth:

$$PW = -12{,}740 + 457\left[\frac{(1+0.03)^{10} - 1}{0.03(1+0.03)^{10}}\right]$$

After running the numbers, PW is equal to – $8,841.70. This is how much it would cost the College in present dollars, assuming no tax breaks for this small amount of electricity generated, or any operating and maintenance costs incurred with the machines over a ten year span. What this number means is that it would cost Lafayette almost $9,000 more to implement these machines than the current alternative.

The solution described produces a respectable amount of energy. The numbers indicate that the college can generate at least $450 worth of electricity per year with 100% implementation. Unfortunately they also fail to generate enough energy to recoup the cost of implementation. It would take our project tens of years to repay the premium of the machines, which is longer than the projected life of the product itself. Economically, introducing regenerative aerobic machines into Kirby Fitness Center is feasible. It is well within the confines of acceptable amounts to spend based on clear goals and objectives that correctly align with current Lafayette College sustainability initiatives. However, fiscally this project is tough to sell at face value to the College Administration simply for the fact that there is not enough recuperation of costs to sustain the capital expense or the operational cost of running the gym.

Unit Costs References:

Sports Art Eco Line:	The Green MicroGym
Sports Art Regular Line:	SportsArt
Competitor Elliptical:	Precor EFX 532i Elliptical
Competitor Vertical Bike	Precor Upright Bike
Competitor Spin Bike	Diamondback 910ic Indoor Cycle

CONCLUSION

FINAL OUTCOMES:

1. Identified why sustainability is a relevant issue at Lafayette College
2. Regenerative workout equipment is a technically sound solution
3. Regenerative workout equipment have very little financial value
4. Analysis of the administrative obstacles facing project approval

The overarching goal of the "Greening Kirby" project was to address the issues of energy over consumption and sustainability at Lafayette College. Our research question: *Can power generation in the Kirby Sports Center workout facility be used to strengthen discussions at Lafayette College about energy over-consumption in everyday life?,* led to an evaluation of the viability and effects of implementing a specific technical solution to increase energy efficiency and strengthen Lafayette's sustainability initiative. The analysis found that regenerative workout equipment can work towards solving these problems by directly reducing energy use in the Kirby Sports Center and raising awareness through educational programs and community engagement. While the project will not be implemented during the course of this report, our group concludes that the "Greening Kirby" project represents one viable solution to making Lafayette College more sustainable. Furthermore, we feel that our analysis accurately highlights current societal forces both on campus and globally that have brought sustainability issues to the forefront of the college's agenda. It also identifies potential stakeholders and administrative obstacles that influence the design and implementation of similar projects at Lafayette.

As senior Engineering Studies students, our group's job is to constantly challenge the assumptions that contributed to the construction of the initial research question. There are a couple of critical flaws with using this technology to advance awareness about energy over-consumption by users of the Fitness Center. First, our technical and economic analyses demonstrate that regenerative workout equipment, within the confines of Lafayette's workout facilities, will not be able to produce enough electricity to financially break even. Given this information, it is clear that the project does not satisfy the college's criteria for sustainability investments. However, as the social and political analyses demonstrate, the regenerative workout equipment project offers vast educational opportunities for Lafayette student and faculty members that can potentially offset the financial shortcomings.

The Greening Kirby project's primary goal is to raise awareness about energy over-consumption and create lasting changes in the user's attitudes. After evaluating the successes and failures of similar projects at other schools, our social analysis concluded that the installation of regenerative workout equipment by itself does very little to accomplish this goal. Since the equipment does not cause a significant change in behavior or attitude, it's impact on users and the surrounding community are extremely limited. However, if the equipment is introduced in combination with

educational and recreational programs, the project has a tremendous opportunity to change users' mindsets towards energy conservation. If the Greening Kirby project is pursued in the future, our group highly recommends the design process incorporates plans to do so.

Financially the cost of implementing a solution in the Kirby Fitness Center that centers on regenerative aerobic machines is within reasonable ranges for the college to invest in. The actual cost to the college is not in the acquisition of these machines, as they can be bought when the existing machines in the Fitness Center need to be replaced. While it is true that these machines represent a premium to an alternative replacement option, it is not a heavily significant cost for the college to take on considering the social benefits that result from this type of campaign. There are many different areas that Lafayette College could look to when it comes to funding the acquisition of these machines, including a capital request or using the funds that the college has pledged to sustainability initiatives. However, these options depend on the administration identifying the "Greening Kirby" project as a viable method of achieving their goal of promoting awareness of energy consumption. So far, our group has received mixed signals from members of the administration that we have contacted. The administration is extremely financially driven, and views the recuperation of funds from energy production as essential to the overall success of a project that they decide to undertake.

The Greening Kirby project is a technical solution to a very complicated problem existing in the socio-technical environment we live in. However, based on the analysis done by this project, our group believes that there should be additional research into alternative forms of energy generation where there are better returns to scale, or that more effectively create a change in an individual's daily routine. Using regenerative exercise machines is too passive, with too little electrical generation over time to be considered a front-runner at this time for the college to consider in its efforts to advance its sustainability initiatives.

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