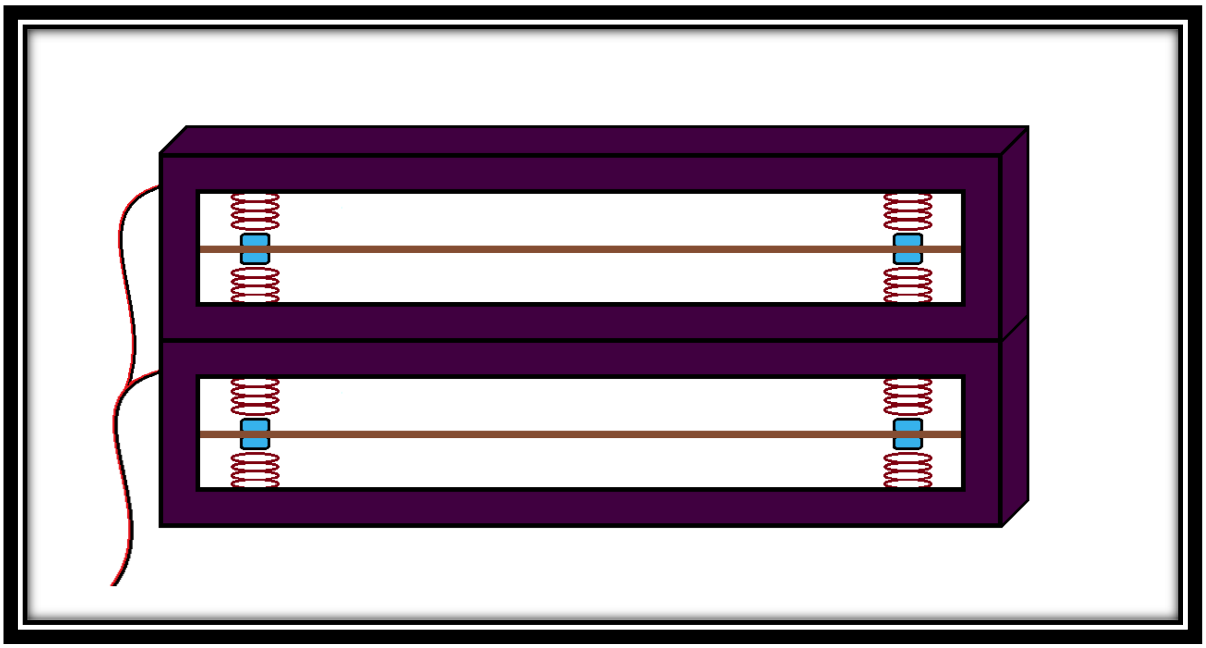
THE BUZZARDS

The Samoa Hostel Windbelt



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1 Problem Formulation

1.1 Introduction

The objective of this project is to create an array of wind belts that will charge USB devices as well as educate and inspire occupants of the Samoa Hostel about alternative wind energy systems.

1.2 Black Box Model

The black box model in Figure 1-1 illustrates how the world will be affected both before and after the implementation of the final product.

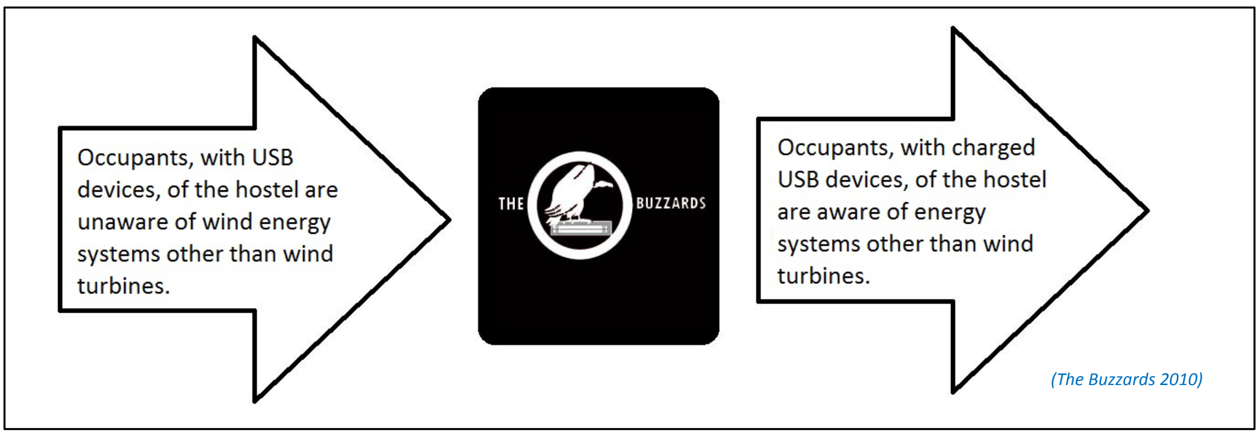

Figure 1-1 Black Box

This Black Box Model shows the affect that the final product will have on the world

2 Problem Analysis and Literature Review

2.1 Introduction

The Problem Analysis and Literature Review examine the different variables concerning the design of a windbelt for the Samoa Hostel.

2.2 Problem Analysis

2.2.1 Introduction

The Problem Analysis section examines and presents specifications, considerations, constraints and concerns that are applicable to building a successful windbelt.

2.2.2 Specifications & Considerations

A number of specifications and considerations needed to be created in order to evaluate the most important and considerable aspects when designing the windbelt.

2.2.2.1 Specifications

Specifications are predetermined aspects that must be met by the design.

- Appearance: Client must find the unit professional looking and aesthetically pleasing
- Safety: Cannot damage the device being charged or harm the user
- Code: Must meet applicable building code
- Display: Must have a display for the amount of current being delivered to the USB port
- Interpretive Qualities: Residents must understand how the electricity used to charge their USB devices is generated
- Voltage: The unit must be able to produce 5 volts in order to charge a USB device
- Power: The unit must be able to produce .4 watts in order to charge a cell phone, a common USB device, within a twelve hour period
- Loudness: Must not produce more than 30 decibels so it does not disturb residents

2.2.2.2 Considerations

There were several considerations that needed to be acknowledged during the design process. These considerations are not guidelines to the design, but they do inform on what should be considered when designing the windbelt in the specific location given.

- Residents: People will be residing in the hostel
- Purpose: The purpose of having a windbelt at the hostel is to help establish a direct relationship between people and their environment.
- Historical Aspect: The unit will be used and displayed in an area that is rich with the history of the lumber industry and Wiyot tribe.

2.2.3 Criteria & Constraints

A list of criteria and constraints, as seen in Table 1, were developed to recognize what characteristics and abilities the windbelt must possess or not possess.

Table 1 – Criteria & Constraints

Criteria	Constraint
Safety	The windbelt should be as safe as possible.
Power	The more power the windbelt produces, the better.
Effectiveness	The windbelt should be able to produce power as often as possible.
Build-ability	The windbelt should be as easy to build as possible.
Cost	The windbelt should be as inexpensive as possible.
Durability	The windbelt should last as long as possible.
Noise	The windbelt should make as little noise as possible.
Attractiveness	The windbelt should be as attractive as possible.

Design's Criteria and Constraints

2.2.4 Usage and Production Volume

A windbelt unit will be designed and built to be mounted on top of the Samoa cookhouse or on a pole nearby. It will produce adequate power and voltage to charge hosteller's USB devices. The windbelt unit will be in use when there is available wind.

2.3 Literature Review

Demand for renewable energy is driving the development of better wind technology and the growth of the wind power industry (Malhotra 2010). The windbelt is a new advent in the world of renewable energy (Ward 2010). The inventor, Shawn Frayne, originally created the windbelt in order to provide homes in third world countries cheap energy to power small appliances such as light bulbs and radios (Ward 2010). Windbelts are most appropriate in climates that have an abundance of wind, but cannot accommodate a wind-turbine due to size, or economical constraints (Ward 2010). The wind turbine is great for large scale wind-energy generation, but becomes extremely inefficient when implemented in small-scale situations (Ward 2010).

2.4 Client Specifications

On September 24th, 2010 The Buzzards met with the client liaison, Sean Armstrong, to discuss his specifications for the windbelt project (6a). Sean expects the following:

- Mounting: The belt apparatus will be permanently mounted outside. It can be mounted on the top of the hostel or on a pole. Roof mounting will allow the unit to be higher and possibly exposed to more wind, but pole mounting will ensure that the windbelt does not generate noise that disturbs the hostel occupants.
- Output: The energy generated by the windbelt will be used to power something small in the building (i.e. a cell phone charging station, Christmas lights etc.).
- Always On: The unit will not be turned on and off. As long as there is wind, the unit will be operating.
- Display: There should be a display that shows how much power is being produced and how much is being used at any given time.
- Safety: The windbelt should not damage any electronics it is being used to power or charge. A battery could help avoid this.
- Inverter: If used, an inverter should have the output specifications of 120v, 60 Hz, AC power.

2.5 Windbelt: The Mechanism of Action

The windbelt generates power by harnessing energy in wind. The windbelt is comprised permanent magnets attached to a belt, a coil, simple wiring, and a solid frame (Ward 2010).

Housed in a solid frame the belt, usually a teflon based material, oscillates a magnet between two coils, due to forces created by passing wind. The electricity generated by the coil and magnet is then harnessed with simple wiring.

2.6 Aeroelastic Flutter

Aeroelastic flutter is the vibration of an elastic body caused by an airstream (McGraw-Hill 2003). Blowing air across the reed of a saxophone to create sound waves is an example of using Aeroelastic flutter to change wind energy into sound waves. Shawn Frayne originated the idea to use this phenomenon to change wind energy into usable electrical power (Ward 2010).

2.7 Electricity

Matter that contains an electrical charge is either deficient in electrons and is positively charged or contains an excess of electrons and is negatively charged (Sams 2004). The objects charge is determined by the number of electrons in excess or deficiency (Sams 2004).

An atom of any matter can contain electrons (Sams 2004). Many metals contain a relatively large number of electrons that are free to move and are called conductors, because they allow electrons to move through them easily (Sams 2004). Nonconductors do not have many free electrons and are considered insulators, because they do not allow electrons to move through them easily (Sams 2004).

2.8 Voltage

Voltage is defined as the electric potential energy per unit of charge and is measured in volts or joules per coulomb. (Nave 2010)

2.9 Current

Current is the flow of electrons from a negatively charged point to a positively charged point and is measured in Amperes (Sams 2004). The two different types of current are direct current and alternating current.

Direct current (DC) maintains a steady flow of electrons in one direction, while alternating current (AC) reverses its direction and continually changes its voltage (Sams 2004). Direct current is generally better suited for smaller appliances, while alternating current is best used as a way to transport electricity over long distances with power lines, or for larger appliances that contain motors (Sams 2004).

2.10 Generation

Michael Faraday discovered that a changing magnetic field can create an electrical current in a circuit in 1831 (Britannica 2002). The windbelt takes advantage of this discovery by using the fluttering belt to move a magnet in and out of a coil and produce current in it.

2.11 Coils

A coil is one or more loops of conductive wire. It can be hollow or wrapped about a core, which in most cases is a ferromagnetic material. According to Faraday's law voltage is produced when a coil is moved through a magnetic field or vice versa (Nave 2010). Voltage is produced whenever the "magnetic Environment" of the coil changes (Nave 2010).

2.12 Magnets

Magnets produce a magnetic field created by electric currents that cause a North Pole and a South Pole (Nave 2010). Rare earth magnets produce the strongest magnetic field compared to their mass (Nave 2010).

2.12.1 Neodymium

Neodymium magnets are very strong and cost roughly ninety percent less than other rare earth magnets including Samarium- Cobalt magnets (Nave 2010).

2.12.2 Samarium-cobalt

Samarium-Cobalt magnets are similar in power to neodymium; however, they are more expensive (Nave 2010).

2.13 Power

Power is the rate at which work is performed and is typically referred to in Watts (W) or Horsepower (hp). (Gary 2010). In terms of electricity it can be expressed as:

$$P=I*V$$

Where "P" stands for power, "I" stands for current, and "V" stands for voltage (Schieber 2010). Another relationship can be expressed as Power equals work divided by time (Gary 2010).

$$P=W/\Delta t$$

2.13.1 Power in wind

The power contained in wind can be found using the following equation (Hughes 2010):

P=1/2(air density*swept area*velocity cubed)

As velocity increases power also increases (Hughes 2010). To find the wind power density, or power/area (in watts/meters squared), divide both sides of the equation by the area (meters squared) (Hughes 2010).

2.14 Climate of Samoa, CA

Samoa is located on the North Coast of California. It has an average wind speed of eight miles per hour (which comes in from the North-Northwest direction), with an average monthly high of twelve miles per hour and an average monthly low of seven miles per hour (Table 2). Samoa's most windy months are from February to June, with April being the windiest month. Its average annual temperature is 52.7 F and its average annual precipitation is 39.28 inches (Table 3). (All data was taken from Murray Field, which is 3.5 miles away from Samoa). (Windfinder 2010)

Table 2 – Wind Data

Murray Field/Eureka (EUREKA)
Statistics based on observations taken between 8/2008 - 8/2010 daily from 7am to 7pm local time.

Month of year	Jan 01	Feb 02	Mar 03	Apr 04	May 05	Jun 06	Jul 07	Aug 08	Sep 09	Oct 10	Nov 11	Dec 12	SUM 1-12
Dominant Wind dir.													
Wind probability > = 4 Beaufort (%)	17	24	29	36	31	25	18	21	13	23	13	10	**21**
Average Wind speed (mph)	8	9	9	12	10	9	8	8	7	9	7	8	**8**
Average air temp. (°F)	51	51	51	50	55	57	55	59	59	57	53	48	53
Select month (Help)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year

Eureka Wind Data (Windfinder 2010)

Table 3 – Climate Data

EUREKA WSO CITY, CALIFORNIA (042910)

Period of Record Monthly Climate Summary

Period of Record : 7/ 1/1948 to 4/30/2010

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	54.4	55.5	55.5	56.4	58.7	60.8	62	63	63	61.1	58	54.8	58.6
Average Min. Temperature (F)	41.4	42.5	43	44.5	47.8	50.6	52.4	53.1	51.3	48.1	44.8	41.7	46.8
Average Total Precipitation (in.)	6.78	5.38	5.24	3.05	1.66	0.63	0.14	0.33	0.74	2.62	5.65	7.06	39.28
Average Total SnowFall (in.)	0.1	0.1	0	0	0	0	0	0	0	0	0	0.1	0.3
Average Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0	0

Percent of possible observations for period of record.
Max. Temp.: 99.8% Min. Temp.: 99.8% Precipitation: 99.8% Snowfall: 99.8% Snow Depth: 99.8%

Eureka Climate Data (Windfinder 2010)

2.15 **Other Projects**

2.15.1 Humdinger

Humdinger Wind Energy, LLC and president, Shawn Fayne were the original creators and developers of windbelt technology. The company developed several different models of windbelts. The microBelt is a small form-factor unit designed to power sensors that is about the size of a cell phone. The Windcell is approximately one meter long and can be used individually or in groups to generate 0.1kWh to 1kWh of power per month. Humdinger is currently looking for partners to manufacture and sell products based on their technology. (Humdinger 2010)

2.15.2 Energy In a Cinch

The Energy In a Cinch project was a design for the Redwood Coast Energy Authority (RCEA) to be used as a display to teach elementary and high school children about alternative energy. They left the windbelt components exposed to better explain how the machine worked and powered a LED with the current generated by their windbelt. The display had to be portable for use in different classrooms. (Johnson 2010)

2.15.3 Chiapas

In the summer of 2010, students from Humboldt State University designed a windbelt system for an organization named Otros Mundos in Chiapas, Mexico. Their goal was to create a windbelt costing less than $150 using local materials that would power telecommunications devices but were unable to generate enough power to do so. They instead focused on designing a system to demonstrate the concept. (Diaz 2010)

3 Search for Alternative Solutions

3.1 Introduction

The purpose of this section is to produce several alternate designs that will be evaluated using a specified list of criteria in Section IV. To do this the Buzzards held several brainstorming sessions. Different belts, generating apparatuses, and a wind channeling solution were all considered in different configurations. This section presents each design being considered as well as the strengths and weaknesses of each.

3.2 The Buzzer

The Buzzer windbelt design incorporates a more rigid oscillating body that is fixed to only one end of the frame. The wind causes the rigid body to flutter, moving the magnet up and down, and generating current by changing the magnetic field around the coil. The current passes out of the unit through a cable. Figure 3-1 shows the rigid belt system using a single magnet-coil combination, but another combination could be setup in similar fashion under the belt.

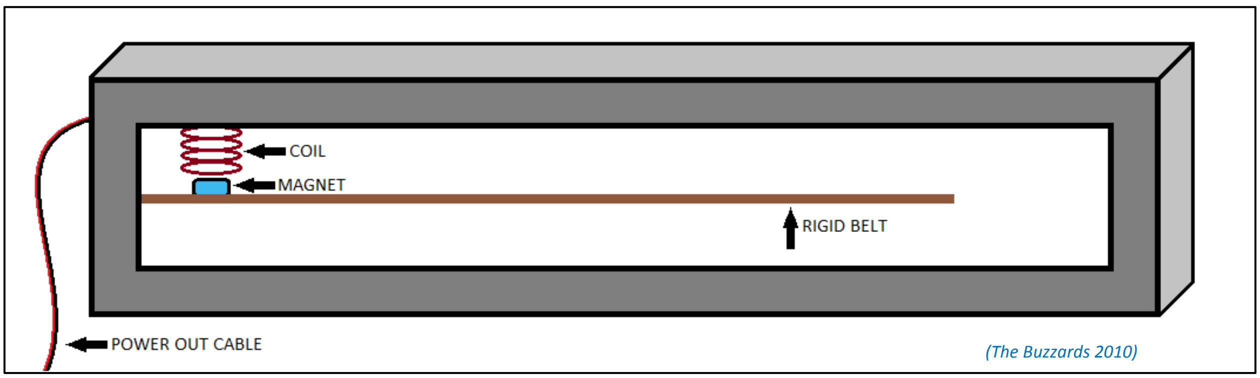

Figure 3-1 – The Buzzer

The "Buzzer" utilizes a rigid belt to flutter in the wind as opposed to the standard Mylar coated taffeta (fabric) belt.

The rigid belt in this system lasts longer than flexible material that must be connected at both ends and kept under tension in other designs. The rigid belt can also be made of inexpensive and easy to acquire materials, such as plastic or wood. Not having to attach the belt at both ends allows the system to be as much as half the size of other units. This makes it easier to build and less expensive. The Buzzer may produce more power than other designs.

The concern with this system is that it may make too much noise under normal operating conditions. Under high winds the loose end of the belt may even oscillate with enough amplitude to hit the unit's frame which in addition to being loud may introduce safety concerns, and decrease reliability.

3.3 Dynamic Coil

The Dynamic Coil system incorporates a flexible belt with a coil mounted on it. The wind causes the belt to flutter which changes the magnetic field around and in the coil by changing its distance to a magnet mounted above it. The current generated in the coil is passed out of the generating unit by means of the power out cable. Figure 3-2 shows the system with the coil and magnet mounted above the belt, but the coil and magnet could also be mounted below the belt in a similar fashion.

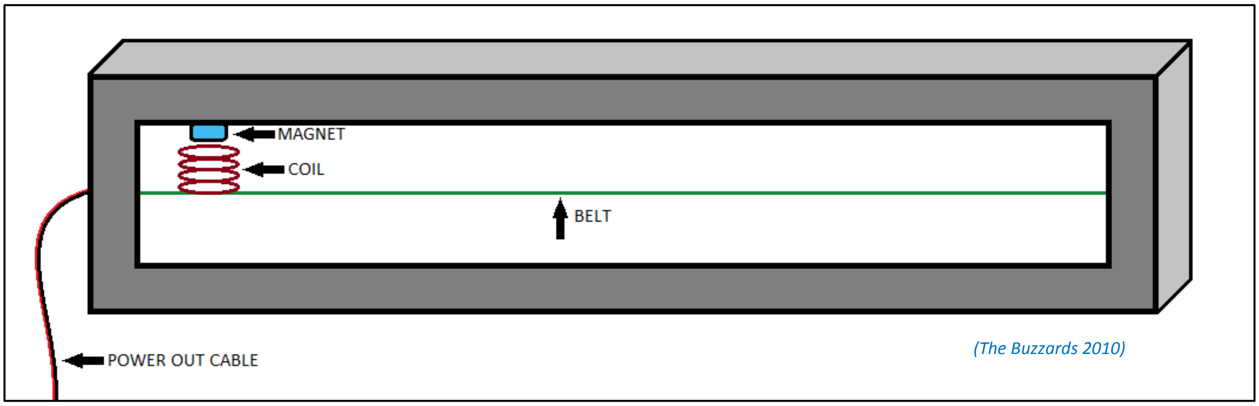

Figure 3-2 – Dynamic Coil

The Dynamic Coil design involves mounting the coil directly on the belt and mounting the magnet in a corresponding location on the frame.

The advantage to mounting the larger coil on the belt rather than the lighter magnet is that it will dampen the amount of flutter created in the belt and the unit does not make as much noise. However, reduced flutter means the unit produces less power. The Dynamic Coil system does not cost more or less than other options with comparable numbers of coil/magnet combinations. This design requires the belt to support more weight and be under greater tension than ones in other systems and thus may not last as long. Lastly, due to the coil being more difficult to secure to the belt as opposed to the frame this unit may be less durable, reliable and safe than other designs examined.

3.4 The One

The One design incorporates a magnet and coil combination on one end of the windbelt as shown in Figure 3-3. The magnets mount directly to the belt and moves in and out of coils mounted to a durable frame, generating power through a power-out cable. The magnet moves based on the tension of the belt it is mounted to and the speed of the wind.

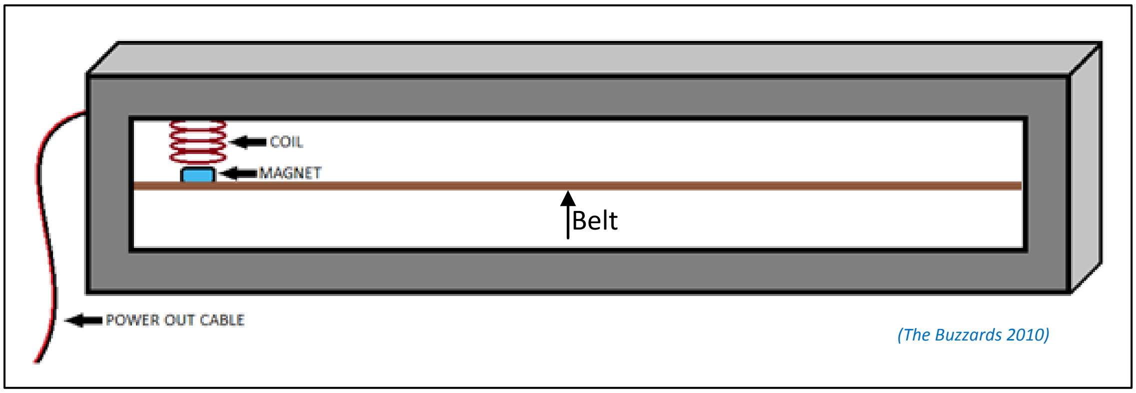

Figure 3-3 – The One

The One consists of a single one meter belt, one coil, one magnet, and a frame. This is the most basic windbelt design being considered.

The One, as shown in Figure 3-3, consists of a single one meter belt, coil, magnet, and a frame to hold it all together. Simplicity is the primary advantage of this design. This design represents the most basic windbelt and is the cheapest design. The One is very compact, and makes less noise than a design that incorporates more windbelts.

Noise, durability, and safety are not a concern with this design as they are with other designs such as The Buzzer. This design may not produce as much power as more complex designs, but it is more durable, simple, and costs less.

3.5 Single-end Mounted Coil(s)

The single end mounted coil design incorporates a magnet and coil combination on one end of the windbelt as shown in Figure 3-4. The magnets mount directly to the belt and moves in and out of coils mounted to a durable frame, generating power through a power-out cable. The magnet moves based on the tension of the belt it is mounted to and the speed of the wind.

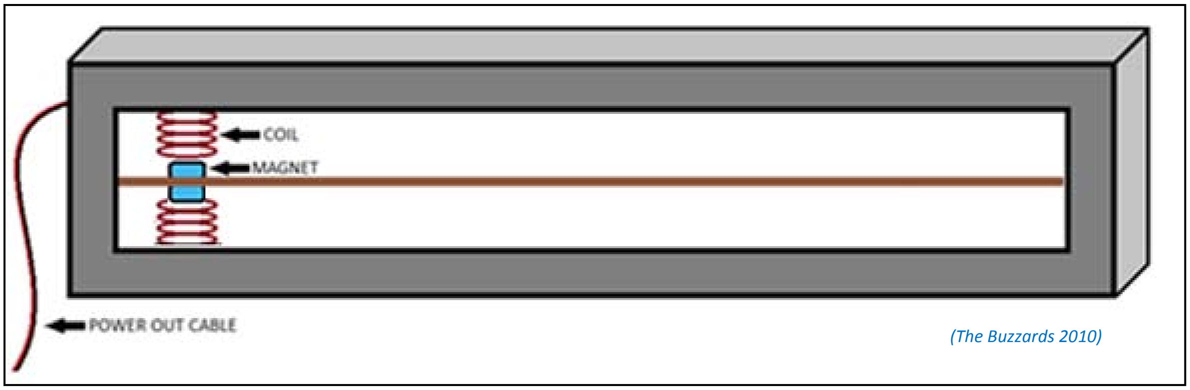

Figure 3-4 – Single-end Mounted Coils

The Single-end Mounted Coils utilizes two coils and two magnets that are both mounted on the same side of the belt.

The benefit of the single end mounted coil is that it would only require one or two coils per windbelt, making it cheaper, more reliable, and simpler to build; however, the weight being unbalanced on the belt could possibly limit the belts flex and ability to create the most power possible. Noise, safety, and durability would not be compromised (like in the more loud and dangerous Buzzer design.)

3.6 Dual-end Mounted Coil

The dual end mounted coil design incorporates dual mounted magnets and coils on both ends of the windbelt, as shown in Figure 3-5, which requires four coils and magnets. Magnets mount directly to the belt, on both ends, and passes through coils to generate power, which is fed through a power-out cable.

Figure 3-5 – Dual-end Mounted Coil

The Dual-end Mounted Coil design utilizes four coils and four magnets, one in every corner.

The advantage to the Dual-end Mounted Coil configuration is that coils on both sides of the windbelt create a weight balance on the windbelt. This allows the system to produce more power than a single-end mounted coil, because both ends of the belt are being utilized. However, the possible power and belt-tensioning advantage come at the cost of simplicity, possible noise increase from more components, and increased cost. Noise, safety, and durability would generally be unaffected (unlike the louder and more dangerous Buzzer design). The dual-end mounted coil design uses 4 coils per Windbelt, so it is more complex and time consuming to build.

3.7 The Generator

In this alternative solution, instead of putting the coil and magnet directly on the belt, the power is transferred through gears and a drive shaft which then turns a generator and produces Direct Current as shown in Figure 3-6.

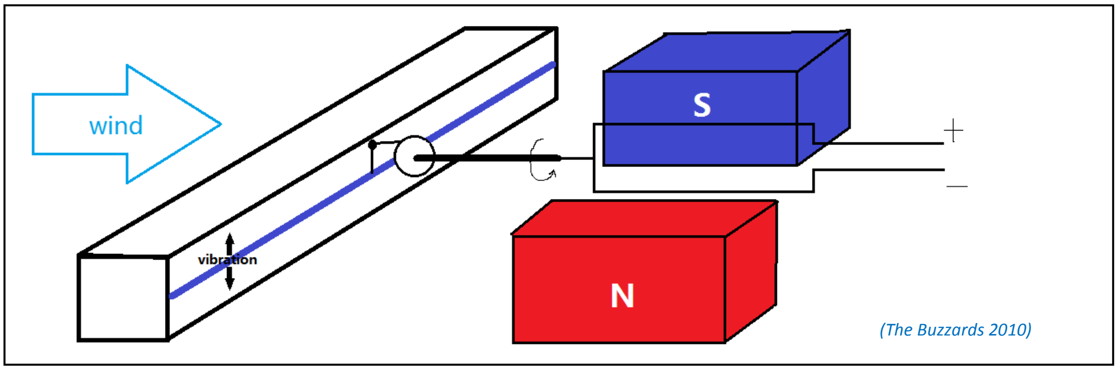

Figure 3-6 – The Generator

The Generator design converts aero-elastic flutter into rotational energy which is then converted to electricity.

The advantage of this solution is that it generates more power, because a drive shaft is connected to the middle of the belt, where the oscillation is greatest; however, this also disrupts the oscillation the most.

There are several disadvantages of this design. Firstly, it is more expensive than other designs because it utilizes the bigger magnets and coils. Secondly, this design is also noisier because the gearing produces noise in addition to the "humming" of the belt, which also indicates a loss of efficiency due to friction. Lastly, the gearing apparatus in combination with the rotating generator make this design more complex and more difficult to build than other designs. This design does not present any unique safety hazards in comparison to the other designs.

3.8 The FUNnel

The FUNnel design, as shown in Figures 3-7 & 3-8, uses an expanded entrance to direct more wind across an array of four windbelts. Each Windbelt consists of a one meter flexible belt with a magnet attached to it with a coil mounted onto the frame directly beneath each magnet.

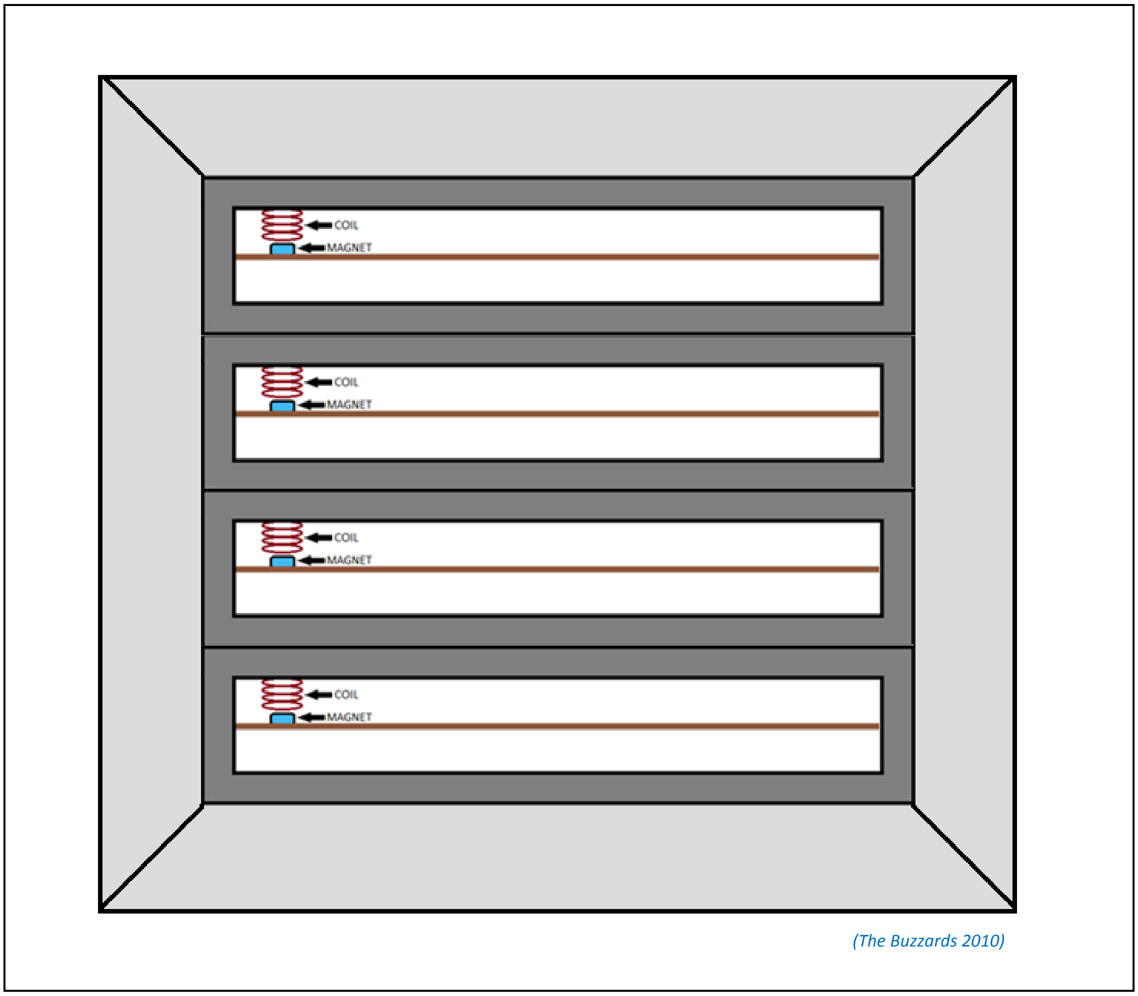

Figure 3-7 – The FUNnel

The FUNnel consists of an array of four windbelts with a funneling component.

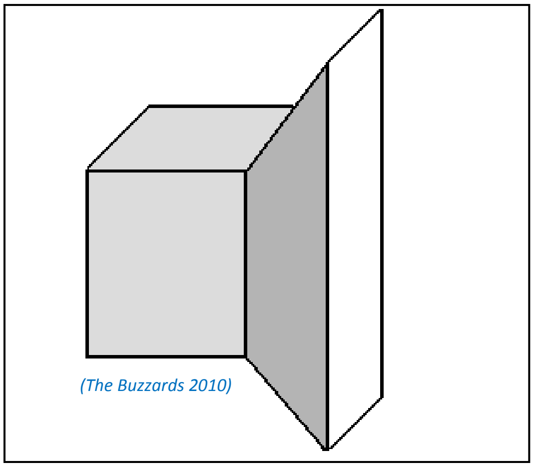

Figure 3-8 – The FUNnel

The FUNnel increases the effective surface area being swept by the wind.

The FUNnel design increases the airflow by channeling more air over the belts, and the array produces more electricity than it would if it did not utilize a Funnel. Thus, the device generates more power per Windbelt. As a result, fewer windbelts are needed to charge a cell phone and the cost of the entire unit costs less. This funneling component also allows the windbelt to generate usable electricity at a lower wind speed, making the entire system more effective. The funneling component of this design can be adapted to fit any windbelt or array of windbelts

However, this system does have some disadvantages. This device must be mounted securely to ensure the FUNnel does not get ripped from the roof (or pole), during high wind speeds, and become a safety hazard. This design incorporates four windbelts and a funnel and it is more complicated and expensive than a design including four windbelts without a funnel.

3.9 MultiBelt Windbelt

This alternative solution utilizes multiple smaller windbelts rather than one large windbelt to generate electricity as shown in Figure 3-9. This design assumes several smaller belts will produce more power than one large belt. There are some reasons for this assumption; the length of the Mylar coated taffeta belt may have a limitation, and the belt may break when the size is too large, because it bears more power from wind with the growing size. This alternative solution is superior in terms of price, because buying five smaller magnets is cheaper than buying one big magnet. Also, if one of the belt systems broke, there are four left and they will still create power. Alternative designs that only use a single belt are riskier because if they break they will no longer be able to produce electricity at all. This solution is as durable as the standard Windbelt design because it utilizes the same theory and construction techniques although it may take longer to build because of the multiple elements.

Figure 3-9 – The MultiBelt

The MultiBelt Design consists of an array of multiple windbelts stacked one on top of the other.

The main concern with this design is that it may be unsightly because it is larger than other designs and likely will have a more noticeable presence when mounted on a roof. This is partially due to the number of elements it contains and partially due to the way they are oriented (stacked on top of one another). It creates more power than a standard windbelt because multiple belt systems are applied. It has no unique safety concerns when compared to other windbelt configurations and designs.

4 Decision Phase

4.1 Introduction

Section 5 explains how a list of criteria was used to decide which alternative solution is the most appropriate. Each group member used the Delphi method to evaluate each criterion. Then, the Buzzards collectively decided how to weigh each criterion in order to select the most appropriate windbelt design for the hostel.

4.2 Criteria Definition

Section 5.2 lists eight criteria for evaluating windbelt alternative solutions.

- **Safety**: Safety entails the harm factor of the windbelt. The windbelt will be mounted on top of the Samoa hostel, so it should be secure. The windbelt will also produce electricity, so it shouldn't be able to shock anyone. The safer the windbelt is the better.
- **Power:** Power is the total DC electrical power output of the windbelt. The more power produced, the faster the USB devices will be able to charge, the better.
- **Effectiveness**: Reliability is how effective the windbelt is at turning available wind into electrical energy. Thus, the windbelt should produce power as often as possible.
- **Build-ability**: Build-ability refers to how difficult the windbelt is to build. The less difficult the windbelt is the better.
- **Cost**: Cost is the amount of money that is spent on the design and manufacture of the windbelt. The cost does not include mounting installation or maintenance. The windbelt has a total budget of $500, so the less money we spend the better. The less money spent the better.
- **Durability**: Durability entails how long the windbelt will last. The windbelt should last as long as possible. The longer it lasts the better.
- **Noise**: Noise refers to how loud the windbelt is. The less noise produced the better. The windbelt will be put above an hostel that will contain residents. The windbelt should produce as little noise as possible so it does not disturb residents and the client does not lose customers.
- **Attractiveness**: Attractiveness entails how professional and aesthetically pleasing the windbelt looks. The windbelt should look as professional and aesthetically pleasing as possible.

4.3 Solutions

Different windbelt variations were compared to determine the best design. The following eight variants were considered:

- The Buzzer
- Dynamic Coil
- The One
- Single-Side
- Dual-Side
- The Generator
- The FUNnel
- Multi-Belt

An in depth description of each solution can be found in Section Three.

4.4 Decision Process

Our group decided to use the Delphi Method in order to evaluate different windbelt designs. To start this decision process each member of our group came up with two original windbelt variations. We then made a diagram of our designs and explained them to each other. Next we individually weighed each criterion on a scale of 1 to 10, ten being the most important to the project's success. Then, we weighed all potential designs on a scale of 1 to 50, fifty being the highest score, according to how well they satisfied each criterion.

We then met as a group and came up with a consensus for the weights of each criterion we had come up with individually. This gave us a better understanding of how the criteria applied to the different solutions, and we collectively weighed them from 1-10, as seen in Table 4 (Power was weighted as 10, Durability as 6, Noise: 2, Cost: 6, etc.). Next, we discussed the potential designs and collectively agreed on how effectively each met the criteria and assigned a value from 1-50 to each potential design, according to how well they satisfied each criterion. The consensus based project criteria values, shown in the left side of the box under each project design heading in Table 4, were then multiplied by the criteria weight in order to numerically evaluate the potential designs and see which scored higher and was the most appropriate based on the criteria we established. The total score from this process, shown at the bottom of Table 4, were varied, but the two highest scoring were The One windbelt and The MultiBelt windbelt.

Table 4 – Delphi Chart

Criteria		Solutions							
List	Weight	The Buzzer	Dynamic Coil	The One	Single-Side	Dual-Side	The Generator	The FUNnel	The Multibelt
Power	10	25 / 250	10 / 100	25 / 250	35 / 350	30 / 300	10 / 100	50 / 500	50 / 500
Durability	6	35 / 350	10 / 100	45 / 450	40 / 400	30 / 300	10 / 100	30 / 300	35 / 350
Noise	2	5 / 10	45 / 90	35 / 70	25 / 50	45 / 90	10 / 20	20 / 40	25 / 50
Cost	6	40 / 240	45 / 270	45 / 270	35 / 210	15 / 90	10 / 60	35 / 210	35 / 210
Effectiveness	8	25 / 200	10 / 80	35 / 280	40 / 320	35 / 280	10 / 80	50 / 400	50 / 400
Safety	10	10 / 100	20 / 200	40 / 400	40 / 400	35 / 350	35 / 350	30 / 300	35 / 350
Attractiveness	6	25 / 150	25 / 150	30 / 180	30 / 180	30 / 180	5 / 30	35 / 210	35 / 210
Buildability	7	45 / 315	35 / 245	50 / 350	40 / 280	30 / 210	1 / 7	25 / 175	30 / 210
	TOTAL:	1615	1235	2250	2190	1800	747	2135	2280

The Buzzards' weight of each criterion, how well each solution satisfies them and each solutions score.

4.5 Decision

Based on the results of Delphi chart, The One windbelt and The MultiBelt windbelt scored the highest based on the criteria we established. However, we decided that we would design The MultiBelt windbelt. The MultiBelt windbelt was chosen over The One, because although they scored similarly on the Delphi method, the MultiBelt windbelt provides more design security as more windbelts can be added if a single windbelt does not provide adequate power. Thus, the MultiBelt windbelt will be designed for the Samoa Hostel, because it is the most appropriate design based on our established criteria.

5 Specification of Solution

5.1 Introduction

This section covers the final solution, The MultiBelt windbelt. Topics include the design specifications, a cost analysis, implementation instructions, and the results obtained.

5.2 Design specifications

5.2.1 Intro

The final design includes two stacked windbelts mounted using a satellite dish mount to the roof of the Samoa cookhouse. Each windbelt has a frame, belt, magnets, coils, and a tensioning device.

5.2.2 Frame

This system will be outside in the elements; therefore, weather resistant materials must be used in its construction. The frame is built from Purple Heart, a South American hardwood that is very strong and weather resistant. These properties make Purple Heart a suitable material to endure the wet and windy climate of the Samoa Hostel and constant tension from the belt. To ensure solid joinery, six pieces of wood were used for each frame as illustrated in Figure 5-1.

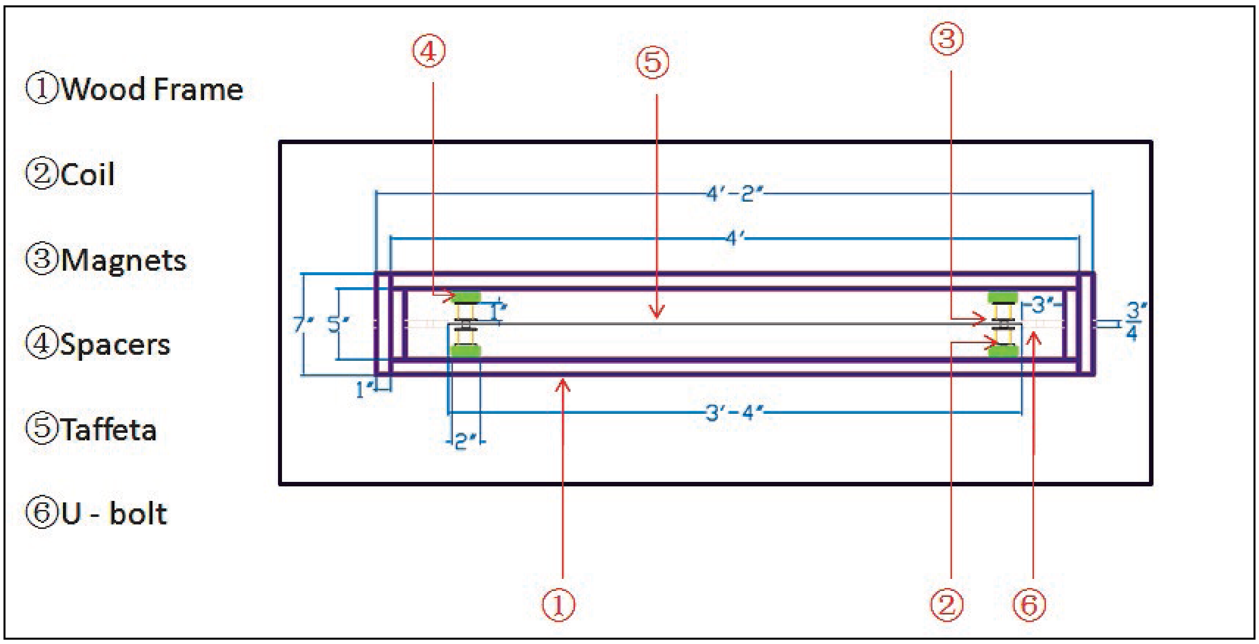

Figure 5-1 – Frame details

Showing the dimensions and components of a single wind belt.

5.2.3 Belt

The belt material is Mylar coated taffeta and measures 48” long by .59”wide making it a relatively large windbelt. Mylar coated taffeta is used because it has very low elasticity and it is light weight, which allows the belt to flutter well. The size of the belt allows for an increase in effectiveness at low wind speeds.

5.2.4 Tensioning Device

The belt must be under precise tension to maximize the frequency and amplitude produced by aero-elastic flutter; therefore, the tension of the belt must be adjustable. The tensioning devices are square U-bolts mounted with the bottom of the "U" outside the vertical end caps of the frame while the threaded regions pass through holes in the vertical end caps and into the interior of the frame. Each windbelt has one of these assemblies at each end. The belt is then attached to a clamp fitted to the U-bolts tightened by nuts. This system allows for easy adjustments to the belt tension from either end of the belt.

5.2.5 Magnets

A double stack of spherical N52 Neodymium magnets is mounted on the belt in all four corners as illustrated in Figure 5-2. Neodymium magnets are very strong in comparison to their weight, making them ideal for this application. The magnet mounted directly to the belt measures 5/8" in diameter by 1/8" tall and the smaller magnet measures 1/2" by 1/8".

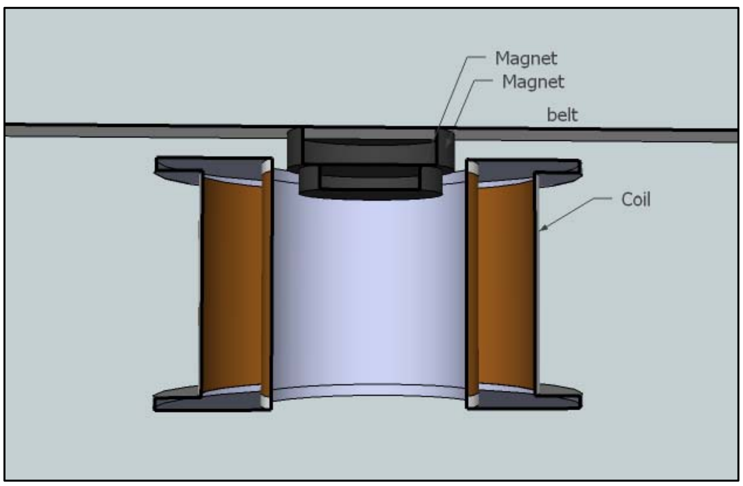

Figure 5-2 – Coil Cross Section

Shows coil and magnets mounted on belt.

Double stacking the magnets allows them to pass deeper into each coil, generating more power.

5.2.6 Coils

Each windbelt uses four coils, one for every stack of magnets. The coils measure 18mm tall by 35mm in diameter and contains 34 gauge magnet wire measuring 200 Ohms of resistance.

5.2.7 Charge Conditioning

Several electronic components convert the electricity generated by the windbelt into electricity that charges USB devices. First, the current must be converted from AC to DC, this is called rectification. The electricity generated by each coil is rectified independently using a full wave bridge rectifier. Each rectifier contains four 1A 20V Schottky diodes because they are more efficient than the typical diodes found in most rectifiers. The rectifiers are then wired in parallel to maximize amperage. Then, a voltage regulator is wired in series and keeps the output steady at 5VDC when there is ample wind as is shown in Figure 5-3.

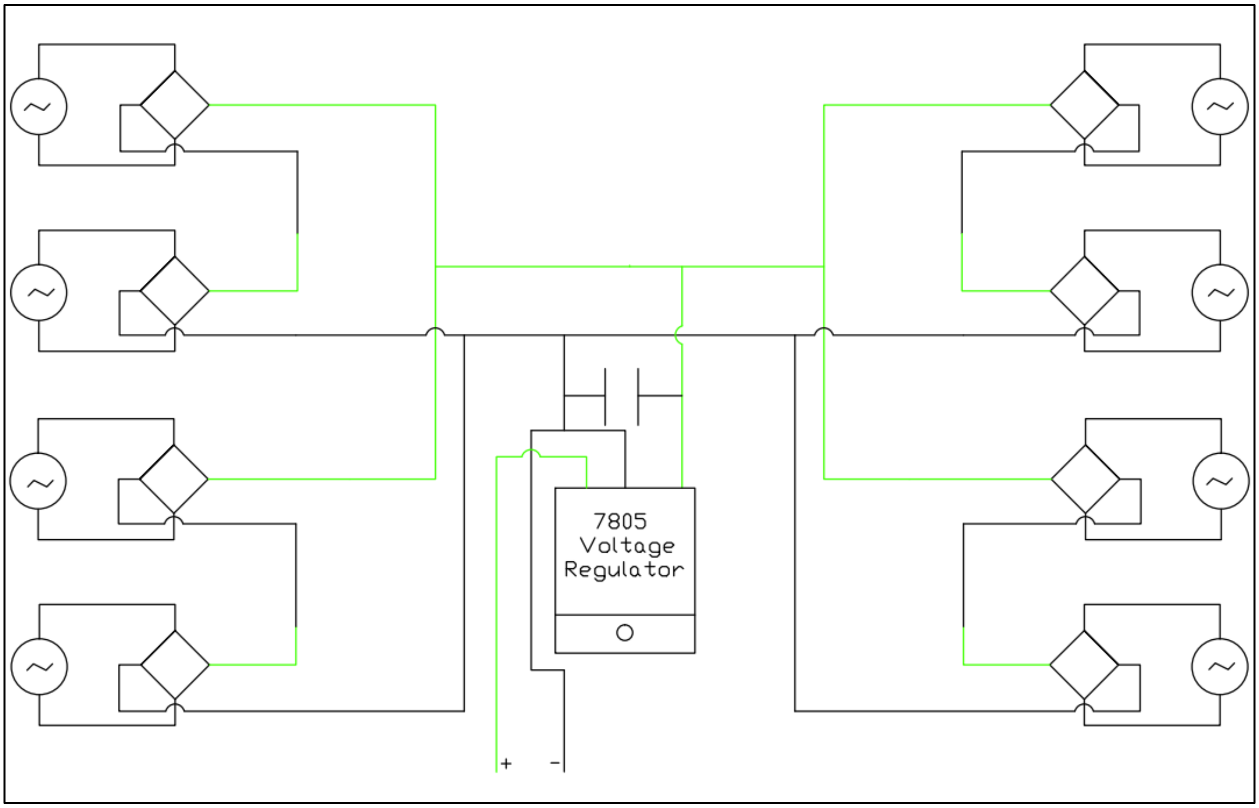

Figure 5-3 – Wiring Diagram

Wiring diagram from coils to voltage regulator

5.3 Cost Analysis

This section reviews the various costs associated with the MultiBelt windbelt design.

5.3.1 Design

605 total hours were spent on the design of the windbelt for the Samoa Hostel by members of The Buzzards team. The majority of this time was spent in the implementation phase of the project and in gathering information as can be seen in Figure 5-4.

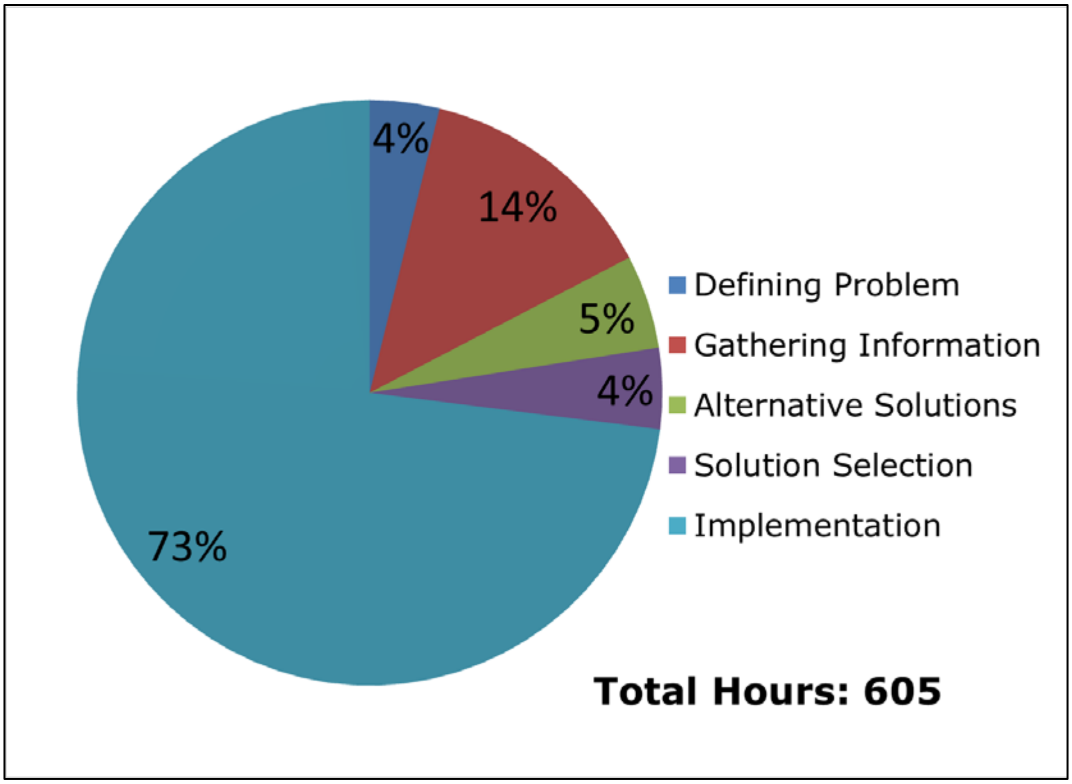

Figure 5-4 – Hour Distribution

Total hours by section.

5.3.2 Construction

The Buzzards had a maximum allowance of $500 for this project. Some items were donated and some were discounted by generous companies. Effort was made to try to keep the costs as low as possible without jeopardizing the integrity of the windbelt system or curtailing it's ambitious goal of charging devices via USB interface. A total of $361.23 was spent on this design. Table 5 lists the prices paid and retail prices of the materials used.

Table 5 – Expense Table

Item	Description	Qty.	Retail Price($)	Our Price($)	Retail Total ($)	Our Total ($)
Magnets	42-Assrtd, incl. ship.	1	42.20	42.20	42.20	42.20
Wood	Per Board ft.	8	5.94	5.94	47.54	47.54
U Bolt	5/16"x2"x4.75"	1	4.13	4.13	4.13	4.13
U Bolt	5/16"x2"x4.75"	3	4.13	3.72	12.39	11.15
Gorilla Tape	2"x12yd.	1	5.47	5.47	5.47	5.47
Washers	5/16"	4	0.17	0.17	0.68	0.68
Nuts	5/16"	4	0.16	0.16	0.64	0.64
Taffeta	3"x9yd	1	9.00	9.00	9.00	9.00
Coils	Wrapped w/35ga.	2	16.00	12.50	32.00	25.00
Coil Housings	Assrtd, incl. ship.	6	0.20	0.00	1.20	0.00
Screws	Wood Screws	16	0.05	0.00	0.80	0.00
Wood Glue	Titebond III 16oz	1	11.00	0.00	11.00	0.00
Magnets	2 Square	2	1.00	1.00	2.00	2.00
9V Battery	For multimeter	1	5.49	3.26	5.49	3.26
Plexiglass	For spacing coil mounts	8	0.20	0.00	1.60	0.00
Diodes	Schottky, unspecified	4	1.94	1.94	7.74	7.74
Magnets	8xDA4-52, 8xD82-N52	1	31.08	31.08	31.08	31.08
Diodes	P/N#:1N5817 Schottky 1A 20V	32	0.32	0.32	10.18	10.18
Coils	Wrapped w/34gauge	8	16.00	10.83	128.00	86.60
Mount	Orig. for Satelite dish	1	70.00	5.00	70.00	5.00
Glue Gun	Ace mini-heavy duty	1	5.99	5.99	5.99	5.99
Glue	For glue gun	1	7.07	7.07	7.07	7.07
Epoxy Enamel	Spray Can	1	7.00	7.00	7.00	7.00
Voltage Regulator	7805 5v voltage reg.	2	1.74	1.74	3.47	3.47
Ammeter	0 to 200 mA, Part #7309Z	1	46.03	46.03	46.03	46.03
					492.70	**361.23**
					Savings:	**131.47**

Expenses for this project. (Paid and Retail prices)

The wood, magnets and coils were the most expensive parts of the windbelt. The wood used was an especially strong type known as Purple Heart. A less expensive type could be used for a windbelt that would not be kept outside in the elements. A certain amount of experimentation was needed on this project to ascertain the appropriate magnets and coil combination. The best result was found with the magnet and coil combinations listed in the Design Specification section and so less of these items would have to be ordered if we were to rebuild this unit.

5.3.3 Maintenance

There is no anticipated financial upkeep assoicated with this unit. Should the unit not produce power it is likely the belt needs to be re-tensioned which can be done with the integrated tensioner. It is suggested that a monthly inspection be done on the mounting mechanisms to ensure the windbelt is solidly connected to the roof.

5.4 Implementation Instructions

The MultiBelt windbelt design can be retrofitted to the hostel above the Samoa Cookhouse with proper mounting, wiring, and fixtures. First, the windbelt must be properly mounted so it is safe, and can make use of available wind. For the hostel, a satellite dish mounting device is the best solution, because it ensures that the windbelt is mounted properly and in the ideal location. Second, wiring is required to send the power created by the windbelt to a remote location. Standard outdoor electrical wiring is connected to the windbelt and eventually ends up at the fixture where the power will be used to charge USB devices. After the wiring from the windbelt is ran, it will need to be connected to a fixture that has female USB connections. A female USB outlet will be bought, pre-assembled, and the wiring will be connected to it. The USB outlet is mounted like a standard wall outlet and is placed in an area that users will be able to access it. Lastly, a metering device is connected. For our purposes, an ammeter will be used. An ammeter measures the amount of current produced from the windbelt, so users can determine when there is an appropriate amount of power to charge their USB devices and also see the relationship between the amount of wind outside and the amount of power being produced by the windbelt. After following these implementation instructions, the windbelt will produce enough power, when there is available wind, to charge USB devices brought by hostellers.

5.5 Prototype Performance

The MultiBelt produces enough power to charge an average cell phone battery (1000mAh) in 12.5 hours at low wind speeds and an estimated 4.4 hours at high wind speed.

For low wind speeds the windbelt should be wired with pairs of coil in series. In this configuration a 24" circular fan will produce .64 watts before the electricity passes through the windbelts rectifiers and regulator. When sets of two coils are wired in series the system will produce 80 milliamps at 5 volts. After the loss caused by the rectifiers and the regulator the MultiBelt windbelt produces .4 watts.

When each windbelts bottom coils are wired in parallel and the top coils are paired up and wired in series, as it would be wired for high wind speeds, the system will produce an estimated 1.8 watts. Once the loss associated with electronic componentry is accounted for the system will deliver 230 milliamps at 5 volts charging a 1000mAh cell phone battery in 4.4 hours.

Appendices

A. References

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B. Brainstorming Notes

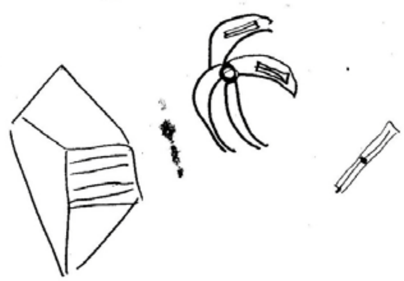
[illegible] 2 coils
[illegible] fferent configurations

10/6/2010
3^{00} pm
Dustin x2

[illegible]sty : 1m belt with one coil
Funnel across 4 x 1m belts

[illegible]AN : Rigid "belt" attached @ one end
(coils where)
Coils mounted to belt instead of magnets

[illegible]b : Belts mounted on Turbine Blades
Multiple smaller belts (8 x .5m)



10/6/2010
3pm
Dustin X2 Bob, Ryan

~~[redacted] m belt~~

Multiple 1m Belts (4 1m belts)

~~Several smaller (4 x .25m) Belts~~ (Ryan)

Multiple .5m belts (8 x)

oils Attached to belt instead of magnets

~~oils on Both sides~~

~~– Alternative corners~~

~~– Same side of belt both corners~~ (Dustin)

unnel in Front (Dusty)

elt mounted Thick side to wind

Magnet Tall cones instead of short

Airplane wings as belt

rigid board fixed @ one end (Ryan)

Belts mounted on turbine blades (Bob)

Criteria	Constraints	Spec's:
Voltage	light bulb ≤	Does not hurt devices plugged into it
		Professional Appearance
Durability	> humdinger WARRANTY	Meets Code
Noise	Noise Level < Disturb. Residents	
Price	< $500	
Reliability	> Better	
Efficiency	> Better	
Attractiveness/	> Better	
Size	< Better	
Niftyness	> Better	
Demonstrative	> Better	

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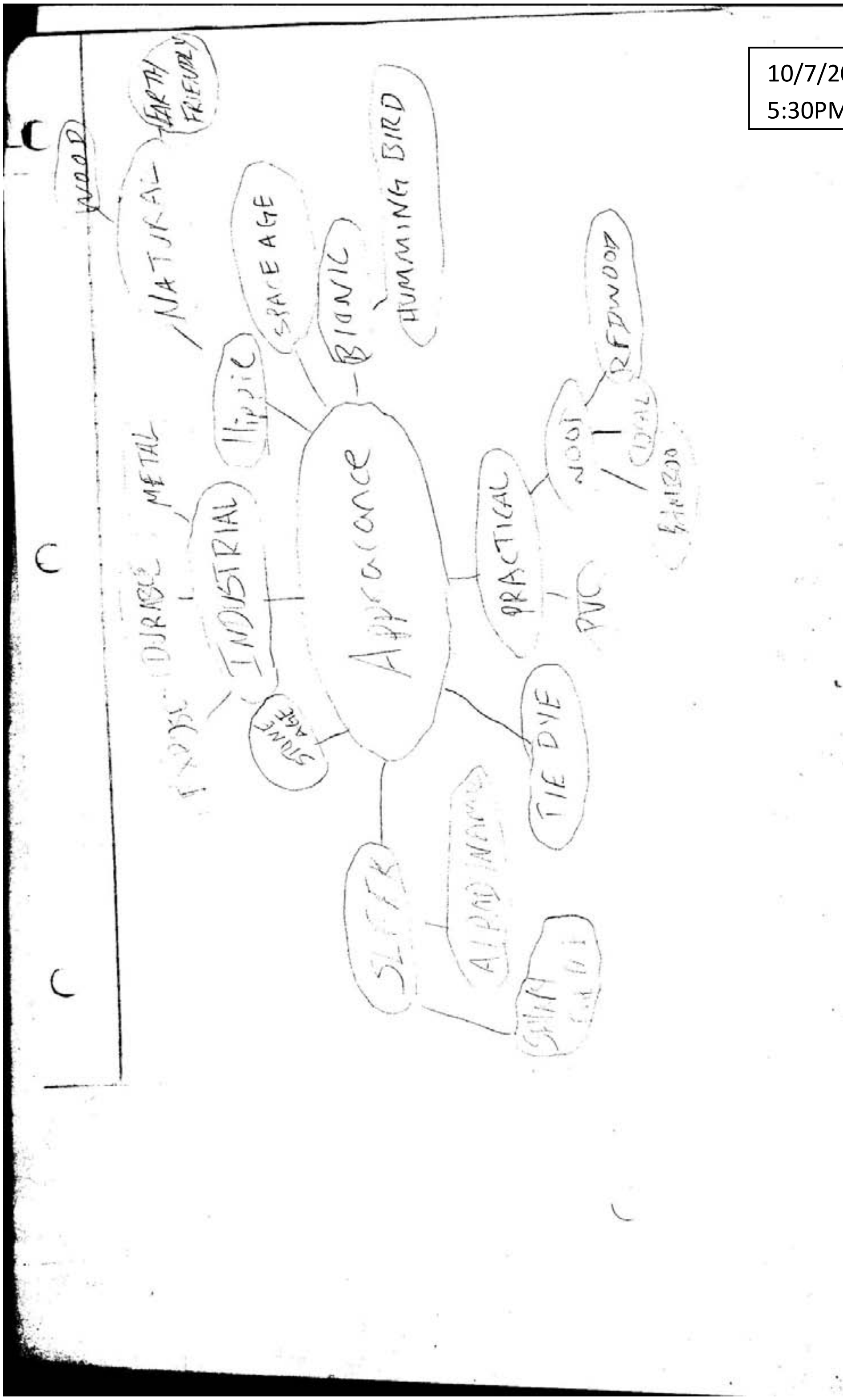

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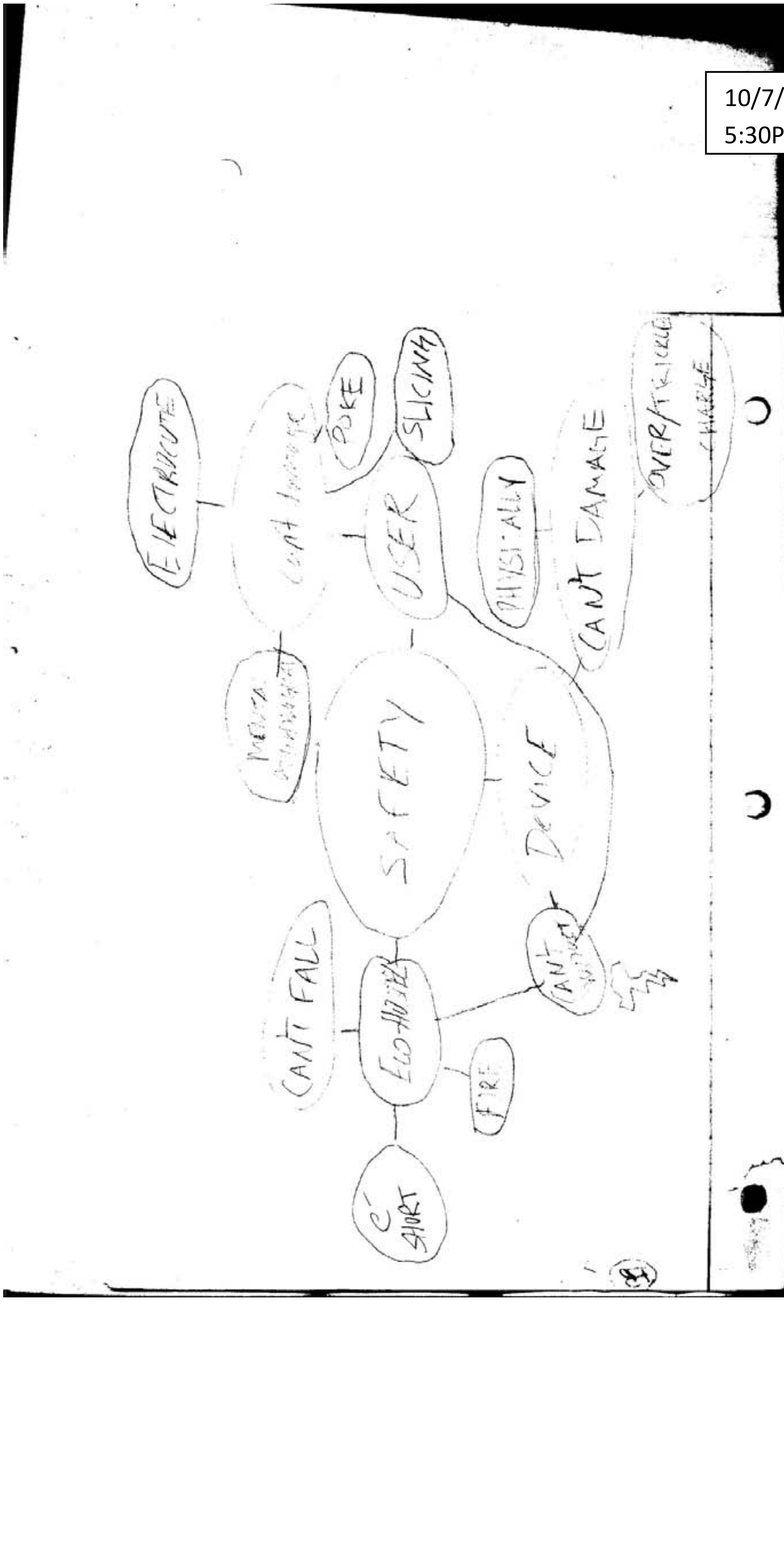

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