Pump'n Power

Team Excergy:

Baron Creager, Brandon Giordano, Luke Halonen, Alberto Jasso
Engineering 215: Introduction to Design
Fall 2011

A Humboldt State University Engineering and Flock House project

Photo by Kellie Jo Brown

Table of Contents

Table of Figures

Table of Tables

1 Problem Formulation

1.1 Introduction

Section one contains an objective statement and a black box model to formulate the problem for the Engineering 215 Design project. Engineering 215 is an introduction to design class, in which design principles and process are studied. Our client, Mary Mattingly, is the head of Flock House project based in New York.

1.2 Objective Statement

The objective for this project is to create a human powered generator that produces energy in an entertaining and innovative way that may be operated by most ages and capabilities.

1.3 Black Box Model

The black box model in Figure 1-1 represents the world before and after an unknown solution, represented by the black box, is implemented.

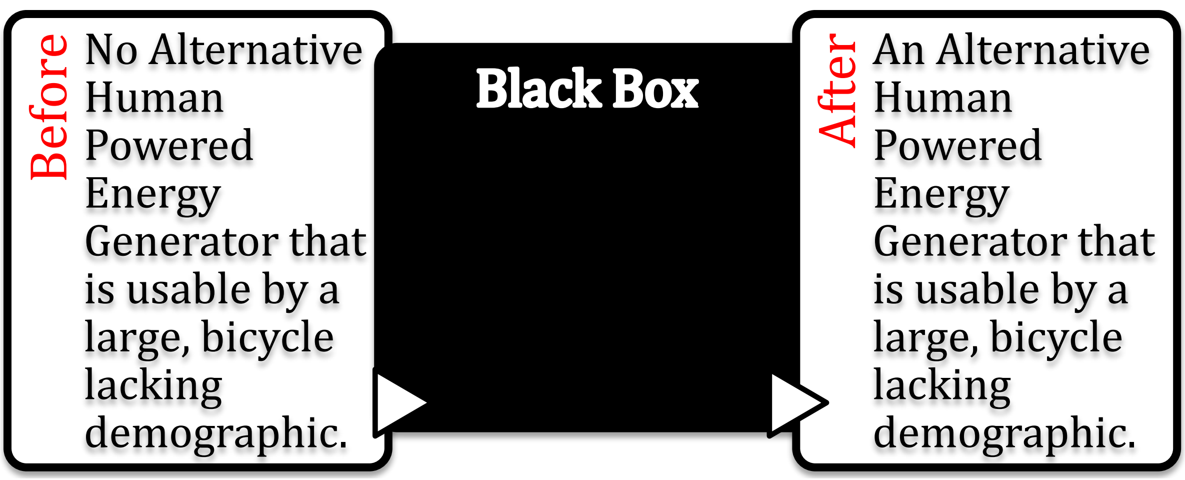


Figure 1-1: Black Box model displaying the effect of implementation

2 Problem Analysis and Literature Review

2.1 Problem Analysis

The problem analysis breaks down, into further detail, the problem introduced in the objective statement. The problem analysis includes specifications, considerations, criteria, usage, and production volume.

2.1.1 Specifications and Considerations

Specifications and considerations are key factors that need to be taken into account in the implementation of the final design.

2.1.1.1 Specifications
There are two specifications for this project that are to be implemented in the design process: the project will convert human energy into electrical energy, and it will do so by incorporating a generator.

2.1.1.2 Considerations
Three considerations for the project are, the weather the design be exposed to, the design's energy output, and the design's size. The design will be used on the streets of New York City, and will likely be exposed to precipitation. Thus, any electrical components will have to be protected from the precipitation. Next, since the design will not solely utilize the power available from one's legs—as witnessed in a bicycle-powered generator design—the energy output will be less than that of the bicycle-powered generator counterpart. Finally, the size of the design should be mobile enough to meet the Flock House's mobility needs.

2.1.2 Criteria and Constraints
Criteria and constraints are used to identify how successful the final design meets the objective. Table 2-1 below contains the criteria and corresponding constraints used in the design process.

Table 2-1: Criteria and constraints.

Criteria	Description
Safety	All electrical components are to be safely weatherproofed as per New York building codes, and all hazardous moving components are to be protected from the user.
Cost	The cost of the project must not exceed $375.
Durability	The design must withstand exposure to New York climate.
Ease of Use	The design must be simple, non-intimidating, and require no instructions.
Transportability	The design must mobile enough for one person manage.
Energy Output	The design must produce a minimum of 50 Watts.
Aesthetics	The design should be attractive without compromising safety, durability, or cost.
Embedded Energy	The design should have a low level of embedded energy.
Educational Value	The design spreads the idea of sustainability though alternative energy.

2.1.3 Usage
The final design will be used to create auxiliary power for Flock House's educational art project. The design will be used to power only low wattage electronic devices, or as part of

an array of power-generating devices like the bicycle-powered generator. The design will be used for about six hours per day, for at least six months.

2.1.4 Production volume

One final design will be completed and shipped to the Flock House in New York.

2.2 Literature Review

The purpose of the literature review is to provide background information for the design and create a base for which the design process will expand upon. Topics covered in the section include: Electrical energy, component analyses, previously designed systems, and waterproofing.

2.2.1 Electrical Energy

The following subsections address the electrical aspects to be considered and analyze how power may be generated, transferred, and stored in a safe and efficient way.

2.2.1.1 Electrical Energy Generator

In the search for a way to convert mechanical energy into electrical energy, in 1831 the British physicist Michael Faraday based his design for a generator on the principle of electromagnetic induction. Faraday determined that if an electrical conductor, such as a copper wire, is moved through a magnetic field, an electric current will be induced through the conductor, as in Figure 2-1 below.

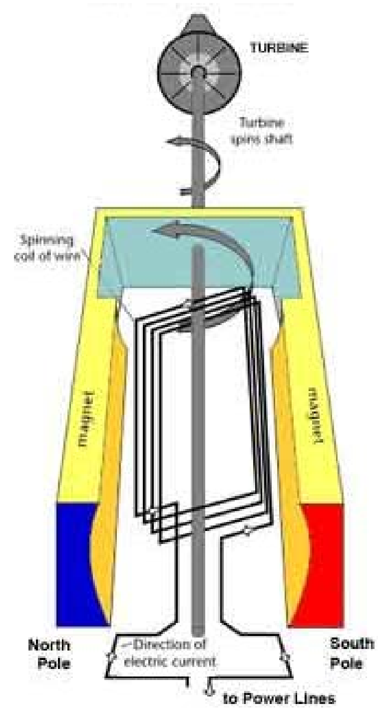


Figure 2-1: Rotation of coiled wires in a magnetic field creates energy in a generator. (Energy Quest 2011)

This results in the mechanical energy of the moving wire to convert into electrical energy. The advantages and disadvantages of different methods of transferring energy are outlined as follows (Kelly 2007):

- Direct transfer of energy from generator to device without battery storage.
  - *Advantages*: Most efficient.
  - *Disadvantages*: A stop in power generation results in a loss of power to the device. Fluctuating energy generation results in fluctuating power at the device.

- Direct transfer of energy from generator to device with battery storage.
  - *Advantages*: Captures excess energy. Versatile.
  - *Disadvantages*: Loss of energy in storage. More complex.

- All energy generated goes straight to battery storage for later use.
  - *Advantages*: No issue with fluctuating energy generation. Most versatile. Simple.
  - *Disadvantages*: Most loss of energy in storage compared to the direct methods.

2.2.1.2 Charge Controller

A charge controller is required to regulate rates of electrical voltage from the source to the battery. The charge controller, Figure 2-2, ensures that the battery is fully charged without sending excess electricity into the system by either reducing or stopping the flow of electricity. When the load is using the generated power, the controller allows the electrical charge to flow smoothly to both the battery and the load. Another feature of the charge controller is that it senses when the load has taken too much energy from the battery and will stop or reduce the flow from the battery until the battery can be sufficiently recharged. (U.S. Department of Energy 2011)

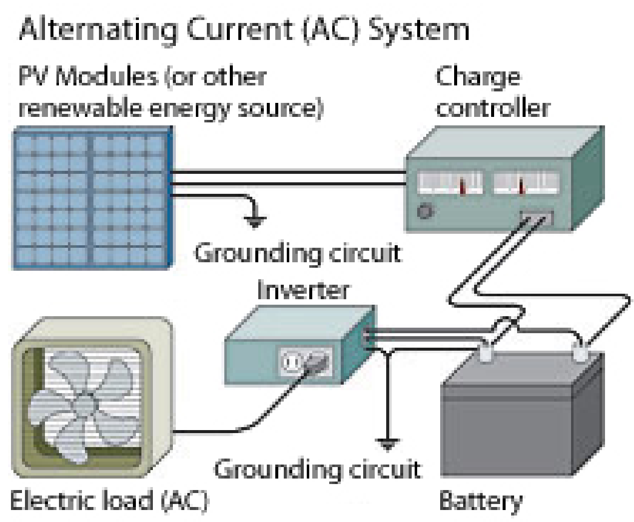


Figure 2-2: Typical AC battery-based system including a charge controller (LTGovernors 2011).

2.2.1.3 Batteries

Batteries store electricity to be used during times when a system is not producing electricity. Storing energy in a battery is less efficient than having the system directly power the load, as you can only reclaim approximately 80% of the energy transferred into the battery (U.S. Department of Energy 2011). Although loss of energy is incurred via battery storage, the advantage is that the battery has the ability to provide electricity over long periods of time, as well as be repeatedly charged and discharged. Deep-cycle lead-acid batteries are better for storing energy than shallow-cycle automotive batteries because automotive batteries are prone to damage if they discharge more than 20% of their capacity. (U.S. Department of Energy 2011)

2.2.1.4 Power Conditioning

Most electrical appliances in the United States such as computers, kitchen appliances, and cellular telephone chargers run on alternating current (AC) electricity while many renewable energy technologies, as well as most generators, produce direct current (DC) electricity (U.S. Department of Energy 2011). In order to run these appliances, an inverter must be used to convert the AC current to DC current and condition the electricity so that it matches the requirements of the load (U.S. Department of Energy 2011). The inverter must match the load's voltage, phase, frequency, and sine wave profile in order to minimize current distortion as in Figure 2-3.

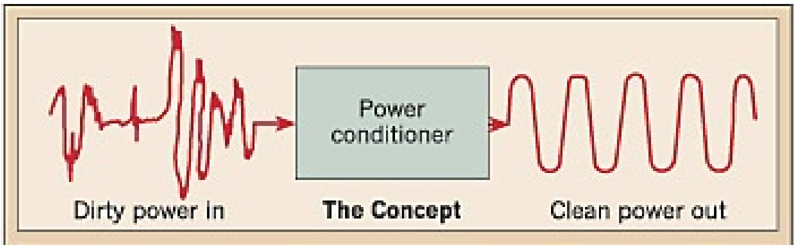


Figure 2-3: A power conditioner turn "dirty" power into steady "clean" power. (U.S. Department of Energy 2011)

2.2.1.5 Blocking Diode

Blocking diodes are semiconductors connected in series with an electrical circuit and a storage battery to keep the battery from discharging through the system when there is no output, or low output, from the generator. It can be thought of as a one-way valve that allows electrons to flow forwards, but not backwards (U.S. Department of Energy 2011).

2.2.1.6 Rectifier

Rectifiers use a diode-bridge of four diodes that allow the sensors of a circuit to be attached to either polarity and receive any polarity input while still having the output be positive. Full wave rectifiers "herd" the current around the diodes so that the current always flows in the same direction for the output. This results in any AC current that is put in the system to leave the system as DC current (Department of Electrical Engineering and Computer Science 2011).

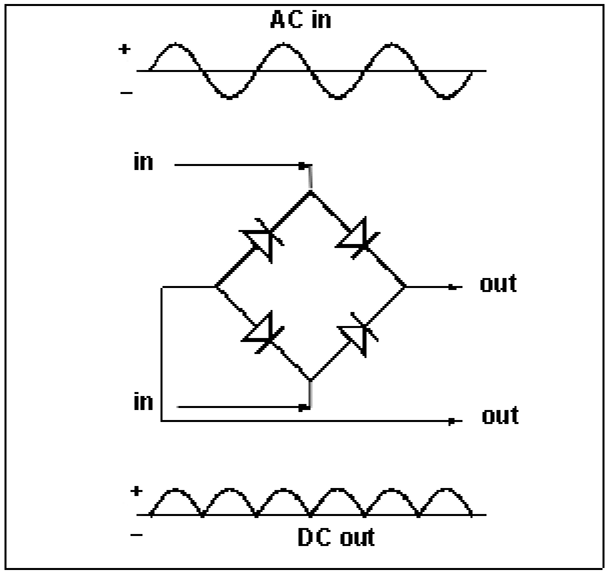


Figure 2-4: Full wave rectifier circuit (U.S. Department of Labor 2011)

2.2.1.7 Energy Generation Methods

The amount of energy that is obtainable from the human body depends on which parts of the body are being used, the mental and physical condition of the user, and the design of the interface between the user and the generator. The data in Table 2-1 is estimated from the maximum force exerted by an average male user between 20-30 years of age (Jansen and Stevels 1999).

Table 2-2: Potential of the human body as an energy generator. (Jansen and Stevels 1999)

Description of Movement	Force x Distance	Max. Human Power
Push	16N x 40mm	0.64 Watt
Squeeze	400N x 30mm	12 Watt
Rotate crank or handle	30N x 100mm x 1.5 x 2π	28 Watt

2.2.1.8 Electrical Safety

Safety features are needed to ensure the system does not damage itself, its surroundings, or harm any people. Features such as automatic or manual safety disconnect, grounding equipment, and surge protectors all provide a safer environment for your system (U.S. Department of Energy 2011).

- **Safety Disconnects**
  Automatic or manual disconnects protect the wiring and components of the system from malfunctions and/or power surges. The safety disconnects also isolate the system from the power source and allow for safe maintenance and repair.
- **Grounding Equipment**
  Grounding ensures that there is a reliable, low-resistance path for current to flow from your system to the ground. This protects the system from equipment malfunctions and electrical surges by sending the energy to the ground. Any

exposed metal should also be checked for possible electrical current and grounded accordingly.

- **Surge Protectors**
  These devices protect against large surges of electrical current that may be introduced into the system from some sort of malfunction or power surge.
- **Power Meter**
  This should be implemented as a visual aid in assessing correct current flow and detecting any issues within the system. Calculations should be made prior to testing so that when malfunctions occur; an abnormal reading from the meter can be easily identified.
- **Batteries**
  Batteries should be positioned in a well-ventilated and isolated space due to containment of dangerous chemicals and emission fumes while charging. The space should be free of temperature extremes and any type of moisture, and the batteries should be recycled properly when worn out.

2.2.2 Component Analysis

The following subsections address individual components that may be useful in the design process. The scope of this section pertains to the possible transfer of energy from one location to another by way of pulleys, rotating bodies, and gears.

2.2.2.1 Pulleys

A pulley is a grooved wheel that rotates around an axis and allows a cord of some type to pass along the groove. Ideally, the axis of rotation is frictionless, thereby allowing the transfer of force without loss to friction. The amount of force transferred is dependent upon the number of pulleys in the system, where the work done on an object is defined as the force times the distance of its travel (Serway and Jewett 2008). For a one pulley system, the work done on a load is equal to the work done by the pull. In a two pulley system, as illustrated in Figure 2-5ii, the work done by a pull will amount to half the distance traveled by the load. Thus, to double the work done with the same load travel distance on a system via two pulleys, one would have to pull twice the distance (Wolfe 2007). Table 2-3 which is based upon Figure 2-5, shows how the force of a pull over a distance across a pulley system translates to the force on a load and its resulting distance of travel.

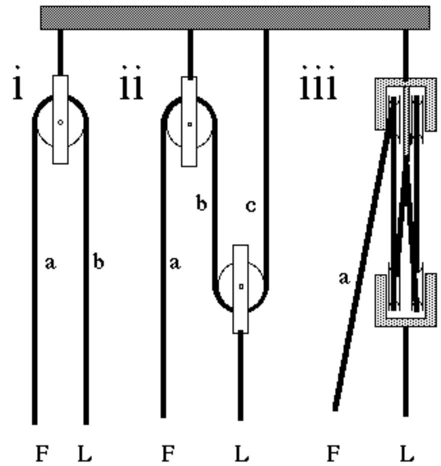


Figure 2-5: Three types of pulley setups. (Wolfe 2007)

Table 2-3: Relationship between work applied and number of pulleys.

Figure	Number of Pulleys	Force of Pull	Distance of pull	Force on Load	Travel of Load
i	1	F	d	F	d
ii	2	F	d	2F	1/2 d
iii	4	F	d	4F	1/4 d

2.2.2.2 Rotating Bodies

A rotating body is a rigid object that rotates about a fixed axis. A rotating body is often described by its radius from its center axis, and its rotational speed (or angular velocity). Since rotational speed is defined by its change in angle over time, "every particle on the object rotates through the same angle in a given time interval" (Serway and Jewett 2008). More simply stated, the rotational speed of a rotating object is the same at any distance from the axis. Conversely, the tangential velocity $\boldsymbol{v_t}$ (or linear speed) at any point on the rotating object is dependent upon the object's radius $\boldsymbol{r}$ from the center axis and its angular velocity (rotational speed) $\boldsymbol{\omega}$ where

$$\boldsymbol{v_t} = \boldsymbol{r\omega}$$

Thus, as in the Figure 2-6 below, when two rotating bodies are connected, their tangential velocities are equated. Given their radii, one can determine the rotational speed that is required rotate the other at a desired speed:

$$\boldsymbol{v}_{belt} = \boldsymbol{r}_{\substack{motor \\ pulley}} \boldsymbol{\omega}_{motor} = \boldsymbol{r}_{\substack{disk \\ pulley}} \boldsymbol{\omega}_{disk}$$

Figure 2-6: Relating the speeds two interconnected rotating bodies (Serway and Jewett 2008).

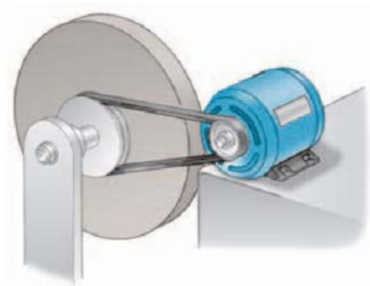


Figure 2-7: Motor and rotating disk (Serway and Jewett 2008).

2.2.2.3 Speed Ratio

Given that the motor in Figure 2-7 is driving the belt, and thus the disk, one can then relate both their rotational speeds to their radii, and determine the ratio between the motor and the disk. That is, how many rotations the disk makes per one rotation the motor makes. Thus, it follows that the speed ratio is the ratio of the diameter, or radius, for any two round interconnected objects (PowerMasters 2003).

$$\boldsymbol{r}_{\substack{motor\\pulley}}\,\boldsymbol{\omega}_{motor} = \boldsymbol{r}_{\substack{disk\\pulley}}\,\boldsymbol{\omega}_{disk}$$

$$\frac{\boldsymbol{\omega}_{disk}}{\boldsymbol{\omega}_{motor}} = \frac{\boldsymbol{r}_{\substack{motor\\pulley}}}{\boldsymbol{r}_{\substack{disk\\pulley}}}$$

$$\boldsymbol{SPEED\ RATIO} = \frac{\boldsymbol{r}_{\substack{driver\\pulley}}}{\boldsymbol{r}_{\substack{driven\\pulley}}}$$

Figure 2-8: Speed ratio as defined by each object's radii (PowerMasters 2003).

2.2.2.4 Gears

There are various types of gears available, but most are classified in two fundamental categories: those that transmit motion parallel between parallel shafts, and those that transmit motion between non-parallel, often perpendicular, shafts. Additionally, these categories can be subdivided into spur type and helical type gears. Spur gears have the teeth that are parallel to the axis of rotation, while helical gears have teeth pitched to the axis of rotation so that "the angle provides more gradual engagement of the teeth during meshing" (Youssefi 2006).

Parallel gear systems include gear and pinion systems (large and small gears), and gear inside a spline system (grooved material with inward pointing teeth). The spline type is often utilized in a planetary gear train system, Figure 2-9 right, where the axis of a spline and central sun gear are fixed and a planetary gear rotates between them. Thus, the planetary gear train is at least a three-gear system. A common gear and pinion system, Figure 2-9 left and center, occurs in a setup called "reduction gears," described in the next section.

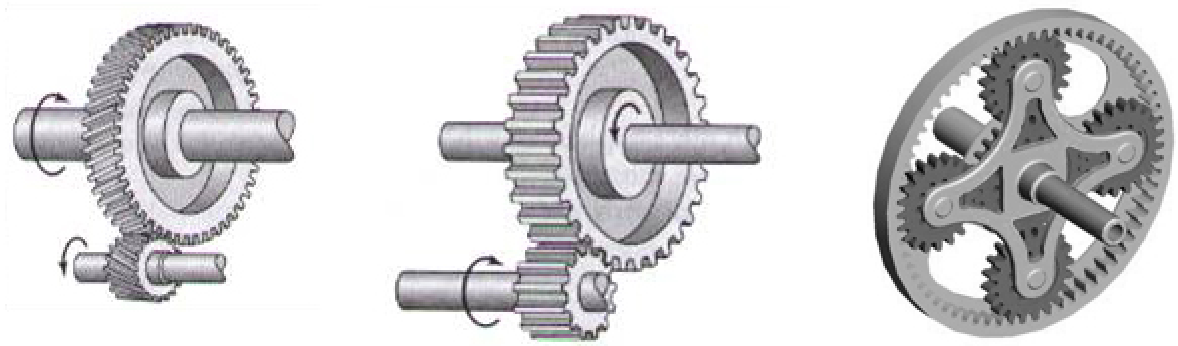


Figure 2-9: Parallel helical, spur (Youssefi 2006) and planetary gear systems (MathWorks 2011).

Perpendicular gear systems include bevel gear sets, worms gear sets, and rack and pinion sets. A bevel gear is a gear made on a conical surface, Figure 2-10 center. Bevel gears are used at the shaft ends when the gears do not meet at a parallel junction. A worm gear set, as in Figure 2-10 left, is one where a helical spur gear meets a perpendicularly arranged worm gear or power screw. In a worm set, the worm gear drives the helical spur gear and is utilized to provide torque in the system. The worm gear set cannot operate in reverse, that is, the helical spur gear cannot drive the worm gear. Finally, in the rack and pinion set type, a parallel gear meets a flattened gear of potentially infinite diameter (Youssefi 2006).

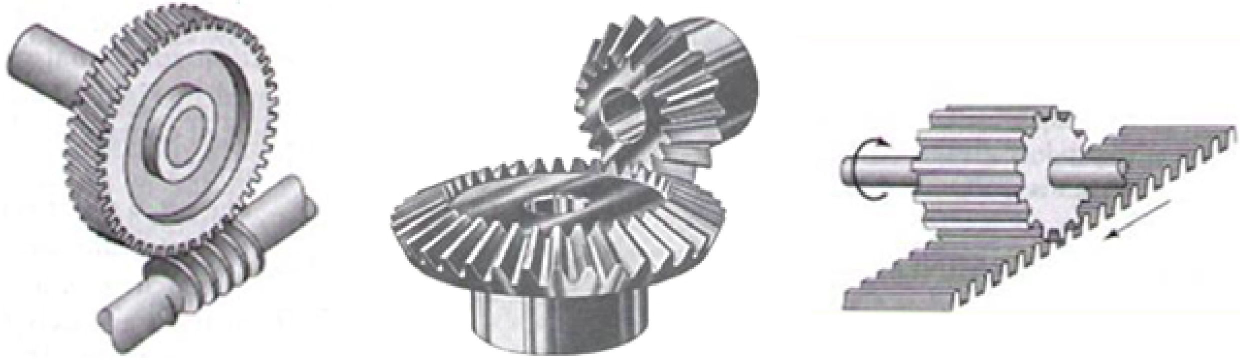


Figure 2-10: Perpendicular helical and worm, bevel, and rack and pinion gear systems (Youssefi 2006).

2.2.2.5 Gear Ratio

When gears are interconnected, their interconnectivity is determined by a gear ratio. A gear ratio is a value that relates a driver gear to a driven gear in a set of interconnected gears within a system. For a system that has one gear driving another, the gear that some amount of rotation is applied to is a driver gear, and the gear that receives the output rotation is a driven gear. Similar to the speed ratio described by two object's radii, a gear ratio indicates a relationship between the rotational speed of a driven gear and a driver gear. The gear ratio is described as the product of the number of teeth in the driver gears over the product of the number of teeth on the driven gears (Youssefi 2006). Since the teeth between gears in a system must line up to one another, the number of teeth accurately relates the number of rotations on the body attached to the driver (input) gear to the number of rotations of the body attached the driven (output) gear. Thus, for an n-gear system the gear ratio is as follows:

$$\boldsymbol{GEAR\ RATIO} = \frac{\boldsymbol{N}_{driver}}{\boldsymbol{N}_{driven}}, \quad \begin{aligned} N_{driver} &= product\ of\ number\ of\ teeth\ on\ driver\ gears \\ N_{driven} &= product\ of\ number\ of\ teeth\ on\ driven\ gears \end{aligned}$$

Figure 2-11: Gear ratio as defined by the number of teeth on the input and output gears (Youssefi 2006).

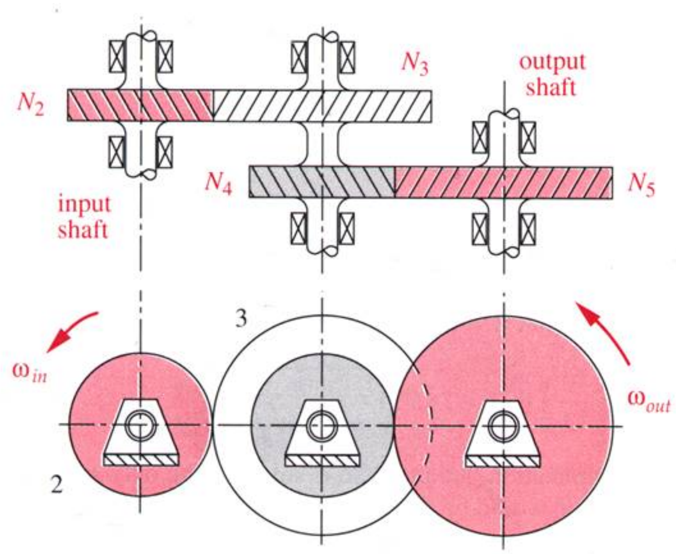


Figure 2-12: Four gear system (Youssefi 2006).

The gear ratio can be equated to the speed ratio described earlier, and can be used interchangeably when gears and wheels are connected together.

$$\boldsymbol{GEAR\ RATIO} = \frac{\boldsymbol{N}_{input}}{\boldsymbol{N}_{out\,put}} = \frac{\boldsymbol{r}_{input}}{\boldsymbol{r}_{output}} = \boldsymbol{SPEED\ RATIO}$$

Figure 2-13: Relating the gear ratio to the speed ratio.

Thus, the gear ratio is also known as a speed ratio in that it relates the speed of an output gear to the speed input gear. Figure 2-14 below illustrates a reduction gear system. The idea behind reduction gears is that the rotational speed from a source might need to be reduced to meet the constraints of rotating body to which it is applying the rotation. An example of this is when a motor outputs a maximum rotational speed that exceeds the maximum rotational speed of boat propeller. Thus, by placing a small gear on the source of rotation and connecting it to a large gear on the recipient, the rotational speed is thereby reduced to some degree, depending on the gear ratio (Nikolaidis 2005).

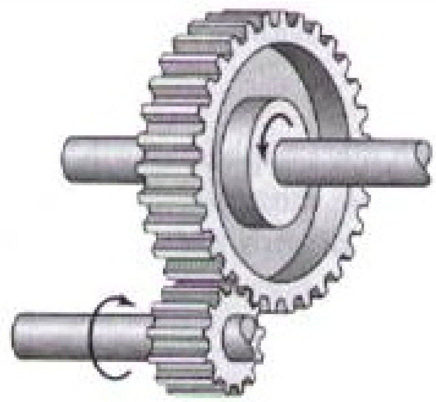


Figure 2-14: Reduction gearing system (Youssefi 2006). The fast moving small gear drives the larger gear at a slower rate (Nikolaidis 2005).

2.2.2.6 Gear Ratios and Power Output

The power output from a bicycle, or other apparatus, is dependent upon the amount of work applied and the gear ratio that is used. As noted in the previous section, one can control the maximum rotational speed by modifying the gear ratio between the two rotating bodies. There is a limit, though, to the maximum amount of power a human can generate in a bicycle system. The following study was performed on ten subjects involving an ergometer attached to a bicycle. The scope of the study was to determine the peak power output (PPO) and mean power output (MPO) of ten second sprints on a bicycle at different gear ratios. The following table indicates the six gear ratios tested in the study, and the accompanying figure indicates the peak rotational speeds (peak cadence) achieved at each corresponding gear ratio.

Gear	Main chain ring	Internal gear	Internal chain ring	Final gear	FR/PCR
1	48	14	35	19	6.32
2	48	14	35	17	7.06
3	48	14	35	15	8.00
4	48	14	44	17	8.87
5	48	14	44	15	10.06
6	48	14	44	14	10.78

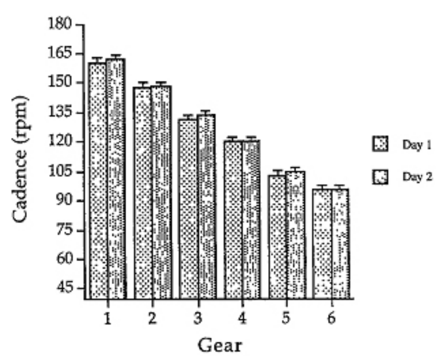


Figure 2-15: Gear ratios and rotational speeds sustained in 10s sprint trials (Barnett 1996).

The under ten second sprint trials, it was determined that peak and mean power output was optimum at a gear ratio of 8.87, which corresponds to gear 4 in the accompanying figures. At the sustained rate of approximately 120 revolutions per minute, a peak power output and mean power output of 1250 watts and 1025 watts, respectively, was produced. Alternatively, gears 3, 4, and 5 elicited the greatest mean power output, which corresponded in gear ratios between 8.00 and 10.06, and rotational speeds between 105 rpm and 130 rpm, respectively (Barnett 1996).

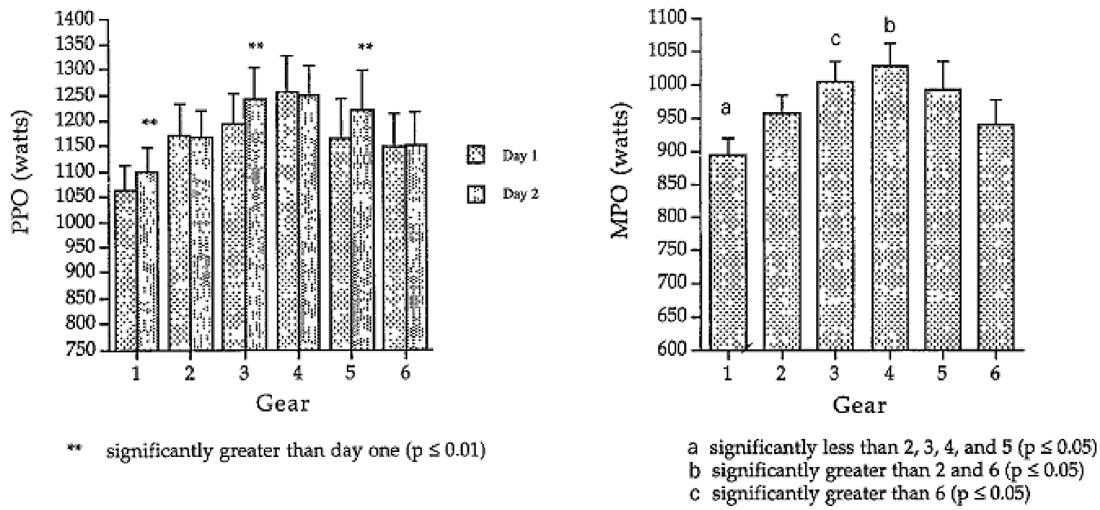


Figure 2-16: Peak and mean power output in 10s sprint trials (Barnett 1996).

2.2.2.7 Crank Lengths

A study by the European Journal of Applied Physiology examined the effect of two different crank sizes and how fast they turned the device. In the results, they found that a crank length of 180 mm was found to have a greater power output than the 220 mm, regardless of the speed at which the individual spun the crank (Kramer et al. 2009). To test whether or not the crank length or crank width would affect the overall power, a two-way repeated measure analysis of variance was used. The optimum crank speed and cadence were determined by the points at which overall power generated was at a maximum as shown in Figure 2-17.

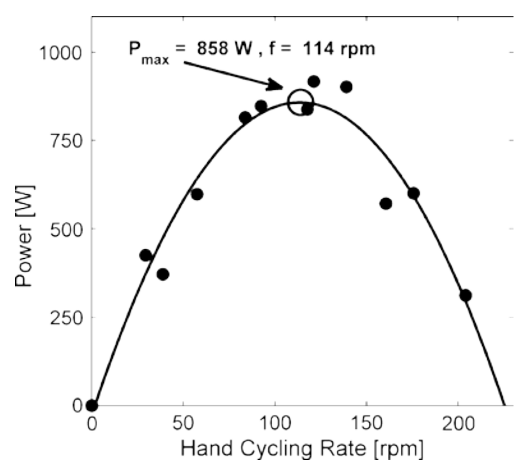


Figure 2-17: Power versus hand cycling rate (Kramer et al. 2009)

The method of testing used, determined that the crank length significantly altered the power generation while overall crank width had a consistent but minimal affect (Kramer et al. 2009).

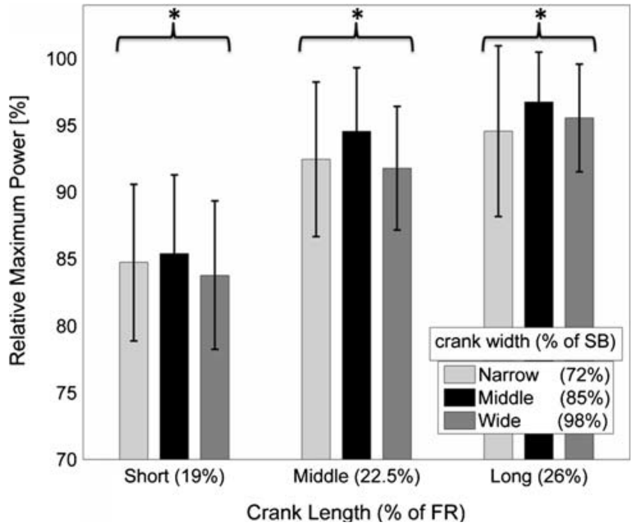


Figure 2-18: Analysis of Crank Length and Width versus Maximum Power output (Kramer et al. 2009).

2.2.3 Previously Designed Systems

This section addresses systems of energy generation that are already on the market.

2.2.3.1 Bicycle Power Generator

The bicycle generator design has been previously implemented and most of them have similar concepts. The back wheel rotates, spinning the axel on the generator, which creates energy. The power output from any generator is not 100% efficient, because the system loses some energy through the process of generation, storage, and inversion. The generation of electricity occurs by way of a stationary bicycle with the back wheel typically raised slightly off of the ground, allowing the back wheel to spin freely. The spinning wheel is then connected to a generator which produces power.

Figure 2-19: Basic bicycle power generator (Airstream Life 2008).

By rotating the pedals, the geared axel causes the wheel to spin which results in the spinning of the generator axle causing to rotate metal coils within a magnetic field, creating an electrical current, as in Figure 2-20. The energy can then be stored in a battery and used when needed.

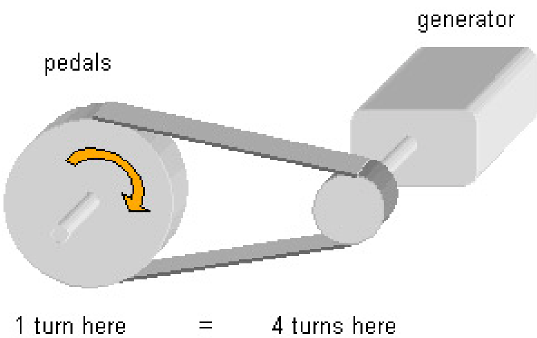


Figure 2-20: Basic belt drive generator setup (AENews Network 2006).

As with all power generating devices that use human work to function the main limiting factor is simply the capability of humans. "A typical healthy adult human is capable of producing about 100 to 150 watts for periods of an hour or more," (Morrison and Thomas 1999). It is good to note, however, that "since legs also naturally project the force of the body's weight, generators pumped by leg motion are an ideal way to obtain more power," (Sterner and Paradiso 2004).

2.2.3.2 Foot Powered Generator

This design utilizes leg power by creating a step pump motion to generate electrical energy. A standing individual places their foot on the unit and presses up and down to cause a generator to rotate and charge an internal lead-acid battery in the device. The capabilities of this device range from jump starting vehicles and boats to powering small gadgets. Due to the small size of the device large load are unable to be powered by the device and like all human powered generators, they are limited by the capabilities of the individual powering them (AENews Network 2006).

Figure 2-21: Foot Power Generator created by Freeplay Energy (AENews Network 2006).

2.2.3.3 Human Powered Gym

There have been a few breakthroughs in creating gyms entirely powered by the gym members exercising on cardio machines. Human Dynamo has successfully implemented such design in Oregon. As customers pedal on the generator/workout systems throughout the facility, a DC current is generated and stored in a battery. It is then inverted to AC current, so people can then plug in and power devices such as a television, lamp or any external device.

Their machines are a combination of a bicycles and hand cranks to ensure as much energy as possible is being generated from that gym member, as well as delivering an adequate workout. There are four machines, Figure 2-22 left, per one generator and battery, Figure 2-22 right, where all of the combined energy is stored. According Human Dynamo, testing of the machines has shown to produce an average of 100-watts generated by each machine. Mathematically, forty machines being used in a gym for one hour translate to 4,000-watt-hours of free "earned" energy (Human Dynamo 2011).

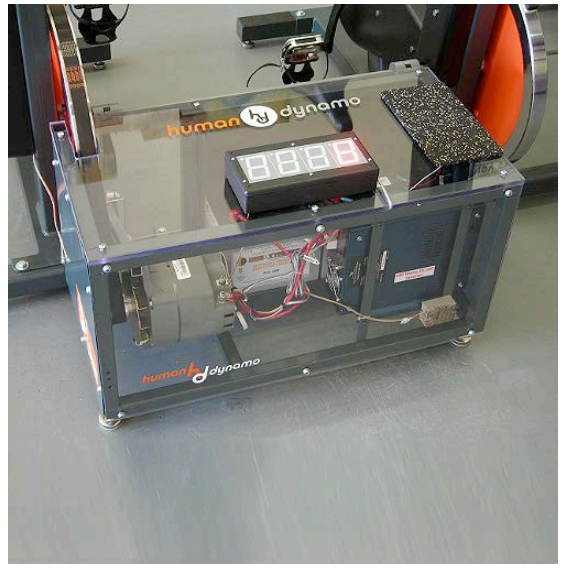


Figure 2-22: Four parallel exercise generators and communal battery pack (Human Dynamo 2011).

2.2.3.4 Other Power Generating Designs

There are various other applications of human powered systems, all using the same basic bicycle pedal design. Since these systems are generating DC current and is it being stored in a battery to be used later, the stored energy can be used however the person chooses depending upon the amount of energy stored. In Afghanistan, laptops have been powered by pedal or crank systems to allow school children access to computers without being connected to a power grid (OLPC Afghanistan 2011), Figure 2-23 left. Even television sets and washing machines have been powered by pedaling, Figure 2-23 right.

Figure 2-23: Pedal powered laptop (left, OLPC Afghanistan 2011),
and a pedal powered washing machine (right, Pilloton 2007).

Foot pedal designs, regardless of whether they are manual or electrically generated, tend to be more effective than hand crank systems due to the increased amount of power generated by the lower body. Wind Stream Power Systems Incorporated is a company that has been creating human-powered energy devices, Figure 2-24, for commercial use that can utilize hand or foot cranking. Proving the efficiency of foot pedaling, Wind Stream recently determined that approximately 125-watts of energy is possible from pedaling generation, while only 50-watts is possible from a hand crank system (Saez 2004).

Figure 2-24: WindStream Power generator system (Windstream Power 2011).

2.2.4 Methods of Waterproofing

Water or weather proofing a system is a crucial part of keeping the integrity and longevity of a system by preventing damage to the system's interior. There are many ways to waterproof a design, some work better than others based on the situation and the objective of the project.

2.2.4.1 Plastic Membrane Dip Method

One method of waterproofing an electronic device uses a rubberized plastic liquid that solidifies around an object to form a water tight skin. The item is taken and dipped into rubberized liquid, Figure 2-25. Then, the item is set to dry, and it forms a soft layer of plastic over the part. Difficulties with this method arise when there are movable parts that need to be waterproofed. When moving parts are covered by the

Figure 2-25: Waterproofing by coating in plastic (Society of Robots 2012).

2.2.4.2 The Water Tight Box Method

A waterproof box or container is created around the item completely protecting the item. However, this method often requires a much larger volume of space than the original item displaced due to the fact that a container must be built that is able to hold the item inside of it.

2.2.4.3 Oil Filled Method

By encasing an entire item with non-conductive oil, it prevents water from entering the space or harming the product. Oil naturally separates from water thus forming a waterproof barrier. The first step in this method is to completely submerge the item into the oil, Figure 2-26 below. The item should be disassembled to allow the oil to enter the item filling the spaces and replacing the air inside (Society of Robots 2012). All air must be removed from the item to allow for maximum protection. Finally, the item must be reassembled with it remaining submerged in the oil. The final step prevents any unwanted air bubbles from being trapped inside and thus negating the effectiveness of your waterproofing. This method is difficult to use due to the handling and containing of the oil itself.

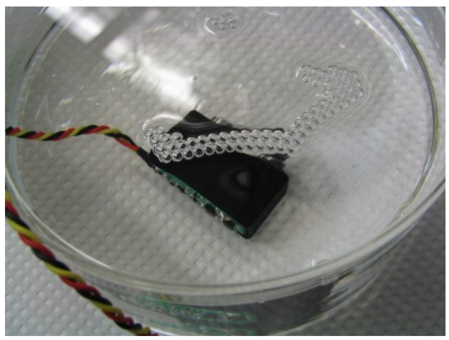


Figure 2-26: Servo immerse in non-conductive oil (Society of Robots 2012).

2.2.4.4 Waterproof Epoxy

Epoxy is one of the most common used substances in the fields of construction and engineering to waterproof a project (Society of Robots 2012). It acts as glue between the cracks and surfaces that allow moisture to penetrate into the system. Epoxy is applied to the critical areas then must be left to dry. Once dry the epoxy becomes a water tight seal.

Figure 2-27: Common types of epoxy (Society of Robots 2012)

3 Alternative Solutions

3.1 Introduction

The alternative solutions section presents possible ideas and different designs of a human powered generator which are analyzed against the given criteria.

3.2 Brainstorms

After a foundation of information was established for projects and ideas that are preexisting in the modern world, a couple of brainstorming sessions in which probable ideas were discussed in order to formulate a list of possible solutions that were capable of meeting set criteria. See Appendix B to view the complete set of Brainstorm notes. (Copy of Brainstorms would greatly improve content in this section)

3.3 Alternative Solutions

From the set of brainstorms a total of nine alternative solutions were developed. Each of which were capable of meeting the criteria established by the team. Each solution provided a separate design that could be used by an individual to produce alternative power. The following is the list of names used to describe each solution:

1. Adjustable Height Hand Crank
2. Multiple Hand Crank Bar Generator
3. Lever Arm Generator
4. Recycling Water Wheel Generator
5. Pull Cord Generator
6. Direct Hand Crank Generator
7. Treadmill Generator
8. Step Pad Power Unit
9. Bus Wheel Energy Generator

3.4 Adjustable Height Hand Crank

The Adjustable Height Hand Crank utilizes an arm that varies in length while the chain connecting the crank to the generator remains under tension. Figure 3-1 shows the basic cutout of the hand crank setup (left) and the position of a rigid tensioner gear and dynamic tensioner arm at different crank arm lengths (right). The hand crank will spin upon rotation, but when hand crank rotation stops, the attached gears will continue spinning, similar to a bicycle crank in the bottom bracket. Attached to the hand crank is a primary gear that drives a smaller center gear at a higher angular velocity. Attached to the middle gear is another, larger gear driven by the smaller gear. This larger middle gear is attached to a smaller gear mounted on a generator. The transformation of angular velocity at the crank to angular velocity at the generator is dependent upon the gear sizes in the system. Ideally, the system will utilize recycled bicycle chains and gears for transferring the power, and recycled steel cross members in the frame.

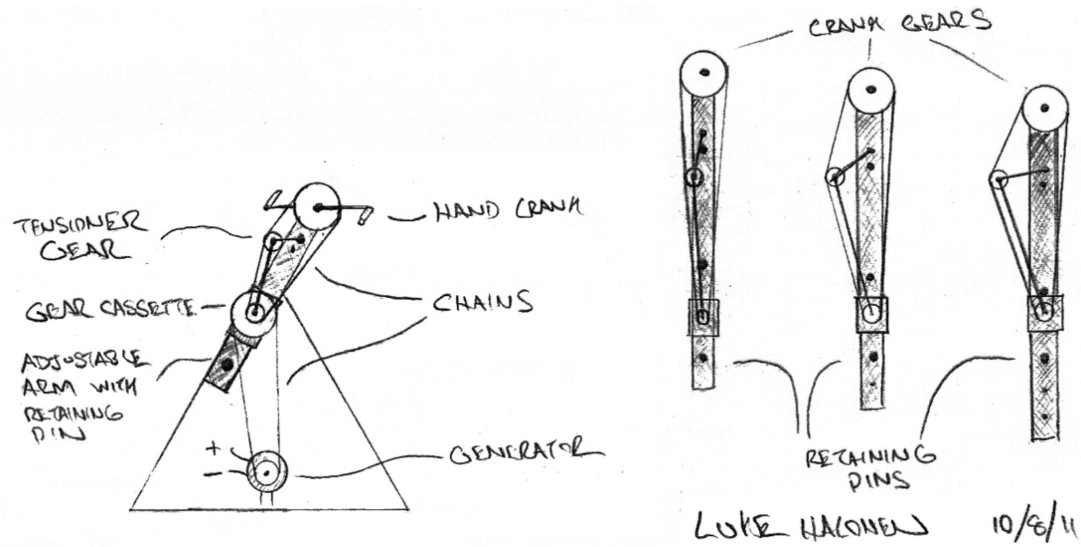


Figure 3-1: Adjustable Hand Crank Generator.

The advantage to the adjustable height hand crank with chain tensioner include it's increased demographic due to its height adjustments, and it could collapse into itself by rotating about the center gear cassette for storage. A disadvantage would be that the tensioner might be the first to fail under prolonged use. Since the tensioner is a vital component to the system, a failure in the tensioner may render the entire system nonfunctional. However, the system can be set to its maximum height where the tensioner would not be used.

3.5 Multiple Hand Crank Bar Generator

The multiple crank system utilizes a rigid bar bent in the shape of multiple cranks along its length, as illustrated in Figure 3-2. On the ends of the crank bar are gears attached to their individual generators. The gear/generator system is in a fixed gear arrangement in this setup, and a bicycle chain will be used.

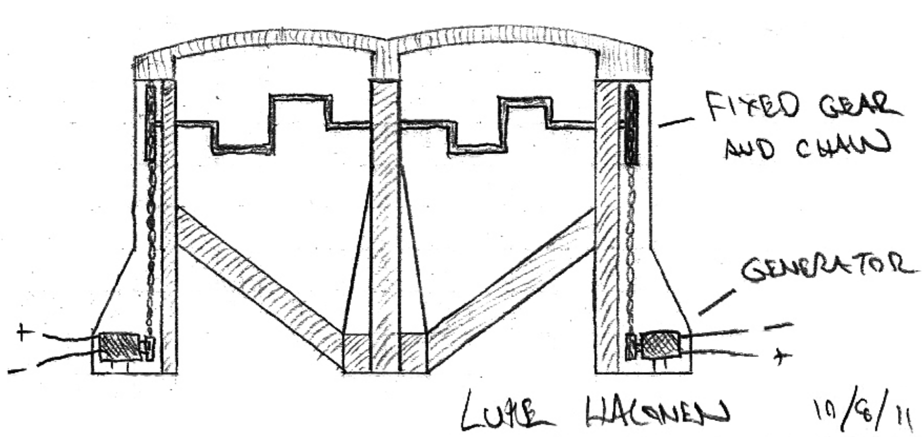


Figure 3-2: Two-Person Hand Crank Generator.

The benefits to this setup include the potential to produce more power, as more people may be able to use it. The disadvantages are that the setup will require a strong framework to maintain its integrity over prolonged usage, and thus it will be large, immobile, and non-compactable.

3.6 Lever Arm Generator

The lever arm system mimics that of a spigot lever, except this lever is used to create power rather than to pump water. The lever arm system requires the user to repeatedly "pump" the lever arm to cause a rotation about the attached wheel as illustrated in Figure 3-3 (right). A pump of the lever causes a bicycle chain to expand an affixed spring attached to its end. The expansion of the spring allows the chain to move across and rotate a gear. The gear is attached to another gear within a gear cassette. The next gear in the cassette is connected to a generator via a bicycle chain. Thus, pumping the lever causes a rotation of the generator to create power. Note that the gear cassette must allow for free reverse rotation, as witnessed in a rear bicycle cassette, to allow for the lever arm to return to starting position. Once the user repeatedly pumps the lever at a great enough force, the wheel will begin to gain enough momentum such that spring masses on the spokes will expand as illustrated in Figure 3-3 (left). The movement of mass further from its axis of rotation will slow the rotation down slightly, but further pumping of the lever arm will cause it to be barely noticeable for the user. Once the pumping stops, these masses away from the axis will cause the wheel to want to maintain its rotation. Since the masses are attached to springs, they will eventually to contract causing the masses to return closer to the axis of rotation. When this happens, due to the law of conservation of momentum the wheel will increase its angular velocity for a short duration before slowly returning to its previous angular velocity, then to a stop.

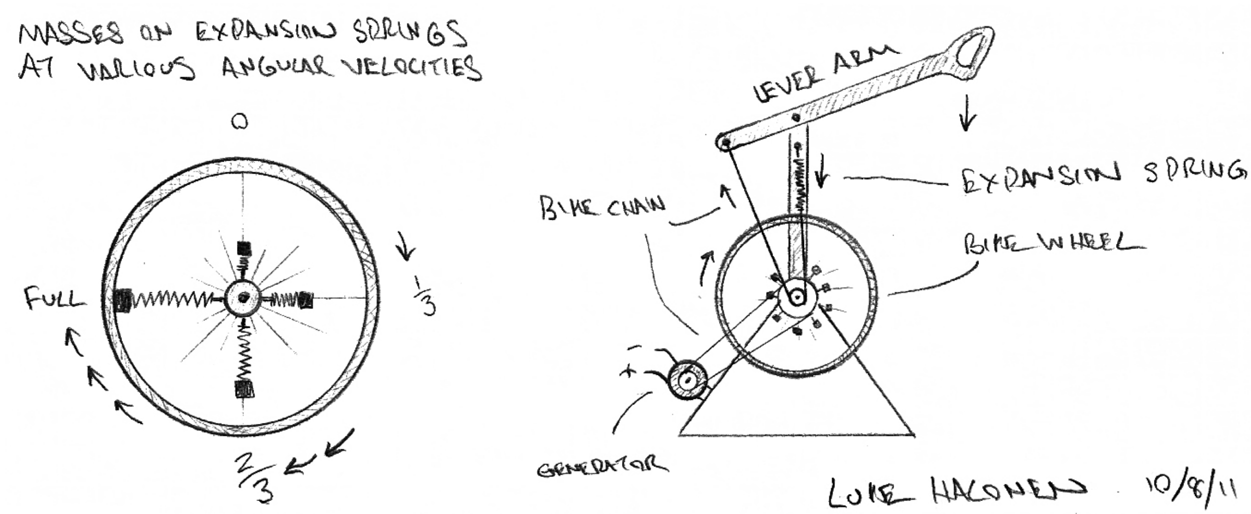


Figure 3-3: Lever Arm Generator.

The advantages of the lever arm system are that it's simple, its components are common and easy to obtain, and the increased angular momentum will attribute a slightly prolonged rotation about the generator thus causing a slight increase in power output. Next, the lever arm system may be modified to be collapsible for storage. The disadvantages to the lever arm system would be the type of movement required to use it may cause uneven strain about the supports due to the constant pulling down on the system. Additionally, fatigue may be observed on the expansion spring at the end of the chain over prolonged use, but may be rectified with a replacement spring on hand.

3.7 Recycling Water Wheel Generator

The Recycling Water Wheel Generator is a modification of a hand water pump to turn a water wheel attached to an energy generator. A similar device would be a scaled down hydroelectric river generator. As shown in Figure 3-4, the hand pump transfers water from the reservoir and pours the water onto the water wheel, taking the kinetic energy from the operator and causing the axel on the generator to spin thereby converting kinetic energy into electrical energy. The pump and wheel setup are placed in the same reservoir and cycle the same volume of water recursively. The general dimensions of the setup are estimated to be approximately 2ft long X 1ft deep X 2ft tall and hold about 1 gallon of water to be cycled through the system. Almost all the materials needed might be accessed through the waste stream, except for the generator and electrical components.

The main attributes of this solution include a high aesthetic value, its ability to utilize reusable resources, and the entertainment and educational interaction the operator experiences while using the system. The main drawbacks to this solution involve the extensive waterproofing and safety measures that would need to be implemented in order to protect a user from being inadvertently shocked. Due to the liquid aspect of the design, the devices portability would be greatly hindered. Another factor relating to this project is the low force acting upon the water wheel which lessens its capability of producing enough rotational momentum to power the generator and thus greatly reducing its power output.

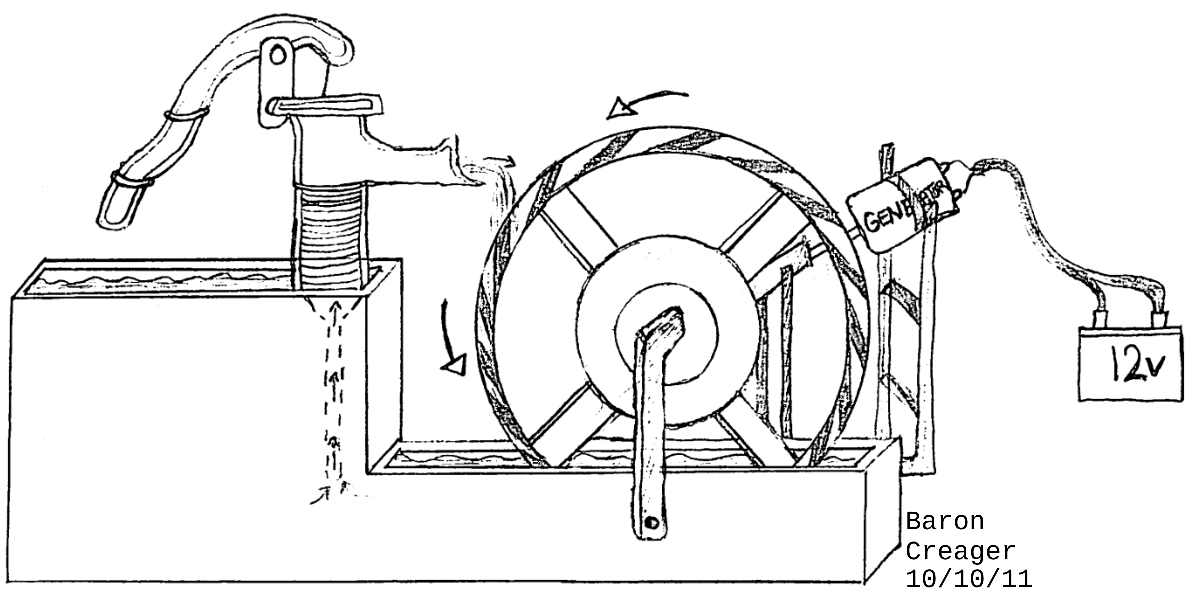


Figure 3-4: Water Wheel Generator in motion (Drawn by Baron Creager)

3.8 Pull Cord Generator

The Pull Cord Generator utilizes a modified lawnmower pull cord that harnesses the operator's kinetic energy. This is accomplished by pulling on the cord and transfers that energy through a gear setup, thus converting the kinetic energy to electrical energy in the generator. The gears and pulleys are arranged so that the operator can continuously pull the cord and repeatedly keep the generator's axel spinning, similar to the design of a pull cord on a lawn mower. The pull cord requires a very high strength cord in order to handle the repeated tension and force, as well as having a handle attached similar to a rowing machine handle. The whole unit is approximately 5ft tall x 2ft deep x 2ft wide, see Figure 3-5. The generator has a small sloped incline in the front of the system to help increase the force the operator can exert on the system by stabilizing their center of gravity. As displayed on the left picture in Figure 3-5 a small power meter can be installed in the front to inform the user on how much energy is being generated with each pull of the cord.

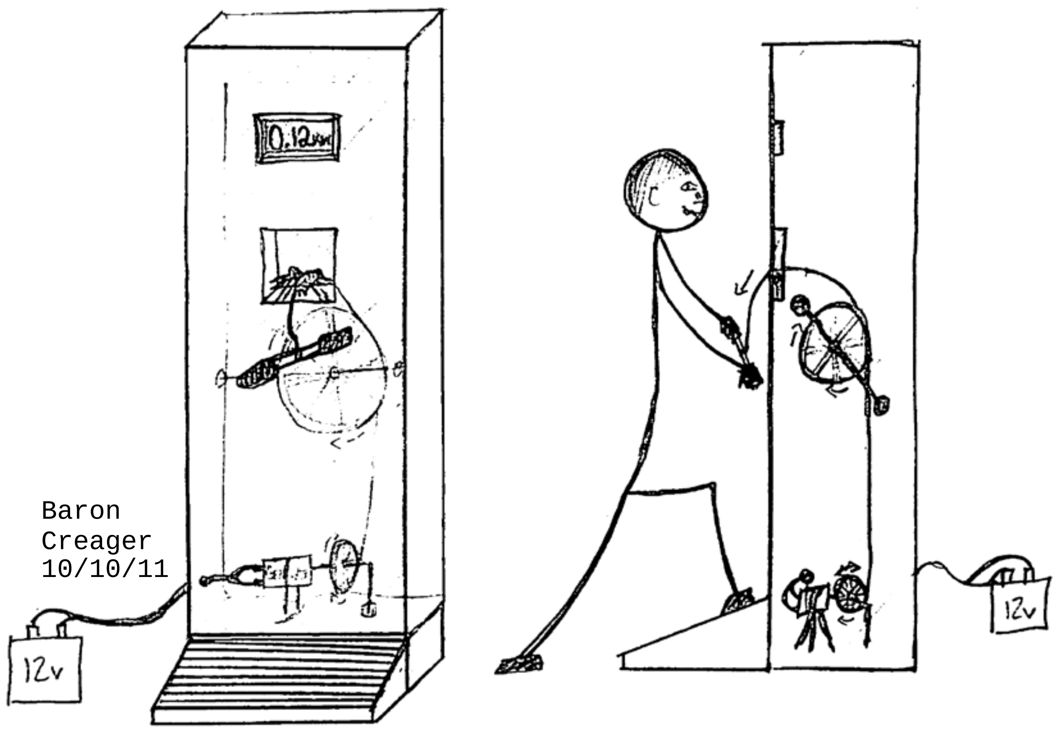


Figure 3-5: Pull Cord Generator

The main attributes of this solution are the power meter's educational value. This design has increased efficiency energy generation when compared to solutions like the Water Wheel Generator and Step Pad Power Unit. The system as a whole is contained, weatherproof, and durable. The main drawbacks include the system's portability due to its size. The high construction cost due to the anticipated lack of reusable resources and the low visual appeal when illustrating how it functions, unless Plexiglas is used in some way.

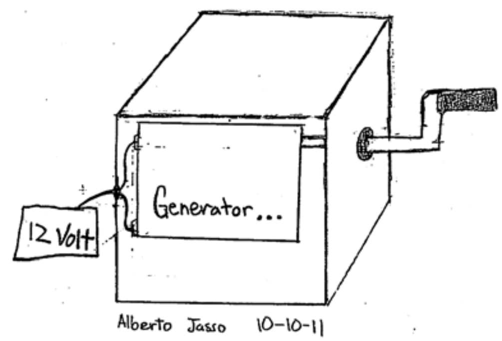


Figure 3-6: Direct Hand Crank Generator

3.9 Treadmill Generator

As seen in Figure 3-7, the treadmill approach utilizes a relatively free turning belt setup similar to an exercising treadmill and transfers the kinetic energy from the user running and turning the belt to a generator that converts this energy to electrical power. This belt must be given an amount of resistance to prevent loss of control by the user on the belt. The resistance also increases the power output of the system, as well as support the load of a meter to display the amount of power generated. The meter will be mounted to a collapsible safety handle to ensure ease and safety during use. The rear roller on the belt will have an electromagnetic generator attached to its axel to capture the kinetic energy from the spinning belt.

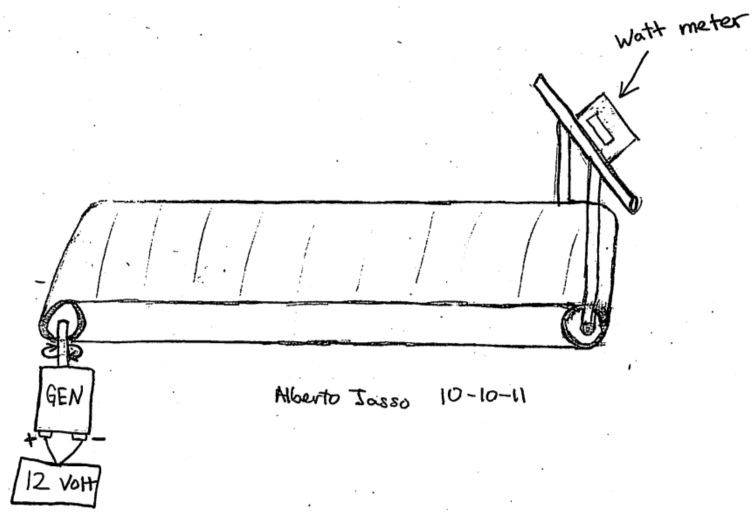


Figure 3-7: Treadmill Generator

The treadmill generator system is not usable by the handicapped demographic and has potential to be hazardous to small children. The portability of this solution is a possible problem due to the size and difficulty of adjusting the size. Weatherproofing is also a criterion that could be of some difficulty since treadmills are meant to be indoor exercise devices. The overall durability of this system should be strong since exercise machines are built for long term use. However, the power output will be the high among the other alternative solutions since we are accessing energy from the lower, more powerful half of the human body.

3.10 Step Pad Power Unit

The Step Pad harnesses gravity by using human weight to produce energy. An individual uses their weight by standing or stepping on a pad for a short period of time. Figure 3-8 shows the pressure of the person forcing oil, stored in a reservoir under the pad, through a small tube (green arrows). Inside the tube is a turbine attached to a power generator, which then rotates as the oil passes through it, thus producing electricity. After the weight of the person is removed the oil moves back through the system, from pressure applied by compressed springs, returning the oil to the oil reservoir and raising the step back to its original resting position. The step pad system uses the least amount of human energy necessary to generate power due to most of the work being supplied by gravity rather than human action.

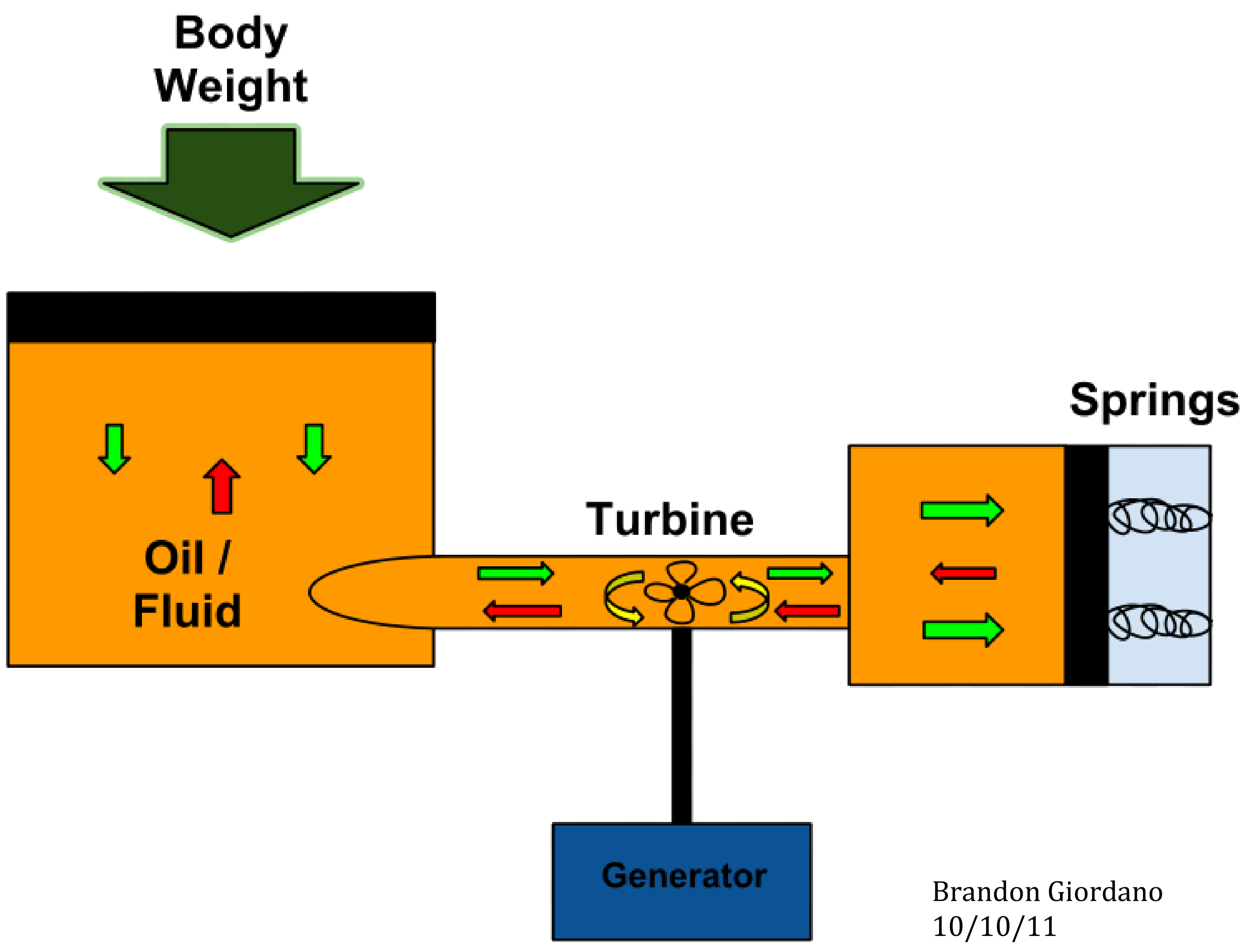


Figure 3-8: Step Pad Generator

Of all the proposed alternative solutions, the Step Pad Power Unit is the most unique. This design would have a high portability with all of the components being relatively compact. The cost of this solution would be of the greatest concern due to most of the components requiring the group to manufacture. The operation of this device would pose very little danger or hazards to the operator making the Step Pad a very safe product. Durability is one of the biggest issues with this solution since it uses oil in a contained environment in combination with a turbine. Other issues with durability could be the spring system used to return the Step Pad to the resting position.

3.11 Bus Wheel Energy Generator

The Bus Wheel utilizes human work to produce energy by rotating a wheel. This generator is similar to the Direct Hand Crank Generator in design. The difference is primarily in the position and orientation of the crank wheel and the muscles used by the operator to generate electricity. A wheel with a rotating handle is vertically attached to a generator that is encased in a weather proof container. The operator spins the wheel from the top, using one of two methods (handle or wheel), which then powers the generator. The Bus Wheel version offers additional methods in which a person can generate power using upper body movement.

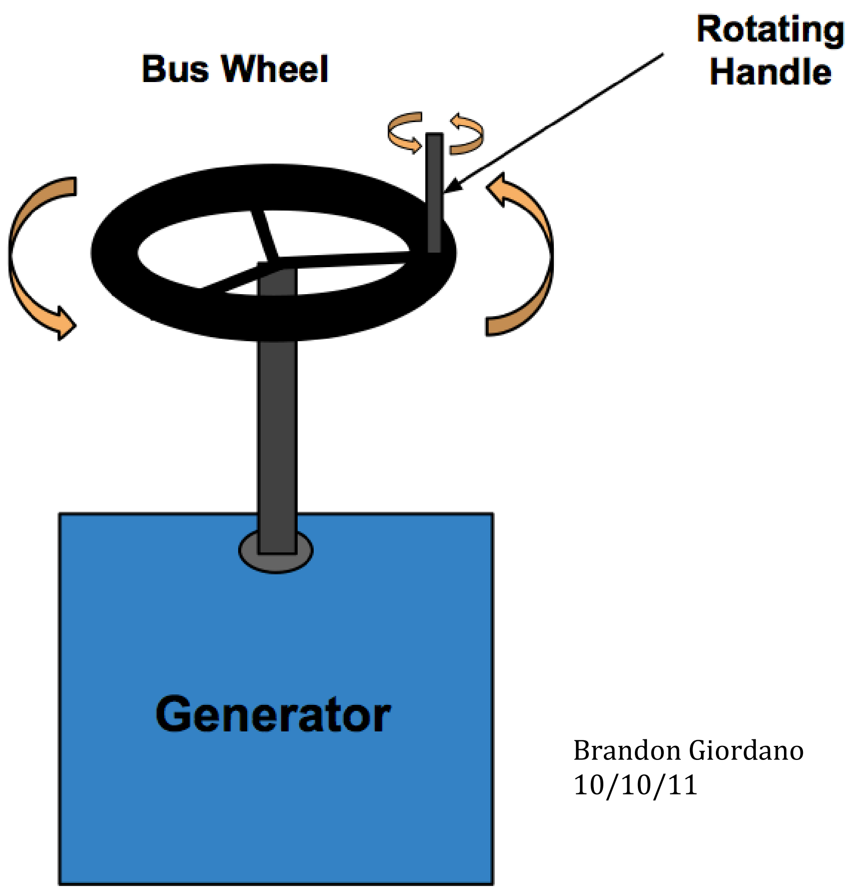


Figure 3-9: Bus Wheel Generator.

The positive aspects of this design include a low cost and high transportability due to the simplicity of design. The negative aspects of this design may include a low educational value and poor aesthetic value. The device overall would be easy to use and require little to no instruction to operate.

4 Decision

4.1 Introduction

The decision section lays out the criteria developed by the team and input from the client, the possible solutions that were developed, the decision making process used to determine the final project, and the final project decision supported by reasoned justifications.

4.2 Criteria

Table 4-1 consists of the team's weighted criteria after input from the instructor, Lonny Grafman, and the client, Mary Mattingly. Descriptions of the criteria can be found in Table 2-1, Criteria and Constraints

Table 4-1: Team weighted criteria.

Criteria	Weight
Safety	10
Cost	10
Durability	8
Ease of Use	7.5
Transportability	7.5
Energy Output	7
Aesthetics	6.5
Embedded Energy	6.5
Educational Value	5

4.3 Solutions

Nine Alternative Solutions are considered in this section. The details of each solution can be found in Alternative Solutions. The nine alternative solutions considered in the decision process are:

1. Adjustable Height Hand Crank
2. Multiple Hand Crank Bar Generator
3. Lever Arm Generator
4. Recycling Water Wheel Generator
5. Pull Cord Generator
6. Direct Hand Crank Generator
7. Treadmill Generator
8. Step Pad Power Unit
9. Bus Wheel Energy Generator

4.4 Decision Process

The process for deciding the final design consisted of developing a team evaluated Delphi Chart and Pugh Chart to aid us in narrowing down the best solutions. The decision process also consisted of feedback from the instructor, Lonny Grafman, and the client, Mary Mattingly. Team brainstorming and research also played a large role in the final design decision.

As shown in Table 4-2 below, the Delphi matrix distinguishes the highest and lowest rated solutions as compared to the weighted criteria. The scores are shaded according to how well or how poorly the solutions meet the criteria, on a scale from green to red, respectively. While there are some solutions that produce a similar result—colored green—the difference between the highest and lowest rated solutions is evident by the red color code, or lowest score.

Table 4-2: Delphi decision matrix.

Criteria		Solutions						
List	Weight	Adjustable Hand Crank	Lever Arm	Pull Cord Row Machine	Treadmill	Step Pad	Hand Crank	Bus Wheel
Safety	10.0	35 / 350	30 / 300	30 / 300	25 / 250	40 / 400	40 / 400	40 / 400
Cost	10.0	40 / 400	45 / 450	35 / 350	25 / 250	20 / 200	40 / 400	35 / 350
Durability	8.0	35 / 280	30 / 240	40 / 320	25 / 200	20 / 160	40 / 320	40 / 320
Ease of use	7.5	45 / 338	40 / 300	30 / 225	40 / 300	40 / 300	35 / 263	40 / 300
Transportability	7.5	35 / 263	35 / 263	25 / 188	25 / 188	20 / 150	40 / 300	35 / 263
Energy Output	7.0	40 / 280	45 / 315	45 / 315	50 / 350	15 / 105	25 / 175	35 / 245
Embedded Energy	6.5	40 / 260	40 / 260	35 / 228	35 / 228	20 / 130	40 / 260	35 / 228
Aeshtetics	6.5	30 / 195	40 / 260	30 / 195	30 / 195	40 / 260	10 / 65	30 / 195
Educational Value	5.0	20 / 100	25 / 125	30 / 150	30 / 150	40 / 200	5 / 25	10 / 50
	Total:	2465	2513	2270	2110	1905	2208	2350

The Lever Arm solution ranked as the most matched solution to the criteria, with its energy output being one of the highest among the alternative and an average ease of use. Some disadvantages to the Lever Arm solution are its lower rated durability and educational value.

The runner-up solutions include the Adjustable Hand Crank, Bus Wheel, and the Basic Hand Crank. The Bus Wheel and Basic Hand Crank compare poorly in their educational value, aesthetics, and energy output. The Row Machine and Treadmill are ranked significantly less when considering their need to be either towed or take up space inside the pod.

The Step Pad solution came in as the least feasible and least matched solution as its energy output, cost, durability, and transportability are rated poorly. However, this solution is very aesthetically pleasing, has a high educational value, and is very easy to use.

The results from the Delphi matrix were tabulated and the top rated solutions where put into a Pugh Chart to further refine each solution's credibility. In this chart we analyzed the Adjustable Hand Crank, the Bus Wheel, and the Single Hand Crank. These solutions were compared to the highest rated solution (Datum) from the Delphi chart, the Lever Arm.

Table 4-3 shows the Pugh chart comparing the best, criteria matching solutions. With a "+" indicating that a solution meets that specific criteria better than the Datum (Lever Arm), and a "–" indicating that the Datum better meets that criteria, we can see more definitively how the "runner up" solutions compare to the Datum.

Table 4-3: Pugh decision chart.

Criteria	Datum: Lever Arm	Adjustable Hand Crank	Bus Wheel	Single Crank
Safety		+	S	+
Cost		+	+	+
Durability		+	+	+
Ease of Use		+	+	–
Transportability		S	+	+
Energy Output		–	–	–
Aesthetics		–	–	–
Embedded Energy		–	S	–
Education Value		–	S	–
Total +'s		4	4	5
Total –'s		4	2	4

The Bus Wheel has an overall better score than the Datum as it better meets the criteria for cost, durability, transportability, and ease of use. The Single Crank is also slightly better than the Datum as its simplicity aids it in safety, cost, durability, transportability, and embedded energy. The Adjustable Hand Crank came in a close tie with the Datum consisting of an equal amount of positives and negatives, making it good alternative solution to the Lever Arm. The Pugh decision method aided in the decision making process by providing perspective within the higher rated alternatives. Additionally, it helped to solidify the final decision.

4.5 Final Decision Justification

After weighing the possible solutions using the Delphi and Pugh methods, Team Excergy chose to design the Lever Arm solution. The Lever Arm not only fit all of the criteria and scored the highest in the Delphi method; it provided a uniqueness that is not present in the higher rated alternatives. The Lever Arm solution was unique in its method of power generation by pumping a lever, where others were simply variations of the same hand crank. The Lever Arm also allowed for individual or tandem use, a feature that was not present in many of the alternatives. For these reasons, the Lever Arm Generator solution was chosen to be implemented.

5 Design Specification

5.1 Introduction

This section will cover the final design chosen in the previous section. Maintenance costs and implementation costs for construction will be analyzed along with the team hours put into the project. In addition to more elaborate details discussed about the design provided will be visuals such as an AutoCAD drawing of our component for the Flock Pod. This section aims to narrow in on our final design with an analytical approach from all sides.

5.2 Description of Solution

The solution we implemented was the Lever Arm Generator. The Lever Arm Generator incorporates the principle of a lever arm as witnessed in a railroad handcar. The Lever Arm's pumping motion, instead of causing a railcar to move, causes a rotation about a generator axle thereby generating power. The following subsections break the final design down into its components and explain them in detail.

5.2.1 The Bicycle

The solution's main components are made up of an exhausted and barely functioning bicycle, Figure 5-1, and scrap bicycle parts including another frame and handlebars. Since a bicycle already has manufactured gears, bearings, a handlebar, a crank, and a support frame, it is the perfect starting off point.

Figure 5-1: Bicycle to modify into a handcar.

5.2.2 The Frame

The frame component is made up of stripped down and rearranged bicycle frames and parts. The front forks are replaced upright into the seat post position to provide a pivot axis for the pump lever, the pedal provides the pivot axis for the crank shaft, and the gears at the crank and rear cassette are used to drive the generator.

5.2.3 The Pump Lever

The middle pivot axis for the pump lever, Figure 5-2, is made up of a front bicycle wheel hub (A) with a quick release skewer for easy removal of the pump lever. Next, attached on top of the wheel hub is steel square bar material which becomes the main lever shaft (B) of the pump lever. Attached to both ends of the main lever shaft are two bicycle handlebars (C) that make up the handles for the pump lever. Offset from the center pivot axis on the main shaft is a bicycle pedal (D) attached to the bottom of the square bar. The pedal makes up the pivot axis for the crank shaft. The wheel hub and pedal are mounted to the main shaft with U-bolts driven through steel plates that are welded to the main lever shaft.

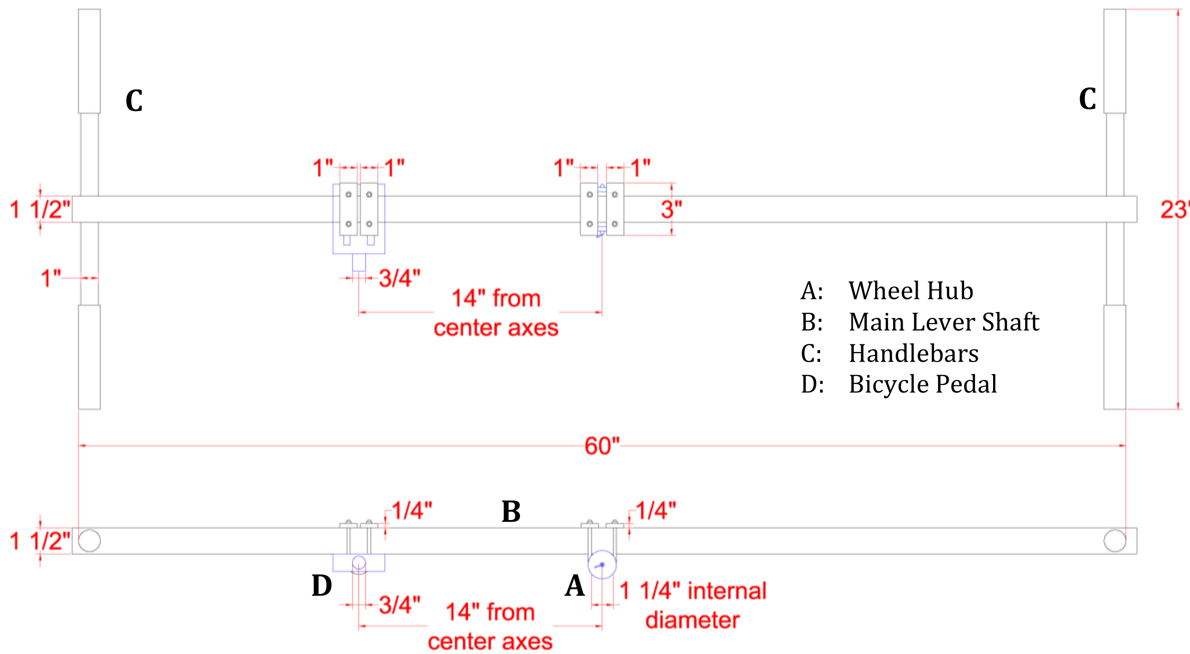


Figure 5-2: Pump lever (Illustration by Brandon Giordano).

5.2.4 The Crank Shaft

The crank shaft, Figure 5-3, is made up of steel round bar material that for the main crank shaft (A), and pedals attached to both ends thereby providing pivot points on both ends of the crank shaft. On one end of the crank shaft is a pedal (B) that was removed from a bicycle crank. The pedal still has some of its crank material still attached so that its external diameter is the same as the internal diameter of the round crank shaft. The crank part of the pedal is inserted into the main crank shaft and welded into place. On the other end of the crank shaft are two steel plates (C), one welded on to the shaft and the other held in place by bolts. The two steel plates and bolts enclose the remaining pedal still attached to the bottom bracket of the bicycle frame. These two pedals on the ends of the crank shaft connect the pumping motion of the lever to the rotating motion of the crank pedal.

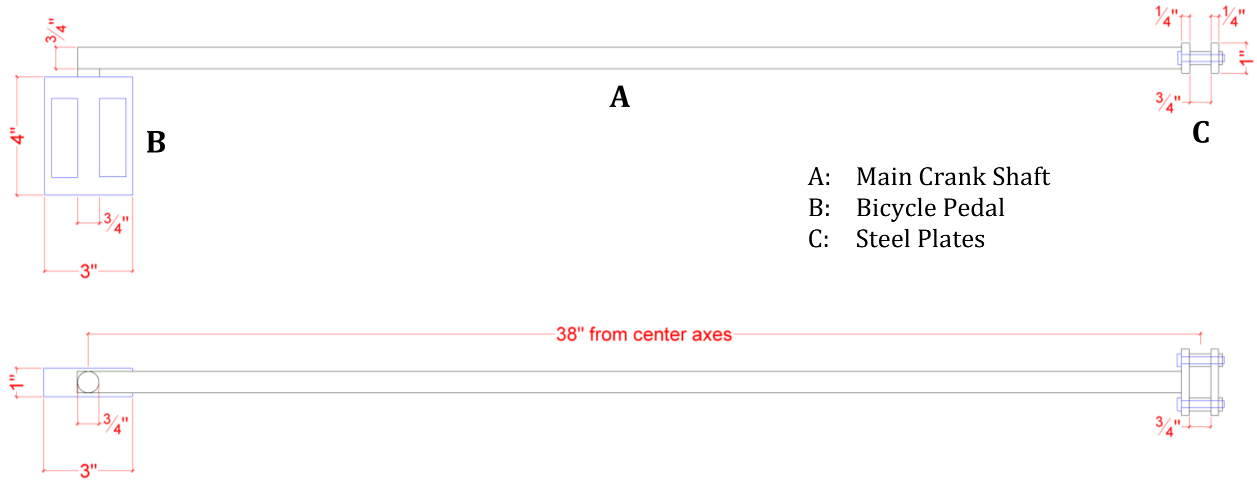


Figure 5-3: The crank shaft (Illustration by Alberto Jasso)

5.2.5 The Gearing

The mechanical power delivered to the generator is dependent upon the gearing of the system, Figure 5-4. The crank shaft is attached to the crank pedal (A) which drives a 40 tooth, or 40T, gear when the lever is pumped. The 40T gear is connected to, and drives, a 34T gear in a rear bicycle cassette by a primary bicycle chain (B). Next, a 14T gear on the cassette is driven when the 34T gear is driven. Thus, the 14T gear drives a 13T gear at the generator by a secondary bicycle chain (C). Finally, the generator is geared internally with a 9:1 ratio. Therefore, one full pump cycle at the lever causes a full revolution at the crank and to about 11.4 revolutions at the generator, according to the gear ratio noted in Figure 2-11.

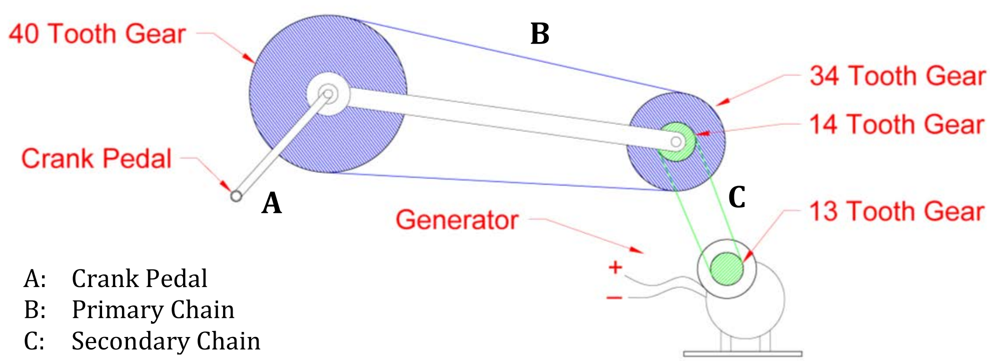


Figure 5-4: The gearing (Illustration by Luke Halonen)

5.2.6 The Electrical

The electrical section for the Pump'n Power generator is a simple circuit that consists of rectifier, fuse, charge controller, and a blocking diode. When the generator is turned, current flows from the generator and into a bridge rectifier. No matter which direction the generator rotates, the rectifier corrects the polarity of the current so that the flow of positive current goes in the correct direction. After the rectifier, the current passes through an 8 amp fuse to protect the charge controller from current overloads. Next, the charge controller conditions the current to flow at a steady rate by reducing spikes in current and protects the battery from overcharge. Finally, the current passes through a blocking diode to prevent a reverse current flow from driving the generator as a motor.

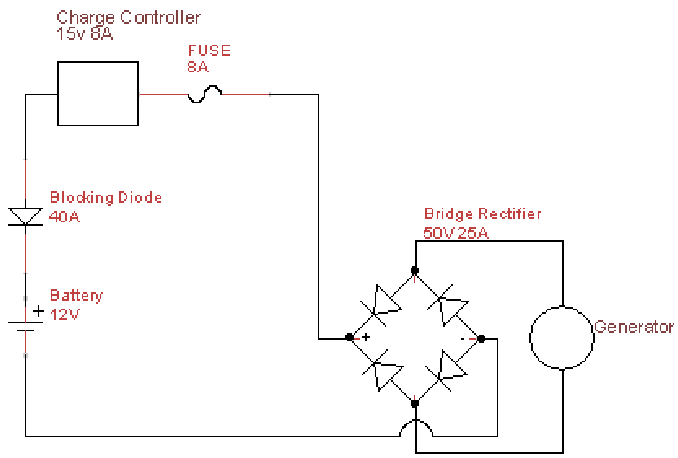


Figure 5-5: Wiring diagram (Illustration by Luke Halonen)

5.2.7 The Final Design

The Pump'n Power generator, Figure 5-6, utilizes kinetic energy from upper body strength to operate a railroad handcar style generator to produce electrical energy. A majority of the materials for the Pump'n Power generator came from the waste-stream, where all of the vital rotating points are repurposed bicycle components. The main pivot point of the pump lever is a wheel hub with quick release attachment, and the pivot points of the crank shaft are made up of bicycle pedals. Thus, by utilizing retired bicycle components, fabrication of the Pump'n Power design is simplified by harnessing already fabricated parts.

The Pump'n Power generator is made up of a pump lever, a crank shaft, a rearranged bicycle frame, and a simple generator system. The pump lever drives a crank shaft connected to a pedal and gear on the lower portion of the recycled bicycle frame. The rear tire gear has two chains connected to it, one to the pedal gear and the other to the generator. The generator is mounted to the lower structure of the bicycle support piece. From the generator a charge controller along with a blocking diode are then connected to a battery or small electronic load.

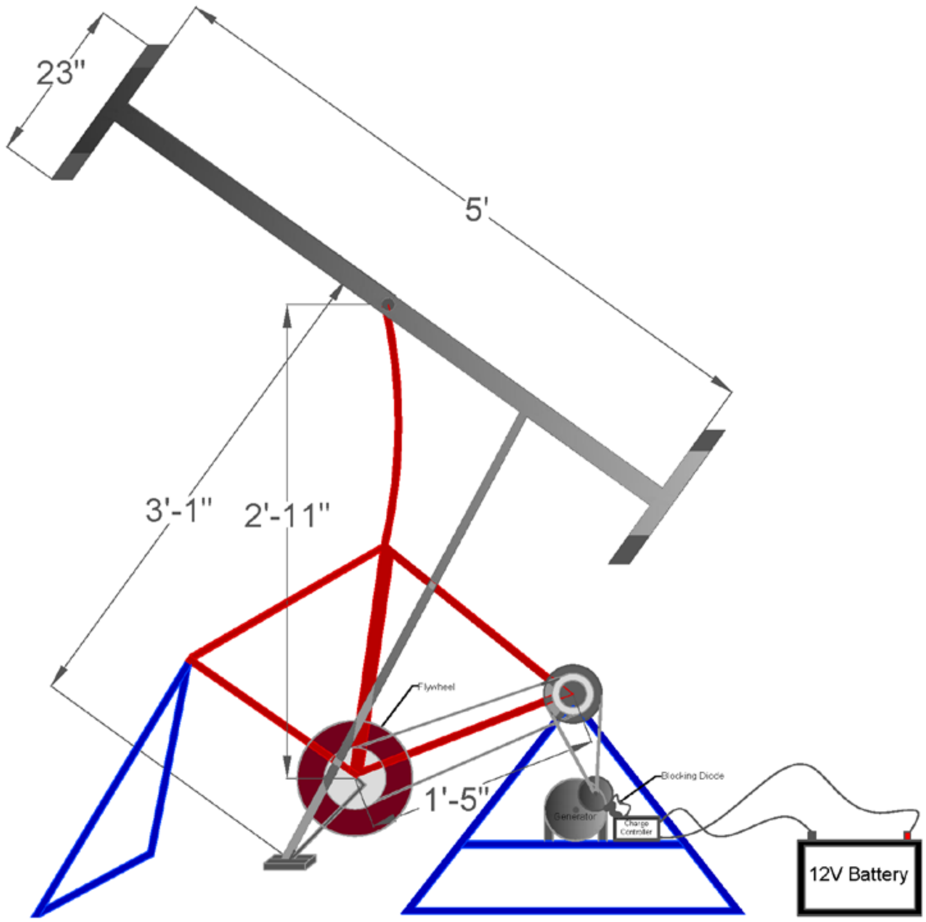


Figure 5-6: Final design (Illustration by Baron Creager)

Figure 5-7: Final design (Photo by Luke Halonen)

5.3 Cost Analysis

The Cost Analysis consists of Cost of Materials, Design Costs, and Maintenance Costs.

5.3.1 Cost of Materials

Table 5-1 below indicates the cost of materials incurred in the research, development, and design of the Lever Arm Generator. Since some of the materials were donated, a retail cost projection for those materials was made to provide a more accurate assessment of the final cost. The total actual cost for the Pump'n Power design was $290.65, with a projected retail cost of $460.65.

Table 5-1 Materials Costs: Materials used, their costs, and their retail costs in the case of donations.

Material	Quantity	Our Cost	Subtotal	Retail Cost	Subtotal
Aluminum "L" Brackets	2	$0.50	$1.00	$0.50	$1.00
Aluminum Frame	1	$10.00	$10.00	$10.00	$10.00
Aluminum Poles	4	$2.25	$9.00	$2.25	$9.00
Bar, Round, Steel 3/4" x 5'	1	$5.51	$5.51	$5.51	$5.51
Bar, Square, Steel 1-1/2" x 6'	1	$18.94	$18.94	$18.94	$18.94
Bicycle	2	Donated	$0.00	$60.00	$120.00

Bicycle Components	Total	Donated	$0.00	$10.00	$10.00
Blocking Diode	1	$9.45	$9.45	$9.45	$9.45
Chain Tool	1	$16.19	$16.19	$16.19	$16.19
Charge Controller	1	$32.98	$32.98	$32.98	$32.98
Extension Cord	1	$5.93	$5.93	$5.93	$5.93
Fuse Holder	1	$3.23	$3.23	$3.23	$3.23
Fuses, 8A, Pack of 4	1	$3.45	$3.45	$3.45	$3.45
Gear, 13 tooth, splined	1	Donated	$0.00	$5.00	$5.00
Hand Grips (set of two)	2	$11.25	$22.50	$11.25	$22.50
Hardware (nuts, bolts, washers)	Total	$51.30	$51.30	$51.30	$51.30
Hub Axel	1	$3.00	$3.00	$3.00	$3.00
Motor, 24V, 350W, 8.9A	1	$63.00	$63.00	$63.00	$63.00
Motor, Used (misc ratings)	2	$3.00	$6.00	$3.00	$6.00
Plate, Aluminum, 6" x 6" x 1/2"	1	Donated	$0.00	$10.00	$10.00
Plate, Stainless Steel, 13" x 21"	1	$5.00	$5.00	$5.00	$5.00
Plate, Stainless Steel, Sample	1	$1.00	$1.00	$1.00	$1.00
Plexiglass, 3' x 3'	1	$4.00	$4.00	$4.00	$4.00
Rectifier, 50V 25A	1	$3.77	$3.77	$3.77	$3.77
Spray Paint, Rustoleum Primer	1	$4.84	$4.84	$4.84	$4.84
Steel Endcaps	2	$2.39	$4.77	$2.39	$4.77
Steel Spacers	5	Donated	$0.00	$1.00	$5.00
Weight, Disc, 10lb	1	Donated	$0.00	$10.00	$10.00
Wire, Red and Black, 3' Each	2	$1.29	$2.57	$1.29	$2.57
Wood Scraps	1	Donated	$0.00	$10.00	$10.00
Wood, 2" x 2" x 8"	2	$1.61	$3.22	$1.61	$3.22
		Totals:	**$290.65**		**$460.65**

5.3.2 Design Costs

The design costs represent the amount of time Team Excergy took to implement the final design. The team as a whole spent a total of 499 hours on the project. Figure 5-8, below indicates the distribution of hours spent on each section of the project.

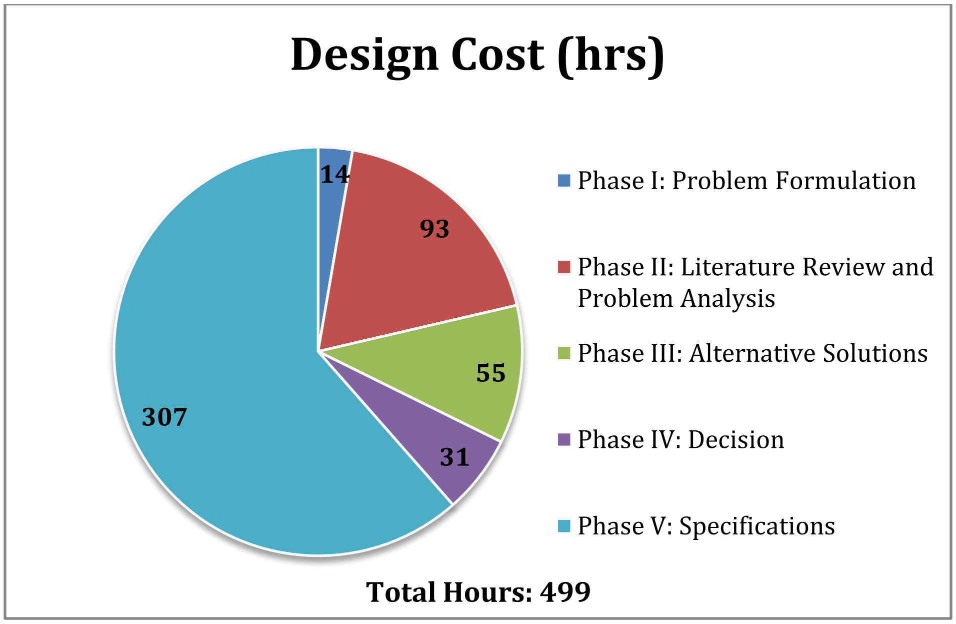


Figure 5-8 Design Costs: Illustrates the distribution of hours on each phase of the design process.

5.3.3 Maintenance Costs

Maintenance of the Lever Arm Generator is required to ensure its functionality over extended periods of time. Table 5-2 illustrates projected maintenance requirements for the Pump'n Power generator, their frequency, and the projected cost of each maintenance task in hours.

Table 5-2: Maintenance Costs: This table illustrates the maintenance costs in number of minutes per task.

Maintenance Task	Frequency	Time (hrs)
Inspect and tighten bolts.	Weekly	0.25
Inspect and oil chains.	Weekly	0.25
Inspect electrical components for moisture.	Weekly	0.25
	Monthly Total:	**3.00**

5.4 Instructions for Implementation and Use of Model

The finished product of the Lever Arm Generator is can be used in two ways. First, small appliances can be directly hooked into the female end of the cable connected to the generator thus powering each item individually. Second, the Lever Arm Generator can be used to charge a battery to store power for later use.

Proper usage of the Pump'n Power generator can be achieved by one or two people by stationing themselves in front of the pump lever and applying an up and down force on the pump lever to start power generation. When operator(s) stops pumping the lever, power generation stops.

5.5 Results

For the final testing of the Pump'n Power generator, the system is hooked up to a multimeter. The pump lever arm can be operated by one or two people to start generation.

As the gears rotate, electrical energy is produced and sent through the leads of the multimeter. The multimeter is used to measure how much energy is being produced and the light bulb presents a physical representation of energy generation.

With a gear ratio of 1.629 to 1 and an achievable rotational speed of 60rpms at the crank pedal, the Pump’n Power generator is able to easily produce over 8 volts and a range of 5-8 amps. With these ratings, the Pump’n Power is able to produce a minimum of approximately 40 watts during generation. This meets our original criteria set and is able to easily power the interior LED lighting of the Flock House, as well as small electronic devices such as cell phones or add additional surplus to a battery supply with an improved gear ratio. With a higher gear ratio, the minimum of 13 volts can be achieved, allowing the Pump’n Power to charge a generic 12 volt battery. If the generator is used at 12 volts and approximately 6 amps, the Pump’n Power is able to generate 72 watts. If this generation was maintain for an average of 6 hours a day, the Pump’n Power could supply the Flock Pod with 432 watt-hours daily and 3024 watt-hours weekly.

With the current gear ratio, this allows for easier use by the operator and already meets our original criteria of having a minimum generation of 50 watts.

Appendices

A. References

AENews Network (2006). "Foot Powered Generator from Freeplay Energy." *Alternative Energy News Network,* <http://www.alternative-energy-news.info/foot-powered-generator-freeplay-energy/> (Dec. 3, 2011).

Airstream Life (2008). "Human Power!" <http://tour.airstreamlife.com/wordpress/?p=1499>

Arseneau, S. (2011) "MWF Morphing Handcycle Project Blog" Posterous, <http://morphhc.posterous.com/new-blog-post-morphing-handcycle-reference-de#> (Sept. 24, 2011).

Barnett, C. (1996). "Relationship between gear ratio and 10-s sprint cycling on an air-braked ergometer." *European Journal of Applied Physiology* 72(5), 509-514.

Bowes, P. (2009). "A gym powered by sweat and tears." *BBC*, <http://news.bbc.co.uk/2/hi/technology/7796215.stm> (Sep. 23, 2011).

Energy Quest (2011). "Turbines, Generators and Power Plants." <http://www.energyquest.ca.gov/story/chapter06.html> (Nov. 20, 2011).

Human Dynamo (2011). "Fitness + Energy." <http://www.humandynamo.com/index.html> (Sep. 23, 2011).

Jansen, A.J. and Stevels, A.L.N. (1999). "Human power, a sustainable option for electronics." *Delft University of Technology*, *Design for Sustainability* (DFS)

Kelly, D. (2007). "Renewables- Wind Energy". *Railroad Commission of Texas*, <http://www.energyeducation.tx.gov> (Sep. 25, 2011).

Kramer, C., Hilker, L., Bohm, H. (2009). "Influence of crank length and crank width on maximal hand cycling power and cadene." Springer-Verlag, *Eur J Appl Physiol* < http://www.springerlink.com/content/9m011843893t833l/fulltext.pdf > (Sep. 24, 2011).

LTGovernors (2011). "Photovoltaic Equipment." <http://energy.ltgovernors.com/photovoltaic-equipment.html> (Nov. 20, 2011).

MathWorks (2011). "Planetary Gear." <http://www.mathworks.com/help/toolbox/physmod/drive/planetarygear.html> (Nov. 20, 2011).

Morrison, T.R. (1999). "Pedal power sensor and human powered vehicle drive augmentation responsive to cyclic pedal power unit." *U.S. Patent,* [57] 11-12.
Nikolaidis, E. (2005). "Gears Review." *University of Toledo* <www.eng.utoledo.edu/~enikolai/3300-files/Gears-review.ppt> (Nov. 20, 2011).

Pilloton, E. (2007). "Cyclean Bike Powered Washing Machine." <http://inhabitat.com/cyclean-bike-powered-washing-machine/> (Oct. 14, 2011).

PowerMasters (2003). Gear Ratios. **<**http://www.powermasters.com/gear_ratios.html> (Nov. 20, 2011).

Saez, M.L. (2004). "Energy Harvesting from Passive Human Power." *Electronic Engineering Ph.D. Thesis*, 3(3.1), 15-16.

Serway, R. A. and Jewett, J.W. Jr. (2008). "Rotation of a Rigid Object about a Fixed Axis." *Physics for Scientists and Engineers with Modern Physics."* 7th ed., Brooks/Cole, Belmont, CA. 269–274.

Society of Robots (2012) "Actuators-How to Waterproof a Servo" Society of Robots, <http://www.societyofrobots.com/actuators_waterproof_servo.shtml> (Sept. 22, 2011).

Starner, T., and Paradiso J.A. (2004) "Human Generated Power for Mobile Electronics." *Low Power Electronics*, *CRC Press*, 1-35.

U.S. Department of Energy. (2011). "Equipment required for stand-alone systems." *U.S. Department of Energy*, <http://www.energysavers.gov> (Sep. 25, 2011).

U.S. Department of Energy. (2011). "Substation Equipment: Rectifiers." *U.S. Department of Energy,* < http://www.osha.gov> (Nov. 30, 2011).

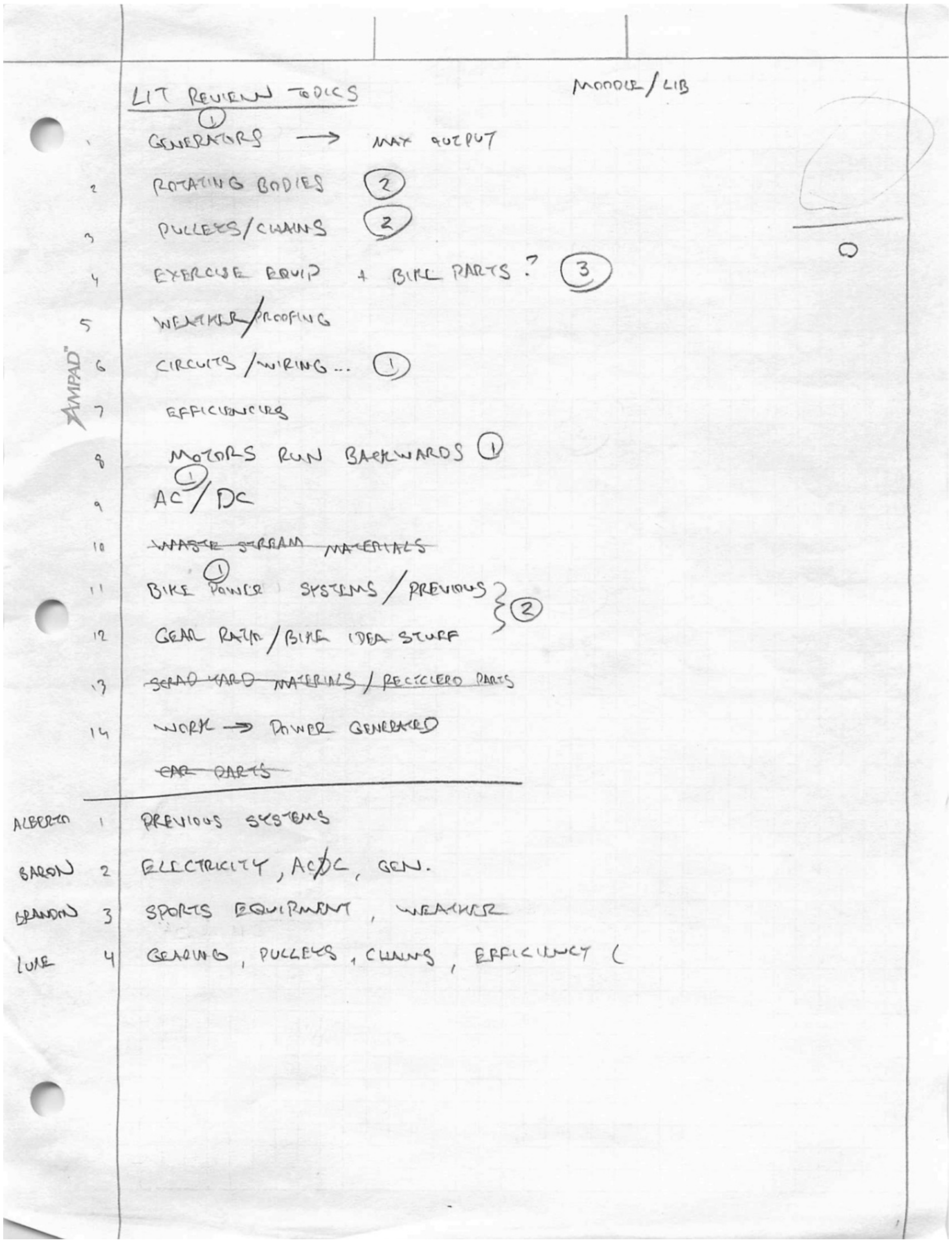
Department of Electrical Engineering and Computer Science. (2011). "Diodes: A Tutorial." *Department of Electrical Engineering and Computer Science*, <http://www.eecs.tufts.edu> (Nov. 30, 2011).

WindStream Power (2011). "Hand Cranks." <http://www.windstreampower.com/sp_Hand_Cranks.php> (Sep. 25, 2011).

Wolfe, J. (2007). "The Physics of Blocks and Pulleys." *University of New South Wales, Physics,* <http://www.phys.unsw.edu.au/~jw/blocks.html>(Sep. 23, 2011).

Youssefi, K. (2006). "Gears Kinematics." *San Jose State University, Mechanical Engineering,* <www.engr.sjsu.edu/youssefi/me157/notes/Gears%20Kinematics.ppt> (Sep. 22, 2011).

B. Brainstorm Notes



LIT REVIEW TOPICS MOODLE / LIB

1 GENERATORS (1) → MAX OUTPUT
2 ROTATING BODIES (2)
3 PULLEYS/CHAINS (2)
4 EXERCISE EQUIP + BIKE PARTS ? (3)
5 WEATHER/PROOFING
6 CIRCUITS /WIRING... (1)
7 EFFICIENCIES
8 MOTORS RUN BACKWARDS (1)
9 AC/DC (1)
10 ~~WASTE STREAM MATERIALS~~
11 BIKE POWER (1) SYSTEMS / PREVIOUS } (2)
12 GEAR RATIO / BIKE IDEA STUFF
13 ~~SCRAP YARD MATERIALS / RECYCLED PARTS~~
14 WORK → POWER GENERATED
~~CAR PARTS~~

ALBERTO 1 PREVIOUS SYSTEMS
BARON 2 ELECTRICITY, AC/DC, GEN.
BRANDON 3 SPORTS EQUIPMENT, WEATHER
LUKE 4 GEARING, PULLEYS, CHAINS, EFFICIENCY (

Figure 5-9: Literature review brainstorm (9/20/11)

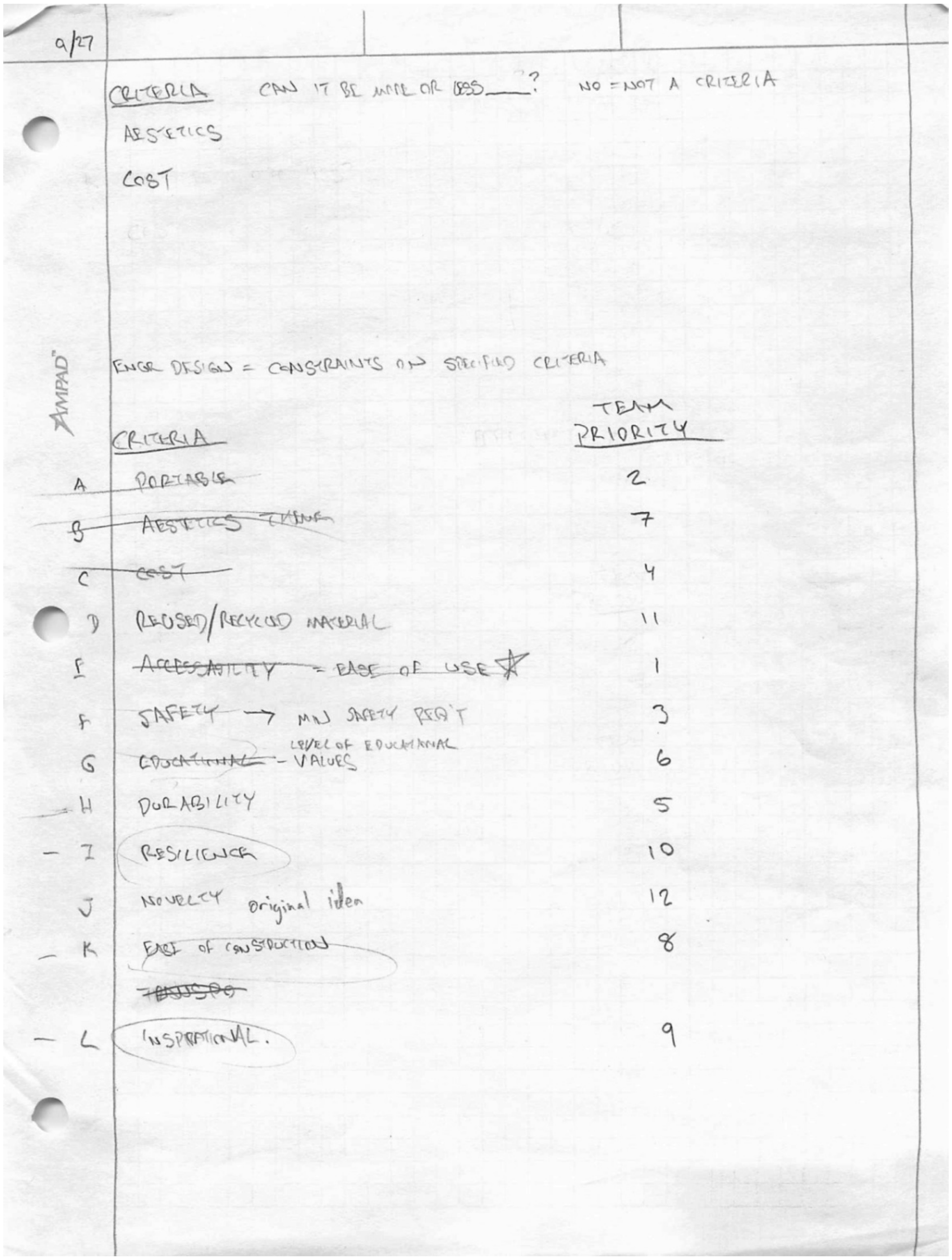


Figure 5-10: Criteria brainstorm (9/27/11)

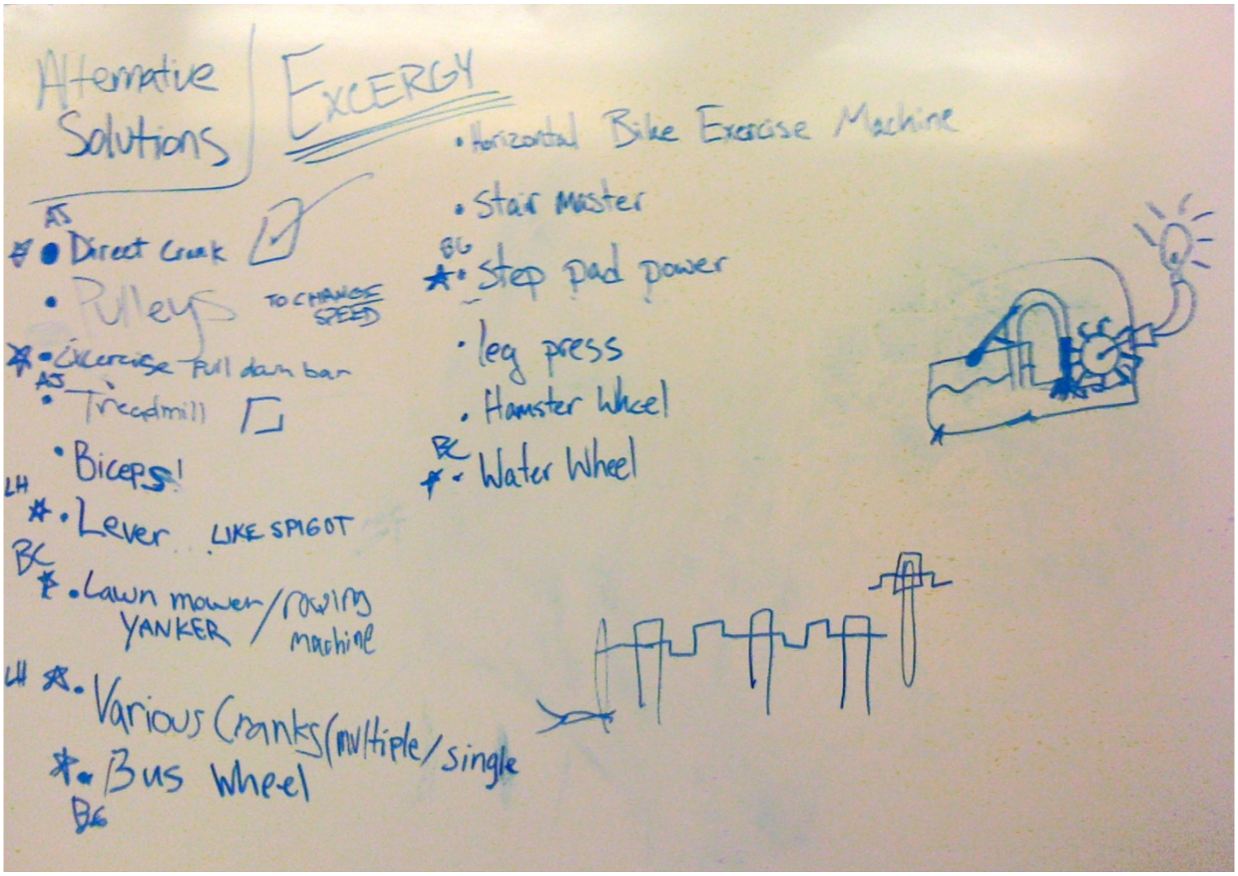


Figure 5-11: Alternative solutions brainstorm (10/2/11)

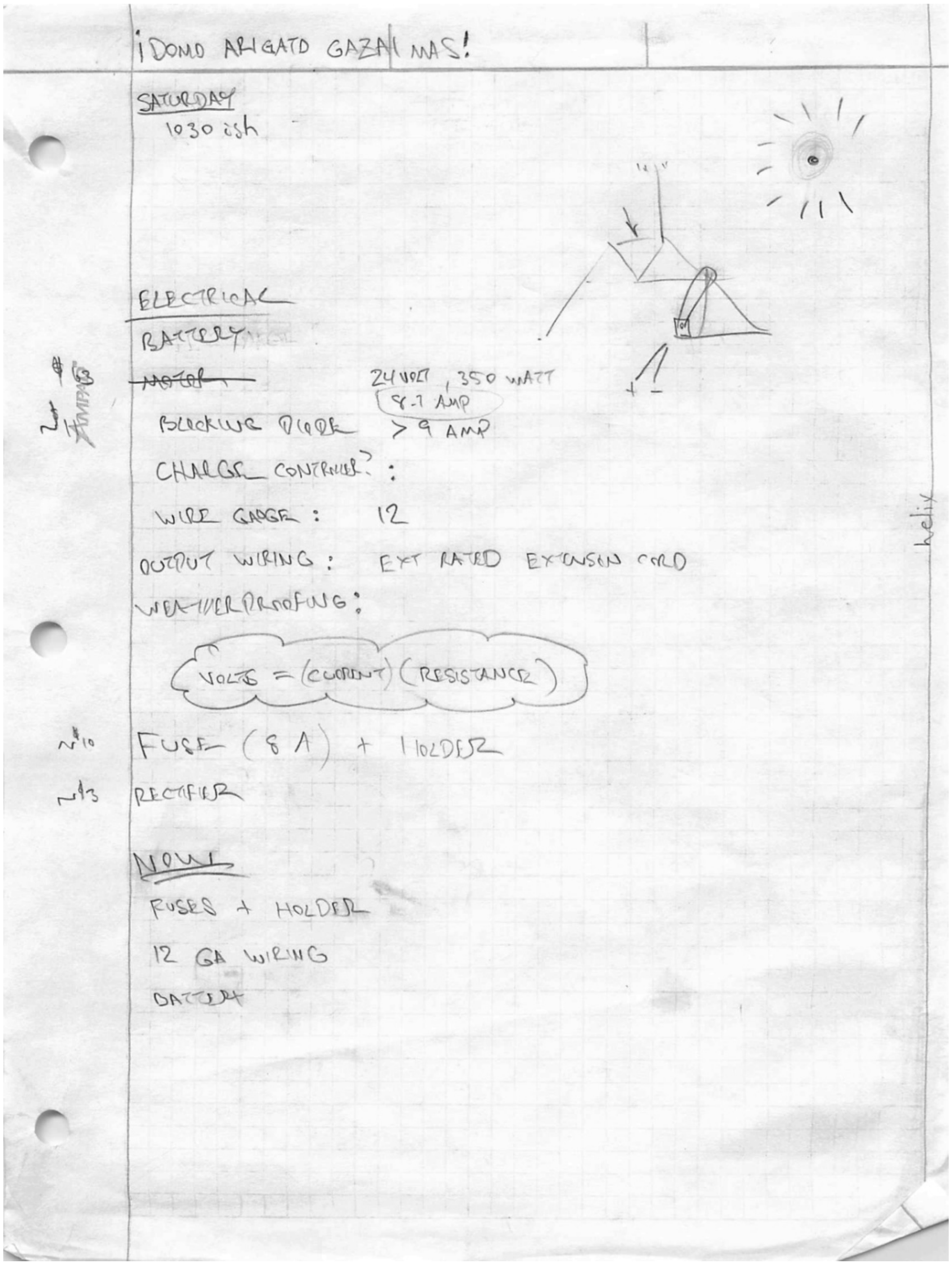
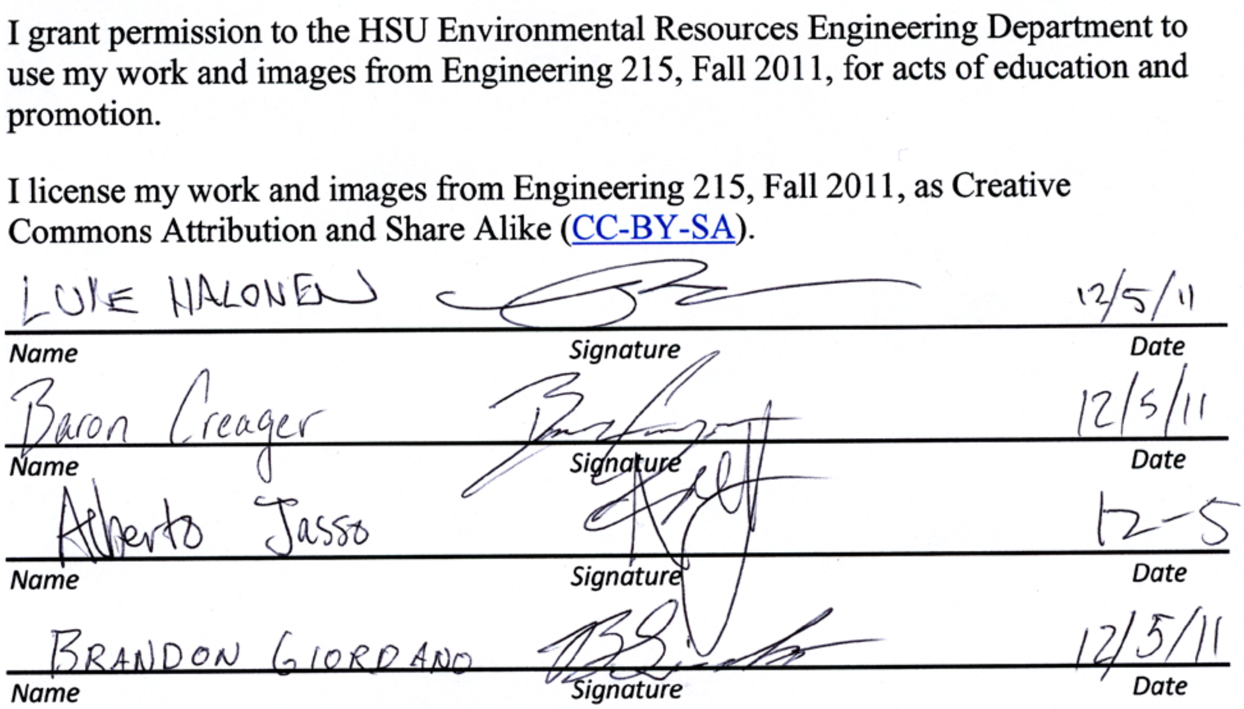


Figure 5-12: Electrical brainstorm (11/11/11)

C. Copyright

Team Excergy and the Pump'n Power:



I grant permission to the HSU Environmental Resources Engineering Department to use my work and images from Engineering 215, Fall 2011, for acts of education and promotion.

I license my work and images from Engineering 215, Fall 2011, as Creative Commons Attribution and Share Alike (CC-BY-SA).

Name	Signature	Date
LUKE HALONEN		12/5/11
Baron Creager		12/5/11
Alberto Jasso		12-5
BRANDON GIORDANO		12/5/11

Figure C-1: Authors' copyright permission