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The Adaptation of Humans for Sustainable Energy Production

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Sustainability is essentially made up of three pillars: social, economic, and environmental. In the modern world, physical activity is now considered a pastime rather than a necessity, electricity is the center point of civilization, and conventional electrical sources are known to have negative atmospheric effects. The senior design project my team is pursuing will address these issues via a bicycle-powered charging system. This system will offer people an opportunity to exercise while simultaneously harnessing the mechanical energy they produce for charging small electronic devices. The system will be composed of two primary parts: the support frame and the charging components. The support frame will be similar to a normal bicycle trainer with a friction cylinder beneath the rear wheel to attach the charging components. The charging components will include a generator connected to a battery pack. The battery pack will be capable of charging small electronic devices such as cellphones and will have multiple removable USB ports for charging after bicycle operation. The increased mobility allowed by the removable USB ports and the physical power provided by the support frame allows us to further integrate the social and physical dimensions of people’s lives. At the same time, less power consumption through traditional electrical sources may further reduce the individual economic burden while concurrently decreasing environmental pollution.
1. SUSTAINABILITY

Sustainability plays a vital role in the world today. Sustainability, in regards to development, is where social concerns, economic dilemmas, and environmental issues are incorporated into projects.\(^1\) This is based on the following Brundtland definition:

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: (1) the concept of “needs”, in particular the essential needs of the world’s poor, to which overriding priority should be given; (2) the idea of limitations imposed by the state of technology and social organization on the environment’s ability to meet present and future needs.”\(^2\)

Projects which meet the above definition are inherently functional. According to Dr. David Bagley, professor in the University of Wyoming Chemical Engineering department, sustainability may be thought of as a three legged stool. In his course *Environmental, Technology and Society*, Dr. Bagley explains that without the support of each leg – the social, economic, and environmental pillars – the stool cannot hope to stand for very long. It certainly will not be able to support any additional weight.

For the social leg of sustainability, the project must be able to build or support civilizations. Specifically, “[t]he objective of development is to create an enabling environment for people to enjoy long, healthy and creative lives.”\(^3\) Dr. Bagley expands on this idea by providing the following four goals of society: maintain the health of people so they may have long lives; produce educated people so they may become active social participants; ensure people have their basic necessities met (food, shelter, water, and personal safety); and provide sufficient stability and wealth so people can follow their own choices.\(^4\)

In the case of the economic leg, the product must be financially viable. To determine financial viability, the Life Cycle Costing of the final product must be analyzed. Life Cycle Costing, as described by Dr. Bagley, “determines the costs and revenues for an activity over the course of its life.”\(^5\) This may be determined through application of Equation 1.2.

\[
LCC = CC + OC - R
\]  

(1.2)

where LCC is the product’s cost over its life (net present $), CC is the sum of all capital costs of that product, OC is the sum of all operating costs of that product, and R is sum of all the revenue accrued for

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\(^2\) Ibid.

\(^3\) Ibid.


In order to ensure the product is financially viable, the end product LCC must not exceed the determined base LCC.

The environmental leg is much simpler to grasp in concept, yet it is very complex in actuality. Simply put, this leg involves analyzing the effects the project has on the environment. Yet understanding and quantifying those effects may be very difficult due to the complex nature of environmental issues. A Life Cycle Assessment is the tool of choice for determining those environmental issues. A Life Cycle Assessment looks into each step of building a product, from mining the raw materials to shipping the end product to disposing of waste materials. In this way, the full environmental impact may be predicted. For my Honor’s project, I will analyze the sustainability of my team’s bicycle-powered charger through tools described.

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8 Ibid.
2. DESCRIPTION AND DESIRED HUMAN BENEFITS

2.1 Description

In the modern world, physical activity is now considered a pastime rather than a necessity, electricity is the center point of civilization, and conventional electrical sources are known to have negative atmospheric effects. The senior design project my team pursued sought to address these issues by producing a commercially viable bicycle-powered charger. The name is misleading, however, since it is not bicycles that operate our product; our product is operated by humans.

In operation, we intended our product to offer a means of exercise to an individual while simultaneously reducing wasted mechanical energy from such exercise. We reduced the mechanical energy waste by building our product to convert that energy into useable electrical energy. The electrical energy would then be used by an individual to charge small electronic devices such as cellphones.

To accomplish this task, we separated our product into two primary parts: the support frame and the charging components. The support frame was reverse engineered from a standard retail bicycle trainer with slight modifications to incorporate the charging components. The charging components included a generator connected to a battery pack via a unified electronics and control. We intended the battery pack to be capable of charging small electronic devices such as cellphones and to have multiple removable USB ports for charging after bicycle operation. A more detailed explanation of each module is provided in Section 2.3.

The increased mobility allowed by the removable USB ports and the physical power provided by the support frame would allow further integration of the social and physical dimensions of peoples’ lives. At the same time, reduced power consumption through traditional electrical sources could lead to reduced individual economic burdens while concurrently decreasing their individual environmental impacts.

2.2 Planning

The planning stage of the bicycle-powered charger built by my teammates, Alex Howell and Daylon Roitsch, and myself began with researching previous models of electrical energy conversion from bicycles. Our initial plan was to build a charger which would operate on a mobile bicycle. Specifically, we desired that our product be able to operate on a person’s bicycle as that individual travelled from one location to the next. From our research, we discovered bottle-cap generators to be the most popular system of this type because of their simplicity, yet they lacked the electrical output we desired.

Attempting to increase the electrical output would result in a system which would hinder the rider by adding excess resistance – the rider would feel as if they were constantly pedaling uphill. Eventually, this plan was thrown out for this reason and because a light-weight commercial product had already been developed.

The next plan we explored involved using a stationary bicycle. We chose to use a standard bicycle trainer as the basis for turning a mobile bicycle into a stationary bicycle. A standard bicycle trainer operates by locking the rear tire of a bicycle in place with the tire resting on a rotating cylinder which allows the rider to pedal. From this simplistic design, we researched methods of converting the mechanical energy of pedaling into the electrical energy necessary for a battery. We first desired to
build a gear system which would attach to the bicycle chain. This system was thrown out for several reasons: (1) the system would either be very cumbersome for the rider or lack sufficient mechanical-electrical energy conversion, and (2) the system would be too costly and would require more time than we had at our disposal.

As our final plan, we decided to incorporate our first idea for a bottle-cap generator and integrate it with a wheel-belt connection system. A wheel-belt connection system operates by running a belt around a bicycle tire and a generator shaft which allows pedaling of the bicycle to operate the generator. To make this project our own, we increased the meager power output of the bottle-cap generator and eliminated the cumbersome belt used for the wheel-belt connection system.

2.3 Construction

After the planning stage, we focused on building. To begin, we designed a bicycle support frame around a standard retail trainer. The difference between the standard trainer and our support frame was that our support frame was designed to be light-weight and strong to reduce the effort of setup by the user while still being structurally sound. The materials we chose to utilize included aluminum for the supporting braces and rubber to cover the pipe-ends. Due to time constraints and lack of heat treating capabilities we were unable to build a working prototype of the support frame so we opted for purchasing a standard trainer in order to test the charging functionality of our product.

The charging components of our bicycle-powered charger involved integrating a generator with our support frame and then attaching several outlets (a 12 V lead-acid battery, connections for direct charge to the consumer’s electronic device, and a resistor) to the generator. Initially, we obtained a used ATV magneto for our generator. This magneto lacked a cover so we designed one and had the machine shop in the University of Wyoming Engineering Building (hereafter referred to as the machine shop) manufacture it. We also had the machine shop construct the shaft system we had designed, shown in Figure 2.3.1.

![Figure 2.3.1: SolidWorks model of the shaft system prototype.](image)
The shaft system was composed of a central shaft made of steel attached to the ATV magneto, a larger cylinder made of PVC for the bicycle wheel to rest on, and a support brace made of aluminum. The larger cylinder was necessary to enable the rotation of the bicycle wheel to cause rotation in the shaft. The shaft rotation caused the rotor in the ATV magneto to spin, thus converting mechanical energy into electrical energy. The support brace was built to connect the shaft and cylinder to the support frame and to ensure the system could be adjusted for various adult wheel sizes ranging from 24 inches to 29 inches in diameter.

To connect the ATV magneto to our three outlets we had to construct a unified electronics and control circuit. This circuit was necessary to convert the alternating current (AC) emitted from the ATV magneto into useable direct current (DC) and to regulate the voltage input to the outlets. The voltage produced by the ATV magneto was subject to variability from the cyclist input which had to be controlled in order to maintain adequate charging capabilities.

The first section of the unified electronics and control involved a shunt regulator, shown in Figure 2.3.2.

![Figure 2.3.2: (Left to right) Prototype of the shunt regulator section of the unified electronics and control circuit and the corresponding Visio model.](image)

In the above circuit, the key components include the bridge rectifier, the zener diode, and the transistor. The bridge rectifier converts incoming AC to outgoing DC while the zener diode regulates the amount of output voltage. The Zener diode does this by maintaining a constant voltage drop, known as the breakdown voltage, with varying current. The Zener diode we chose was 5.1 V and operated within the current range of 10 to 100 mA. The transistor, on the other hand, acts to regulate the current. The transistor we utilized was a NPN transistor. NPN transistors turn on when a small amount of current passes through the base terminal (between the Zener diode and Resistor 2 in Figure 2.3.2) allowing much larger current to be diverted from the output to the collector terminal (top side of the transistor in Figure 2.3.2) and through the emitter terminal (bottom side of the transistor in Figure 2.3.2).

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10 Ibid.
11 Ibid.
13 Ibid.
2.4 Project Testing

We began the testing phase by observing the feasibility of generating sufficient voltage from our product to charge the 12 V battery. To do this, we placed a personal road bicycle into the support frame with the shaft system and ATV magneto attached. The results from this test are shown in Table 2.4.1.

<table>
<thead>
<tr>
<th>Voltage (V rms)</th>
<th>Current (A)</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>2</td>
<td>14</td>
</tr>
</tbody>
</table>

The results were not at all what we had expected. We predicted that the ATV magneto would produce closer to 13.4 V rms and would produce large resistance to the cyclist. As may be seen in Table 2.4.1, the output voltage was approximately half our predicted value. Also, after operating the bicycle in the system described we discovered that the ATV magneto produced very little resistance. In fact, the resistance was so low we decided to design our own generator for future systems. Designing our own generator would also allow us to ensure an output of at least 13.4 V rms.

After testing the ATV magneto, we tested the operation of our shunt regulator. The results from this test produced the Load Line shown in Figure 2.4.1.

![Figure 2.4.1: Shunt regulator testing results. A standard 7 V rms AC source was used to represent the ATV magneto output shown in Table 2.4.1.](image)

A load line similar to the one presented in Figure 2.4.1 will be useful for further designs since it will show where the optimal operating conditions are for specific outlets. One such outlet will be the 12 V lead-acid battery described previously. To determine the best operating conditions for each outlet, we will plot the voltage requirements for each outlet versus the current and note the point where those lines intersect the load line. The points of intersection show where the optimum operating conditions are.
As a final test, we chose to measure the peak power consumption of various household electronics. We did this since very little information was available and the information that was available was dated prior to 2010. Figure 2.4.2 shows the results from this test.

![Figure 2.4.2: Peak power consumption of household electronic devices.](image)

With this knowledge we have a better understanding of what we need from our generator. We need our generator to produce around 30 W which means that we will need to design our generator in the future, which is the same conclusion reached from our previous tests. Further detail into the design, prototype construction, and testing of my team’s bicycle-powered charger is provided in our group report *Bicycle-Powered Charger* by Alex Howell, Daylon Roistch, and myself submitted to Dr. Kevin Kilty for our Mechanical Engineering Systems Design course (ME 4060).

### 2.5 Cost Estimation

To determine the commercial viability of my team’s bicycle-powered charger we estimated the cost for our intended product under mass production. The results from this analysis are shown in Table 2.5.1.

<table>
<thead>
<tr>
<th>Module</th>
<th>Estimated Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unified Electronics &amp; Control</td>
<td>16.45</td>
</tr>
<tr>
<td>Display</td>
<td>15.00</td>
</tr>
<tr>
<td>Battery, Microprocessor, Boost Power Converter, Resistors</td>
<td>35.50</td>
</tr>
<tr>
<td>Shaft System</td>
<td>47.12</td>
</tr>
<tr>
<td>Generator</td>
<td>20.00</td>
</tr>
<tr>
<td>Support Frame</td>
<td>30.00</td>
</tr>
<tr>
<td><strong>Total Cost Estimation</strong></td>
<td><strong>164.06</strong></td>
</tr>
</tbody>
</table>
From Table 2.5.1 we were able to estimate the retail price of our bicycle-powered charger to be between $300 and $400. This would place our product in the commercially viable range since similar support frames (called trainers) sell for around that same price range but do not include the added benefit of harnessing the physical energy expended by a cyclist.

2.6 Benefits

The benefits associated with my team’s bicycle-powered charger are evident when analyzed from a sustainable design and development point of view. Sustainable development was explained previously in Section 1. Sustainable design is explained by Striebig et al. (2016) in the following way:

“Sustainable design is the design of products, processes, or systems that balance our beliefs in the sanctity of human life and promote an enabling environment for people to enjoy long, healthy, and creative lives, while protecting and preserving natural resources for both their intrinsic value and the natural world’s value to humankind. The engineer who practices sustainable design must have a grasp of the social, economic, and environmental consequences of their design decision and a thorough understanding of the scientific principles of the technology available.”14

Essentially, sustainable design explains where and how engineering products may be applied to sustainable development.

Along those lines, my team’s bicycle-powered charger has many benefits which fall under the categories of social, economic, and environmental. For the social benefits, our product aids and encourages exercise by enabling the energy expended by an individual to become energy for charging their electrical devices. As mentioned previously, most people in today’s world depend heavily on some form of electronic device(s), so providing a way to charge those devices is a motivator to use our product. By using our product, people have the potential to improve their physical health.

For the economic benefits, our product has the potential to reduce an individual’s electric bill. The significance of this reduction will depend largely on the amount of time the individual chooses to spend using our product. A greater beneficial impact may come from the promotion of bicycle use. If individuals operate our product enough, then perhaps they will decide to use their bicycles for in-town transportation. Again, depending on how often an individual chooses to use his/her bicycle, the cost for transportation could be greatly decreased.

For the environmental benefits, these must be addressed by looking at the entire life cycle of our product. In our case, many of the products were purchased pre-built, so we did not have a hand in the waste emitted by the production processes. However, since the system was designed to integrate different pre-built components into one operable system, it was built to be recyclable after its useful life. Specifically, each component was connected to allow easy separation from the rest of the system. In addition, our system does not emit any waste during operation other than the inevitable loss of energy in the form of heat. This is because the source of energy being utilized is that of humans exercising. In addition, the emissions from conventional electrical sources and vehicles have the potential to be largely

reduced depending on how often and how many individuals use our product. Further analysis on the benefits associated with the environment is provided in the following sections.
3. LIFE CYCLE

The lifecycle of the final design of my team’s bicycle-powered charger begins with the extraction and production of the raw materials used: steel, aluminum, PVC, and BUTYL rubber. To reduce complexity, other minor materials and materials of prebuilt components are not included in the scope of this life cycle. Following the production, the raw materials are formed into useful components for the bicycle-powered charger system. This process involves designing the components, creating 3-D models using SolidWorks, and sending those designs to a machine shop for construction. The shunt regulator will be constructed by soldering various pre-obtained electrical components into a single circuit. After the custom-built components are completed and the pre-built components are obtained, they are joined using several methods to form a complete bicycle-powered charger. The aluminum support frame components are connected by welding and using bolts. The welding process will weaken the aluminum and so heat treatment is necessary for the support frame to remain structurally sound. Once the support frame is constructed it is connected to the shaft system by bolts. The shaft system is connected to the generator by bolts and a key. For the charging components, the outgoing wires of the generator must be connected to the shunt regulator which may be done by soldering. Finally, wires must be attached to the shunt regulator and connected to the three potential outputs – direct charge of small electronic devices, a boost power converter attached to a 12 V lead-acid battery, and a resistor. At this point, the bicycle-powered charger is completed and ready for use.

In the operation stage, the consumer will attach his/her bicycle to the support frame and will treat the system as a regular exercise bicycle. It is expected that the system will experience an average of 144 hours of operation per year. Maintenance of the system is expected to be minimal.

After operation, the components of the bicycle-powered charger may be easily separated and either recycled or refurbished and reused. The support frame and part of the shaft system, being composed of aluminum, may be recycled and formed into other aluminum parts.15,16 The tube ends of the support frame are composed of BUTYL rubber which may be recycled separately. As with aluminum, the market for recycling steel is strong and so the steel from the shaft system may be recycled, as well.17 As the last primary material of our product, the PVC from the large cylinder on the shaft system may also be recycled.18 Moving into reuse, the generator is a prime candidate to be reused due to its durable nature and thus may be refurbished and reused in other applications or in a new bicycle-powered charger product. The unified electronics and control, being composed of different elements, may be further separated into individual electrical components and reused. Figure 1 shows the life cycle diagram for a commercially produced version of my team’s bicycle-powered charger.

17 Ibid.
As shown in Figure 1, each stage in the life cycle of a commercially produced bicycle-powered charger requires energy input and releases some form of residuals. The energy type and form of residuals depends on the type of operation required at that stage. The impact of each stage is addressed in detail in the next two sections.
4. ENVIRONMENTAL IMPACTS

3.1 Known Impacts

To fully analyze the environmental impacts of the bicycle-powered charger, the impacts from each stage of the life cycle should be considered. The first stage of the life cycle includes extracting and producing the raw materials for the custom-built components. The pre-built components were not analyzed in this way due to complexity. The primary materials for the custom-built components were aluminum, steel, PVC, and BUTYL rubber.

Aluminum extraction and production releases several greenhouse gases including perfluorocarbons, polycyclic aromatic hydrocarbons, fluoride, sulfur dioxide, and carbon dioxide.20 All are greenhouse gases.20 In addition, sulfur dioxide can lead to acid rain which can cause the soil pH to drop and then can cause an aluminum solution to leach into water supplies, damaging root systems and acidifying lakes.21,22 This also effects the environment through the large input of energy required for extraction and production.23

Steel production leads to slag, dust, sludge, and process gas by-products.24 Specifically, steel production releases between 0.2 to 0.4 kg of by-products per kg of steel, not including the gases.25 The environmental impacts from these by-products are minimal seeing as a majority of the by-products are reused for steel production or sold for other applications.26 Without reuse, these by-products would increase landfill waste and carbon dioxide emissions as well as reduce the natural resources required.27

PVC and BUTYL rubber extraction and production contribute very minimally to environmental impacts, as well. PVC, in particular, has sodium hydroxide and hydrogen as initial by-products which are then utilized for further processing of PVC.28 BUTYL rubber’s production impacts stem primarily from the use of electricity to operate the necessary equipment which includes extruders, dryers, molding machines, and a conveyor belt, among others.29 This has a potential to impact the environment by the emissions released from conventional electrical sources such as coal, oil, and gas.30 The primary emissions from

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20 Ibid.  
21 Ibid.  
25 Ibid.  
26 Ibid.  
27 Ibid.  
such sources include the National Ambient Air Quality Standards criteria pollutants of carbon monoxide, particulates, nitrogen oxides, and sulfur dioxide.\textsuperscript{31} Carbon monoxide and particulates will be addressed in Section 5. Nitrogen oxides effect the environment through animals by potentially causing emphysema in animals and acting as precursors to smog.\textsuperscript{32} The impacts from sulfur dioxide are as explained previously.

The next stages of the life cycle, shown in Figure 1, involve cutting and shaping each component and constructing the finished components into complete modules. Such processes primarily include some amount of electrical energy input with the environmental impacts being the same as discussed previously. The main variation between electrical-based environmental impacts will come from the amount of electricity used.

In the operation stage, there is no significant environmental impact since the energy required is from human exercise and the primary residuals are perspiration, respiration, and heat. Perspiration and respiration will have no more effect on the environment than people exercising at a gym. The excess heat will come from the inevitable inefficiency of our product in converting mechanical to electrical energy.

The last stage, the afterlife, has the potential to negatively impact the environment through the processing methods used to recycle the materials as well as the shipment of used products. The impacts from shipment involve vehicle emissions which include carbon dioxide, nitrogen oxides, volatile organic compounds, particulates, and carbon monoxide.\textsuperscript{33} Carbon dioxide, as stated previously, is a known greenhouse gas while nitrogen oxides may cause emphysema in animals and lead to smog formation. Volatile organic compounds have the effect of degrading flora and fauna health and contributing to global warming.\textsuperscript{34} The level of impact from shipment is relatively low, however, since many other products are shipped across the world daily.

\begin{itemize}
\item \textsuperscript{31}Ibid.
\end{itemize}
5. HUMAN IMPACTS

4.1 Known Impacts

As for human impacts, those may also stem from the emissions explained in Section 4. Of key focus are the polycyclic aromatic hydrocarbons, sulfur dioxide, carbon monoxide, particulates, nitrogen oxides, and volatile organic compounds. Polycyclic aromatic hydrocarbons are potential carcinogens. Sulfur dioxide, carbon monoxide, and particulates are all labelled as criteria air pollutants according to the National Ambient Air Quality Standards. While the nitrogen oxides and volatile organic compounds are not listed as criteria air pollutants, they do contribute to the formation of a criteria air pollutant by reacting with each other and sunlight to form tropospheric ozone.

The effects to humans vary depending on the pollutant and the level of exposure. Sulfur dioxide effects the respiratory system in individuals and may aggravate current asthmatic conditions. In addition, when particulates are present along with sulfur dioxide in the air the severity of respiratory symptoms increases three- to four-fold. Carbon monoxide, on the other hand, hinders the transport of oxygen to the brain, organs, and muscles and, as a result, can aggravate existing heart conditions. Particulates, along with aiding sulfur dioxide in effecting the respiratory system, has its own effects on the respiratory system. Specifically, particulates can trigger coughing, decrease lung function, cause chronic bronchitis, aggravate existing asthmatic conditions, cause heart attacks, and cause premature death, among other similar effects. As for the ozone formed by nitrogen oxides and volatile organic compounds, that also can cause negative effects to the respiratory system. Ozone in the troposphere causes decreased lung function, coughing, worsened asthma/emphysema/chronic bronchitis, and lung damage, among others.

4.2 Potential Impacts

In addition to the health effects, sulfur dioxide has the potential to cause other negative impacts to humans. Such impacts include corroding buildings and other similar structures from the formation of acid rain. This could pose a safety risk to humans if enough acid rain comes in contact with the structure of interest.

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36 Ibid. Pg. 528.
37 Ibid. Pg. 278, 281.
38 Ibid. Pg. 278.
39 Ibid. Pg. 278.
40 Ibid. Pg. 277-279.
41 Ibid. Pg. 287.
42 Ibid. Pg. 284.
As for polycyclic aromatic hydrocarbons, heating of PVC can also cause their release into the air.\textsuperscript{44} However, risk of this occurring is minimal due to the large ignition requirement of PVC.\textsuperscript{45} While my teammates and I do expect the PVC on the shaft system to become warm after use, we do not expect the cyclist to maintain a pace long enough or fast enough to cause the PVC to begin smoking. This issue will be addressed by providing warning labels stating such potential impacts.

Aside from emissions, the actual materials used for my team’s bicycle-powered charger may also have negative human impacts. Specifically, the aluminum from the support frame presents one of these impacts. Excessive aluminum consumption is toxic for humans, but those levels are such that only miners, production workers, and dialysis patients are under real threat of toxicity.\textsuperscript{46} Also, since aluminum does not bioaccumulate significantly in plants and animals there is little danger of being contaminated secondhand.\textsuperscript{47} Another toxicant is lead from soldering the circuitry on the shunt regulator. Lead, according to Striebig et al. (2016), “negatively affects the nervous system, kidney function, the immune system, the reproductive and development system, the cardiovascular system, and the oxygen-carrying capacity of the blood.”\textsuperscript{48} It can also cause neurological issues in adolescents.\textsuperscript{49} This amount of lead is very small, however, and will be covered to avoid electrical injury.

Another potential impact to humans is from physical injury due to operating our product. Physical injury can include injuries ranging from a pinched figure from setting up the support frame to a child’s smashed hand from playing with the shaft system to shock from electrical components. All these impacts will be addressed in my team’s design by following the relevant safety standards of the Consumer Product Safety Commission and the American Society for Testing and Materials organizations. Accordingly, our final product will have areas of risk fully covered, partially covered, and/or labeled depending on the level of risk and the feasibility of covering such areas.

Our product may also affect humans by reducing the amount of livable space. This is not as serious as the other impacts, though it could play a role in whether people are able to enjoy their workout or not. Some people may live in small apartments where space is limited and thus adding a bicycle-powered charger system (let alone the bicycle) would significantly reduce their living area. My team addressed this impact by designing our bicycle-powered charger to be light-weight so our consumers can easily setup or take down the system as they choose.

\textsuperscript{45} Ibid.
\textsuperscript{47} Ibid.
\textsuperscript{49} Ibid. Pg. 278.
6. SUSTAINABILITY ANALYSIS

From the description and impacts discussed in the previous sections, the sustainability of a commercially produced version of my team’s bicycle-powered charger may be determined. As described, sustainability is composed of three pillars – social, economic, and environmental. For the social pillar of sustainability, our product has potential to improve the health of individuals by providing the equipment and motivation for individuals to exercise. For the economic pillar of sustainability, by allowing individuals the option to avoid use of conventional electrical sources their individual electricity bills may be reduced. The amount of reduction depends largely on what devices the individual chooses to charge and how much power he/she produces from operating our product. In addition, the Life Cycle Costing of a commercially produced version of our product shows it to be economically viable when compared to a standard trainer without any energy conversion equipment. Since both products are intended to be used in approximately the same way the operating costs may be negated. Also, since we expected the individual to not be able to produce enough power to sell we negated any potential revenue. Thus, the only cost for comparison was the capital costs, otherwise referred to as the retail costs. With our estimated commercial product costing around $164 for the materials, we could sell our product for under $400. Further analysis of the economic pillar would need to be conducted on our final product design in order to fully understand the economic impacts of our product. For the environmental pillar, our product provides a means for individuals to lower their individual environmental footprints. This may be accomplished by directly reducing the use of conventional electrical energy sources, which have the impacts discussed previously, or by promoting the use of bicycles for transportation. As with the economic pillar, the level of impact our product has on an individual’s environmental impact depends largely on the amount of time and effort the individual puts in to using our product.
7. IMPROVEMENT ANALYSIS

From the sustainability analysis, I found that my team’s bicycle-powered charger could be improved to be more sustainable. The first improvement would be to design a generator that meets our needs specifically. In so doing, the generator would become more efficient and thus more effective at converting a cyclist’s mechanical energy into useful electrical energy, perhaps increasing its power production ability. Essentially, less energy would be lost to heat. The environmental impact presented earlier as well as economic considerations could be reduced significantly by creating incentives for consumers to return worn bicycle-powered chargers. Those worn products could be separated into their modules and either reused or recycled. Reusing modules for the construction phase would reduce the emissions from raw material extraction and would also reduce manufacturing costs from forming new modules. In the generators case, it could be applied to other systems, not just a bicycle-powered charger. However, since it would be custom-built, it would not necessarily easily integrate into other systems. Recycling the materials would also reduce the environmental impacts of extracting and producing the components. With enough products sold and worn products returned, we could completely eliminate the impacts from the Raw Material Extraction and Production stage in our product’s life cycle.
8. CONCLUSIONS AND RECOMMENDATIONS

Essentially, by designing a bicycle-powered charger, my team provided a method for people to adapt their habits to more sustainable living. The use of mechanical energy produced during exercise allows people to improve their individual health while simultaneously charging their electronic devices. Correspondingly, removing the need for conventional electrical sources to power such devices can lead to lower individual electric bills and smaller individual environmental footprints. Thus, from this analysis, I learned that the level of impact my team’s bicycle-powered charger has on an individual’s life greatly depends on how much effort that individual is willing to expend. My team’s bicycle-powered charger is simply a means for humans to live sustainably, not an end.