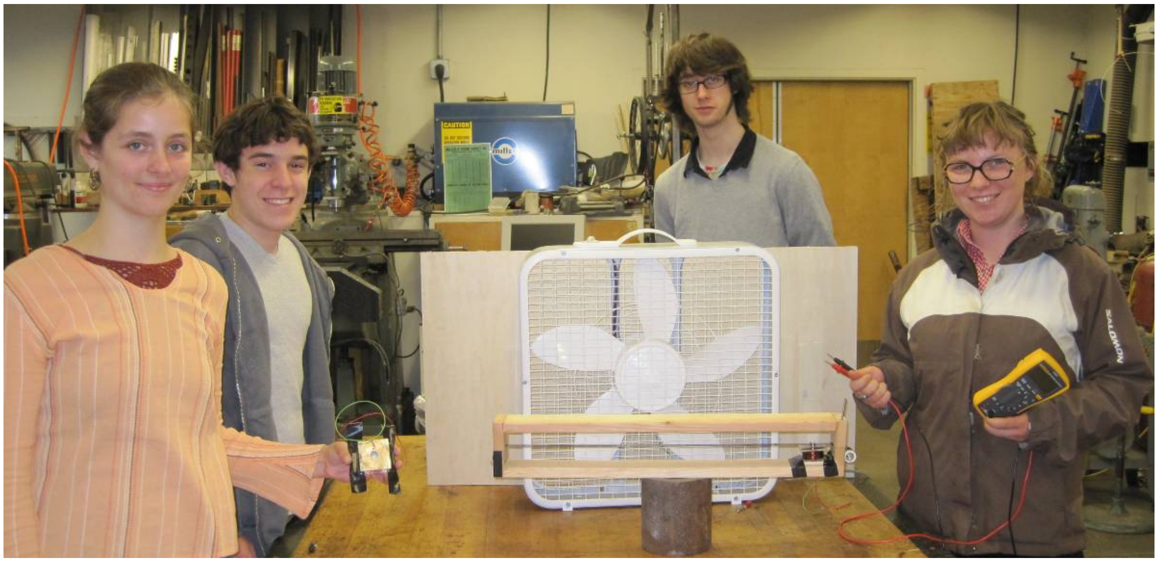
Energy in a Cinch: Windbelts



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Engineering 215-Introduction to Design

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1 Problem Formulation

1.1 *Introduction*

The problem formulation section develops an objective statement and a black box model, seen in Figure 1, for the design project.

1.2 *Objective*

The objective of this project is to design an interactive curriculum that can be contained and transported in a box to schools in Humboldt County. The contents of the box will educate high school students about renewable energy and its impacts.

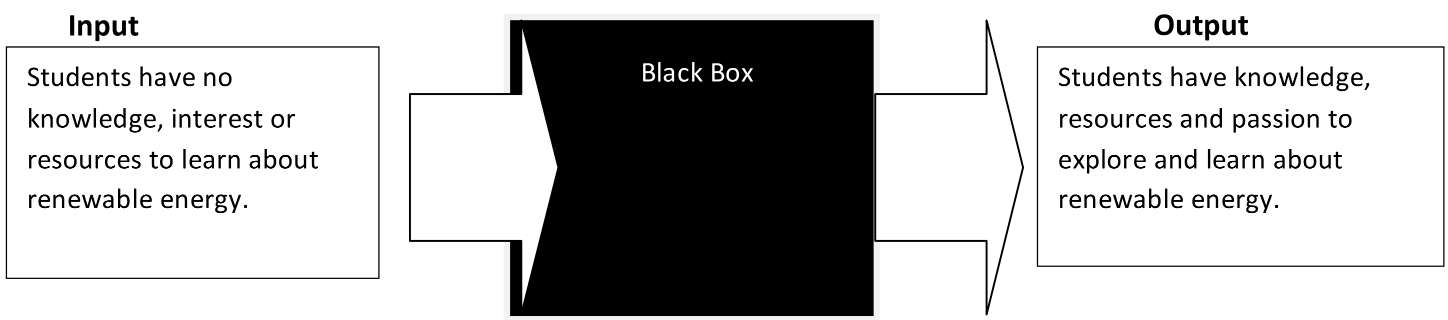

Figure 1- Black Box Model: This model is a simplified representation of the objective of this project.

2 Problem Analysis and Literature Review

2.1 *Introduction*

The problem analysis identifies the specifications, considerations, criteria, usage, and production volume of the design project.

2.2 *Problem Analysis*

2.2.1 **Specifications**

The instructional materials must fit inside a portable vessel, with dimensions 28 x 20 5/8 x 15 5/8 in. The vessel must be light enough to be carried by one individual, and transported to and from the schools in the Humboldt County area. The vessel must be able to be stored and stacked at RCEA. Content of the box will align with California education standards for High School science and provide students with an understanding of renewable energy concepts.

2.2.2 Criteria

Table 1: Criteria and Constraints of project

Criteria	**Constraints**
Level of student engagement	Interesting and fun to learn for students
Ease of use	Simple set up and clean up
Transportability	Can be transported by a teacher to and from school from RCEA, can be carried by one person
Cost	Materials must be under $400
Durability	Must withstand weekly usage in multiple classes for at least a year
Pertinent to Humboldt County	Address renewable energies applicable to Humboldt County
Safety	Must not harm students.
Take Home Knowledge	Students will go home feeling that they have learned something, and interested to learn more.
Aesthetics	Must be visually appealing to students.

2.3 Literature Review

2.3.1 Introduction

The purpose of the literature review is to provide research in areas relevant to this design project. The literature review will cover client criteria, California education standards, learning styles, solar, fuel cells, wind, geothermal and hydro-power.

2.3.2 Redwood Coast Energy Authority

The Redwood Coast Energy Authority (RCEA) is a Joint Powers Authority representing seven cities in Humboldt County; Arcata, Blue Lake, Eureka, Ferndale, Fortuna, Trinidad and Rio Dell. The RCEA's mission is to develop and implement sustainable energy initiatives that reduce energy demand, increase energy efficiency and advance the use of clean, efficient and renewable resources available in the region. (Appropedia 2010)

2.3.3 Client Criteria

The team met with Oliver Hulland, the representative for the Redwood Coast Energy Authority (RCEA) on February 19, 2010 to review criteria to create an appropriate design. The main criteria to considered for our final design for creating an educational box that effectively presents renewable energy to high school students were that the design should:

- Follow California Educational Standards
- Be safe
- Longevity and durability
- Engaging, get students thinking
- Be interactive and "hands-on"
- Relevant to the Humboldt County community

2.3.4 Education standards

In order to make sure that students are being taught relevant information, the are standards that must be followed. The California State Board of Education (SBE) has set the "Science Content Standards for California Public Schools". For grades nine through twelve, the physics standards include students having a basic grasp on the following: Newton's Laws, conservation of momentum and energy, waves, electricity and magnetism, thermodynamics and heat. Chemistry standards include a basic understanding of the following: Atomic and molecular structure, and its relation to the periodic table, chemical bonding, conservation of matter, acids and bases, properties of gases, solutions/dilutions, reaction rates, and chemical equilibrium. Standards are also set for "Experimentation and Investigation" for high school students to gain greater understanding in all areas of science. This includes being able to develop a hypothesis, having knowledge of scientific tools and technology, and being able to identify experimental error. (California State Board of Education, 2003)

2.3.5 Learning styles and Teaching effectiveness

There has been much debate around the topic of what the most effective way of teaching science is. In a recent study by Robert Tai and Philip Sadler it was found that the "self led" instruction, which has recently become very popular in science courses, may not be very effective to all students (Arrington 2009). Students learn most effectively when they are presented new information in several different ways. Students who work together and gain feedback from one another, will gain greater understanding of a subject as they reanalyze it from new perspectives. Young people learn better by physically seeing or doing something. Encouragement and confidence are important aspects of how someone learns. Encouragement and success build confidence and make a person want to learn more. Providing historical relevance and perspective is important in teaching science. Students need time to work things out, go over them from different approaches, talk it over with one another, and have time to take wrong turns and come back to find the correct answer (Ahlgren, Rutherford. 1991).

2.3.6 **Solar**

Solar power is a renewable energy that captures the suns radiation and transforms it into other useful forms of energy. This is generally done in two ways, by converting it to electricity or by absorbing radiated heat. Photovoltaic cells and solar hot water heaters are common examples of solar power. Solar power is limited by the amount of sunlight that can be obtained, for instance less power is produced on cloudy days (EIA, 2008). Another way solar energy is commonly used is for solar cookers, using the suns energy to cook (SCI, 2009).

2.3.6.1 **Photovoltaic**

Photovoltaic (P.V.) cells are electricity-producing devices made of semiconductor materials (material that has electrical conductivity between conductor and insulator.) A P.V. cell converts light energy into electrical energy. When light shines on a P.V. cell the light may be reflected, absorbed or pass directly through. Only the absorbed light generates electricity. The energy of the absorbed light is transferred to electrons of atoms within the P.V. cell. These electrons which escape from their normal orbital positions with this newfound energy become part of the current in an electrical circuit as seen in Figure 2. When P.V. cells are combined into a P.V. system they produce a greater amount of power than a single P.V. cell. P.V. systems can be connected together into larger units called modules to create a larger power output. Modules can be connected to form arrays, which produce greater amounts of power (U.S. Department of Energy 2005). P.V. Cells are used to power many household devices such as calculators and watches, and according to the U.S. Department of Energy, P.V. arrays are becoming a common source of energy for businesses and households. Houses utilizing P.V. systems to provide electricity to the residence can receive tax credit for up to $500 per .5 kW of power capacity. (U.S. Environmental Protection Agency 2010) P.V. systems require little maintenance once installed. Some downfalls of P.V. systems are that they are a more expensive power source for areas close to an electric grid, as they require equipment that is expensive initially and a P.V. system takes up a large amount of space. (U.S. Department of Energy 2009a) P.V. systems are also dependant on the sun for their energy production, which can lead to energy shortage if there is no back up energy source. (CET 2008)

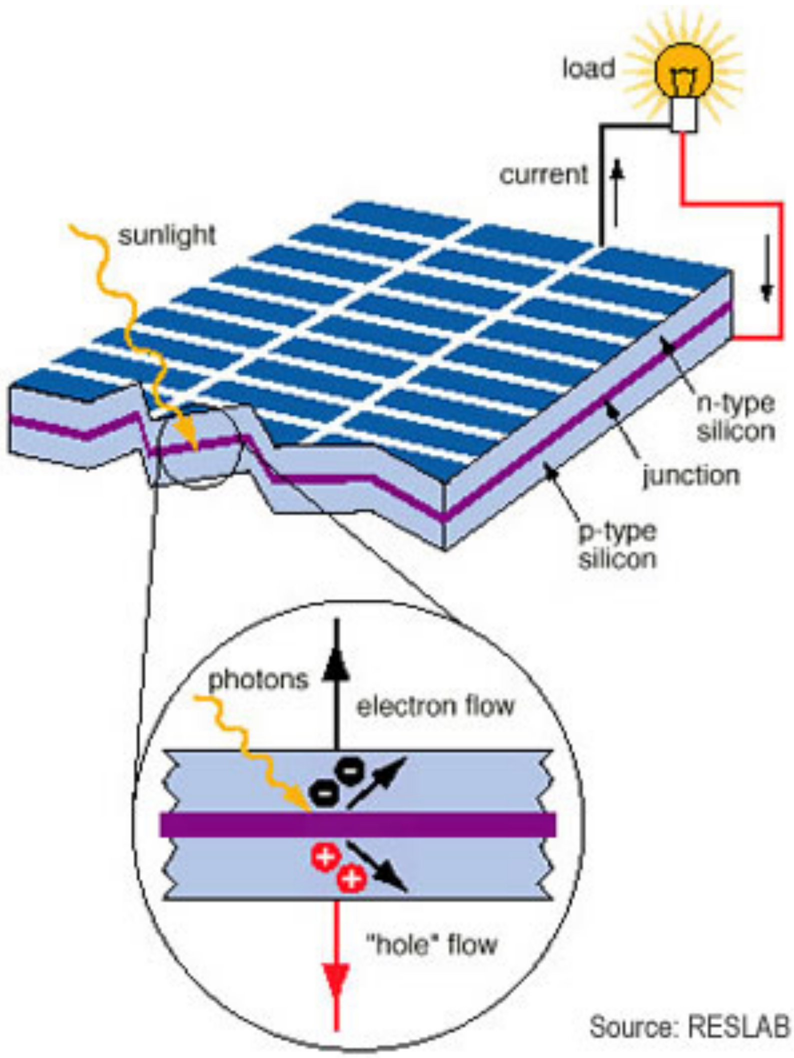

Figure 2: Diagram of P.V. Cell (RESLAB 2009)

2.3.6.2 **Solar Cookers**

Solar cookers are a way of capturing sunlight and harnessing its energy for use in cooking. Solar cookers work best in areas where it is expected there will be long hours of sunlight. Solar cookers do not work at night or when it is overcast for most of the day. The effectiveness of solar cookers and cooking time is affected by wind (SCI 2009).

2.3.6.2.1 **Box cookers**

Box cookers are one of the most commonly used types of solar cookers. This is what is commonly referred to as a solar oven. A box cooker, Figure 3, is a box that is dark on the inside to increase the absorption of heat. The box should be air tight, with a clear window to allow the sunlight to enter in but not radiate out. Most box cookers also have a reflective surface that helps to direct sunlight into the box (Intermediate Technology Development Group 2006).

Figure 3- Solar box cooker. (http://www.rksolar.com/catalog.8.html)

2.3.6.2.2 **Concentrating cookers**

Concentrating or "parabolic" cookers use a large surface area, and concentrates the heat gathered from the area to a central area where a pot is placed and food can be cooked. Figure 4 shows the conventional parabolic shape. This type of solar cooking works the only when in direct sunlight (Intermediate Technology Development group 2006).

Figure 4- Parabolic solar cooker. (http://www.humboldt.edu/~ccat/solarcooking/parabolic/parabolic_solar_cooker_pg_3_html.htm)

2.3.6.2.3 **Panel cookers**

A panel cooker incorporates the idea of both the box and concentrating cookers as shown in Figure 5. It uses reflective panels to concentrate the heat from sunlight onto the cooking surface. The pot that is being used to cook in is covered in durable plastic that can withstand heat or with an inverted glass bowl to keep in the heat. Generally made with cardboard and aluminum foil, these are a relatively inexpensive solar cooker to make. (SCI 2009).

Figure 5- Panel cooker made from cardboard and aluminum foil. (sunnycooker.webs.com/)

2.3.7 **Fuel Cells**

A fuel cell is an energy conversion device, which generates power through chemical reaction. For a fuel cell to work a catalyst must first split hydrogen into a positively charged hydrogen ion (proton) and a negatively charged electron. The positive ions travel through a membrane to a second catalyst where they combine with oxygen and electrons to produce water and heat as shown in Figure 6. The electrons move through a Polymer Electrolyte Membrane, which forces them through an electrical current external to the cell, causing electricity to be generated. (National Renewable Energy Laboratory 2009) Fuel Cells offer a way of generating electricity that is cleaner and more efficient to gasoline combustion and other fossil fuels. (U.S. EPA 2010) Fuel Cells are expensive initially due to the necessary components.

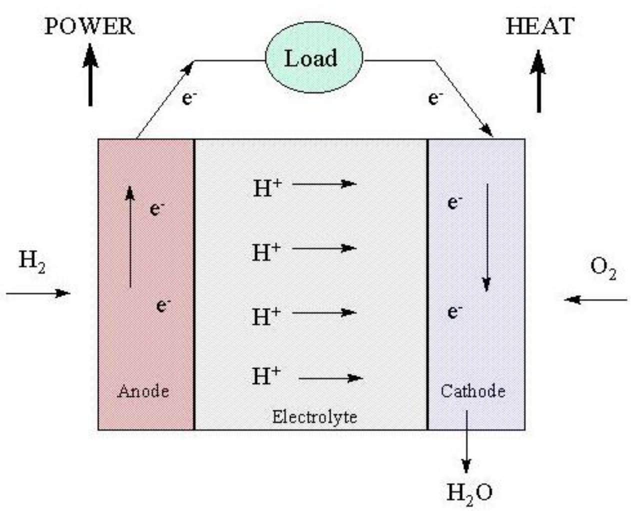

Figure 6- Diagram of a Fuel Cell (NASA 2002)

2.3.7.1 **Polymer Electrolyte Membrane**

The Polymer Electrolyte Membrane (PEM) is a critical part of a fuel cell. PEM's are an electrolyte polymer (plastic) that holds negative ions, only allowing positive ions in the membrane to be mobile and therefore carrying positive charge through. Hydrogen ions are only able to move in one direction, from anode (negative electrode) to cathode (positive electrode), electrons must travel through an external wire to complete the circuit, which provides electrical power to run a light bulb, power plant or car. (Los Alamos National Laboratory 1999) PEM Fuel Cells operate at a low temperature and have a fast start up time, putting less strain on system mechanisms. PEM fuel cells are used primarily for transportation applications. PEM fuel cells are expensive because of the use of a platinum catalyst. The platinum catalyst is also sensitive to carbon monoxide (CO) as the CO adsorbs to the Platinum and blocks the reacting surface, requiring an additional reactor to reduce CO if hydrogen is derived from an alcohol or hydrocarbon fuel. (U.S. Department of Energy 2009b)

2.3.7.2 **Electrolyzer (Water Electolysis)**

An electrolyzer converts electrical energy into chemical energy by breaking water up into hydrogen with oxygen as a byproduct. The electrical energy can be recovered by reacting hydrogen with oxygen in a fuel cell. To make a fuel cell a renewable energy source the electricity from the electrolyzer would have to come from a renewable resource such as wind, solar or geothermal. Hydrogen produced from an electolyzer can be used for fuel cell vehicles or electricity generation. During periods of low electrical demand, many renewable power generators, such as wind turbines, produce lost excess electrical energy. An electrolyzer enables storage of excess energy in the form of hydrogen, which can be converted to electrical energy on demand. ((U.S. Environmental Protection Agency 2010)

2.3.7.3 **Fuel Cell Car**

Vehicles powered by fuel cells emit no greenhouse gases, fuel cell vehicles (FCV's) powered by pure hydrogen emit no harmful air pollutants. A fuel cell provides electricity to power motors located near the vehicles wheels (Figure 7). PEM fuel cells are the most common type of fuel cell used in vehicle applications. FCV's must carry either compressed or liquid hydrogen onboard, or from secondary fuels, such as natural gas. If powered by a secondary fuel, a reformer which provides non hydrogen fuel to an FCV, is needed onboard. Vehicles fueled with pure hydrogen emit no pollutants, only water and heat, where vehicles powered by secondary fuels and reformers produce a small amount of air pollutants. (U.S. Department of Energy 2009c) Hydrogen powered vehicles qualify for alternative fuel vehicle tax credits. Problems with FCV's include the lack of hydrogen refueling stations, and onboard hydrogen storage systems are large, heavy, and expensive. Fuel Cell systems in vehicles are not as durable as combustion engines and do not perform well in extreme environments. (Fuel Cell Economy 2008)

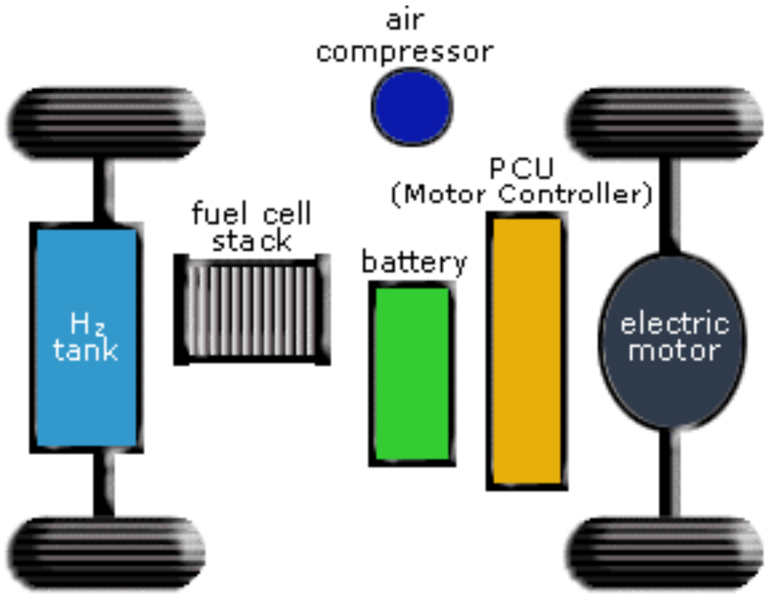

Figure 7- Diagram of a fuel cell car. (US Department of Energy 2009c)

2.3.8 Wind belt

The Wind Belt was designed to be a cheap, wind powered device that third world countries could produce and improve. Its design and scale makes it ten to thirty times more efficient than a turbine of the same scale. It works by using aeroelastic flutter using the energy to move magnets through copper coils. (Humdinger 2009).

Figure 8- Prototype Windbelt designed by Humdinger Wind Energy. (KindWind Project 2010)

2.3.9 Turbines

There are four different kinds of turbines that harness the energy from wind, steam, water, and gas. Each one is designed specifically to capture energy from the moving liquid or gas. (Explainthatstuff 2010).

2.3.9.1 Wind Farms

Wind farms are composed of large areas of land filled with wind turbines. They are a renewable resource but are only cost effective in certain locations. Currently they are the main source of wind energy but are disliked because of their size and look, so therefore people say NIMBY (Not in My Back Yard). They work by using the wind to rotate a slow moving shaft with a gear on the end which is connected to another smaller gear on a high speed shaft that runs to the generator housing.

2.3.9.2 High Altitude Wind Turbine

A high altitude wind turbine takes advantage of higher strength winds about 1000 feet in the air. Figure 9 demonstrates how the turbine transfers energy. Being lighter than air it is anchored to the ground by a winch. It is mobile and can be taken anywhere.

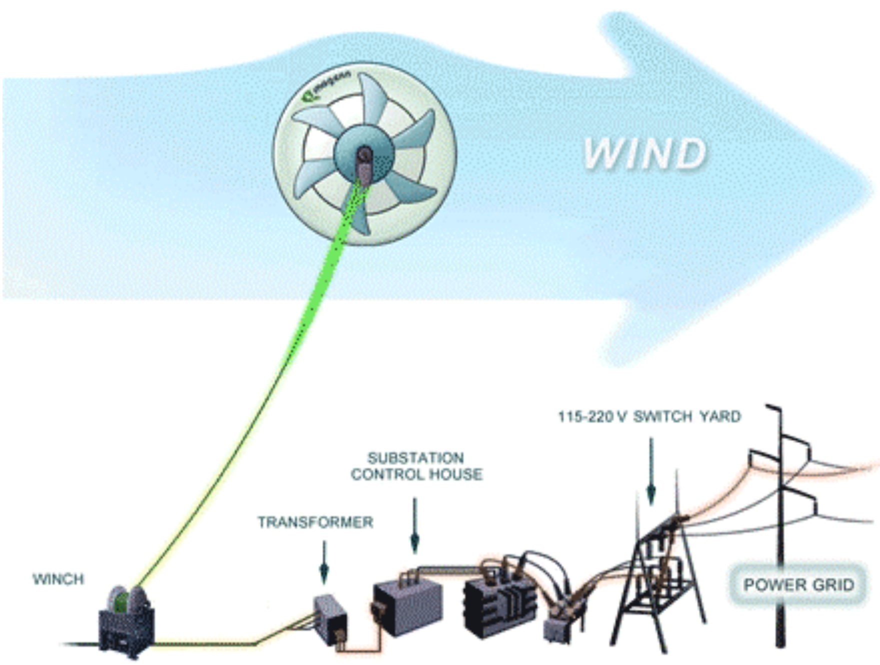

Figure 9- High Altitude Wind Turbine. This is a visual representation of where electricity will be transferred. (Magenn 2010)

2.3.10 **Kite Power**

A kite power machine converts the up and down motion of a large tethered kite into electrical energy using a power converter mechanism and a generator on the ground. As the kite moves up and down it moves the rocking arm it is attached to. A series of turning gears which move with the rocking arm convert kinetic energy into electrical energy as they spin a turbine. The electricity generated can be then stored in batteries. Kites are more economical in lower-speed wind regions than wind turbines, and kites can also reach higher elevations with greater wind speed. Kite systems are inexpensive. (Hill 2008)

2.3.11 **Hydro Power**

All hydro- electric power generation operates by utilizing water and its natural motion to power a generator, thus harvesting electricity. The specific setting, situation and conditions affect what types of Hydro are utilized and where. Due to the constant natural motion of water and the fact that it covers 70.9% (CIA, 2010) of the planet appropriate application could provide vast amounts of energy for human consumption. Hydroelectric power is very appealing when used in a *sustainable* manner. Especially considering the fact that our planets water is in a constant state of motion, and will be for the entirety of the existence liquid phase water on earth.

2.3.11.1 **Wave/Tidal**

There are many different ways of harnessing wave and tidal energy. Every design differs, some remarkably so. Wave and tidal energies are a relatively new technology with various designs still being prototyped. The main idea is to use the natural movement of bodies of water to either turn a turbine, crank or hydraulic piston, according to the suitability of the various technologies to the situation at hand.

2.3.11.1.1 **Bio-mimicry**

Though there are many valid options forthcoming; some of the most promising designs look to life itself to find a suitable solution. This is called Bio-mimicry and is a new push in the field of appropriate technologies. By using solutions created by the evolutionary process many challenging problems are being overcome. In the case of wave energy one company in particular, Australian Bio Power Systems, has two seemingly feasible designs, though both seem most suited for relatively shallow waters. According to their website bioWAVE, their 25-meter tall design, "is based on the swaying motion sea plants in the presence of ocean waves." A 250 KW pilot project is now underway off of the coast of King Island Tasmania. Pictured below is representation of what a bioWAVE farm would look like.

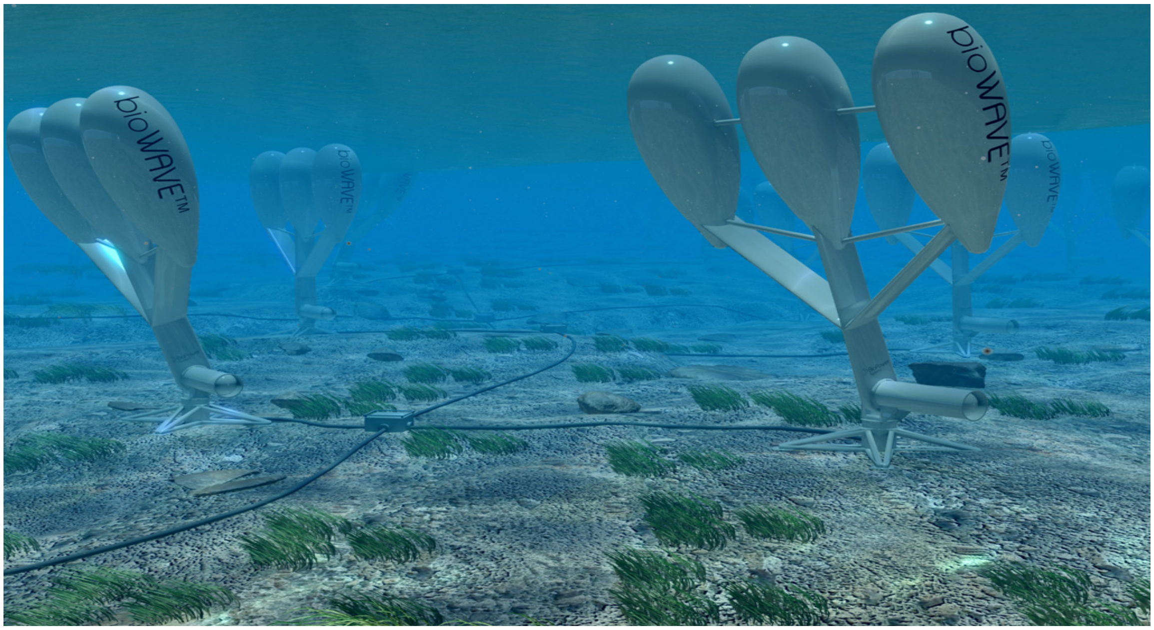

Figure 10-Image of BioWAVE computer models.

Their other design, bioSTREAM, according to their website, "is based on the highly efficient propulsion of Thunniform mode swimming species, such as shark, tuna, and mackerel." Instead of using the fin design of these species for propulsion, this design captures tidal energy by doing the opposite, and is fixed in a moving current. This design basically entails a 15-meter tall fin attached to a 20-meter crankshaft that turns the generator located in the base shaft. A 250 KW pilot project is now underway off the coast of Flinders Island, Tasmania and is predicted to be completed and delivering power to the grid sometime this year. Pictured bellow is a representation of what a bioSTREAM farm would look like.

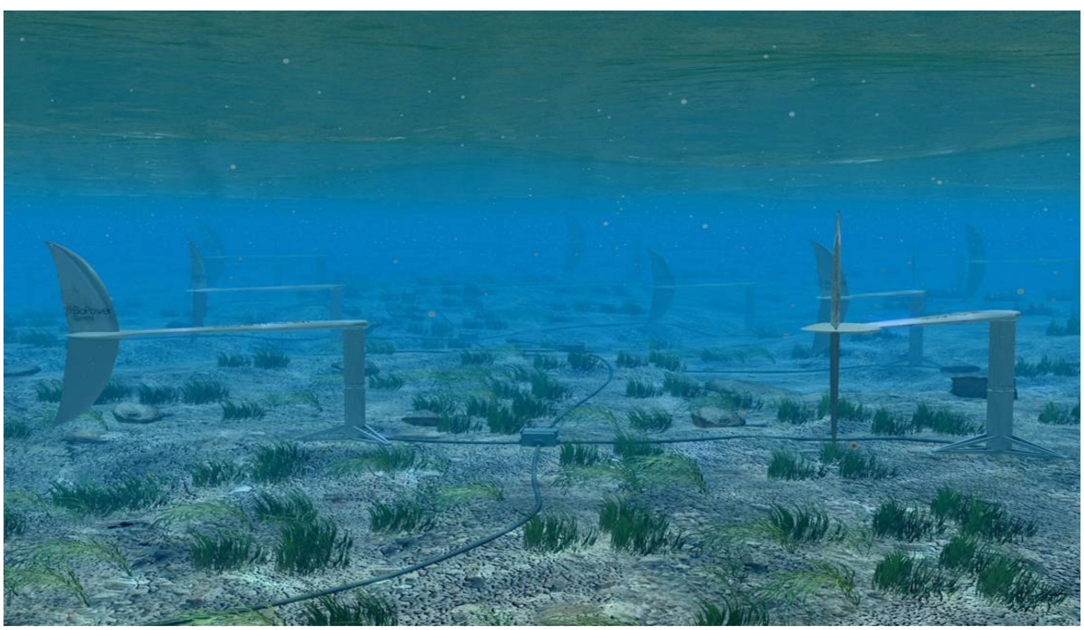

Figure 11-Image of BioSTREAM computer models.

3 Search for Alternative Solutions

3.1 Introduction

In the search for alternative solutions three brainstorming sessions were conducted to compile a list of eight alternative solutions. These alternative solutions are described in detail in the following sections of the document.

3.2 Brainstorming

Our team conducted three brainstorming sessions. The first was an unstructured brainstorm where all ideas were taken into account without consideration of feasibility. The second brainstorming session was more structured in which we compiled ideas from the first brainstorming and thought about feasibility and our criteria stated in the problem analysis. From the second brainstorming session a list of ten ideas was formulated. During the third brainstorming session each member of the group was given time to add their input of each solution. Each member of the group was assigned two solutions to develop into a description and visual of the solution. The brainstorming notes from these sessions can be found in Appendix D.

3.3 Alternative Solutions

The brainstorming sessions resulted in eight alternative solutions:

- Build it, Fly it, Kite it
- Hydro-Racers
- Course Directed curriculum
- Minis
- Hydrogen Balloon Demo
- Educational Diorama
- Human Renewable
- Energy in a Cinch: Windbelts

3.3.1 **Build it, Fly it, Kite it**

Build-it, Fly-it, Kite-it is a curriculum that uses a kite design competition to introduce kite power as a renewable energy to high school students. The teacher introduces the basics of kite power, how the energy conversion machine works, give information on what makes a kite effective and present a few kite designs. Students are divided into groups and given material to design a kite. Each group develops one kite and presents their final design to the class. Each group tests their design outside with the rocking arm conversion device. A kilowatt meter will show the amount of energy produced by each kite and then the most effective design can be determined. The students will be introduced to concepts of energy conversion, wind power, flight, bio-mimicry and building and design concepts. The box will contain a prefabricated rocking arm, a kilowatt meter, kite energy information, kite building material and kite design information (Figure 12). The most expensive components to this box would be a kilowatt meter and the generator in the rocking arm.

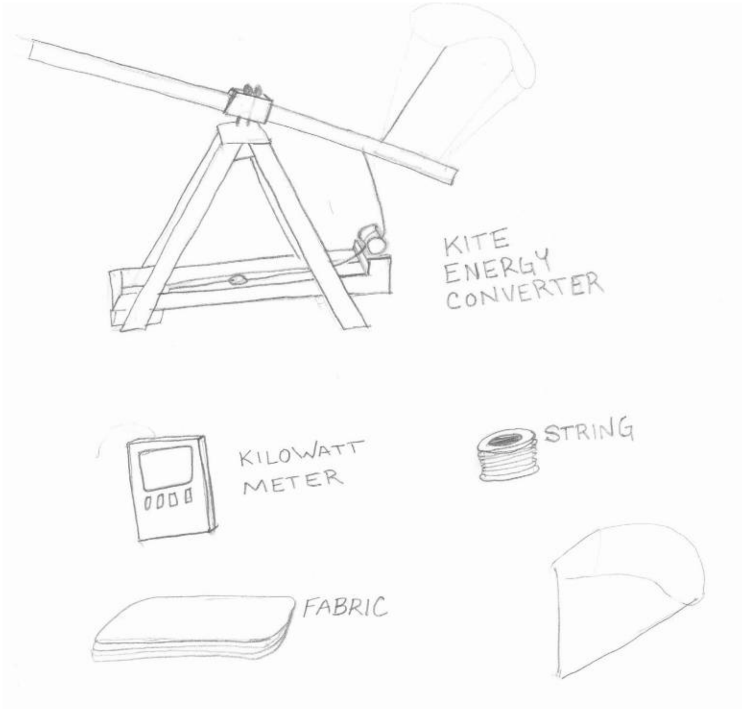

Figure 12- Build it, Fly it, and Kite it materials. (Leopardi 2010)

3.3.2 **Hydro-Racers**

Hydro-Racers is a curriculum that uses miniature fuel cell powered cars to demonstrate how fuel cells work. The Hydro-Racers box contains a P.V. cell, an electrolyzer, FCV toy car and an incline as seen in Figure 13. The teacher presents the box by giving an overview of how an electrolyzer splits hydrogen from water and then how a fuel cell uses the hydrogen to create an electrical current to power something, which in this case is an electric car motor. Students break off into small groups to use the material they just learned to make a miniature fuel cell car run. Students determine the correct method of wiring for all parts to be connected, what influences the production of hydrogen and the amount of hydrogen needed to reach certain speed or reach the top of a specific incline and introduces hydrogen as a renewable fuel. The cost for this box would be about $60 for each car as fuel cells are expensive.

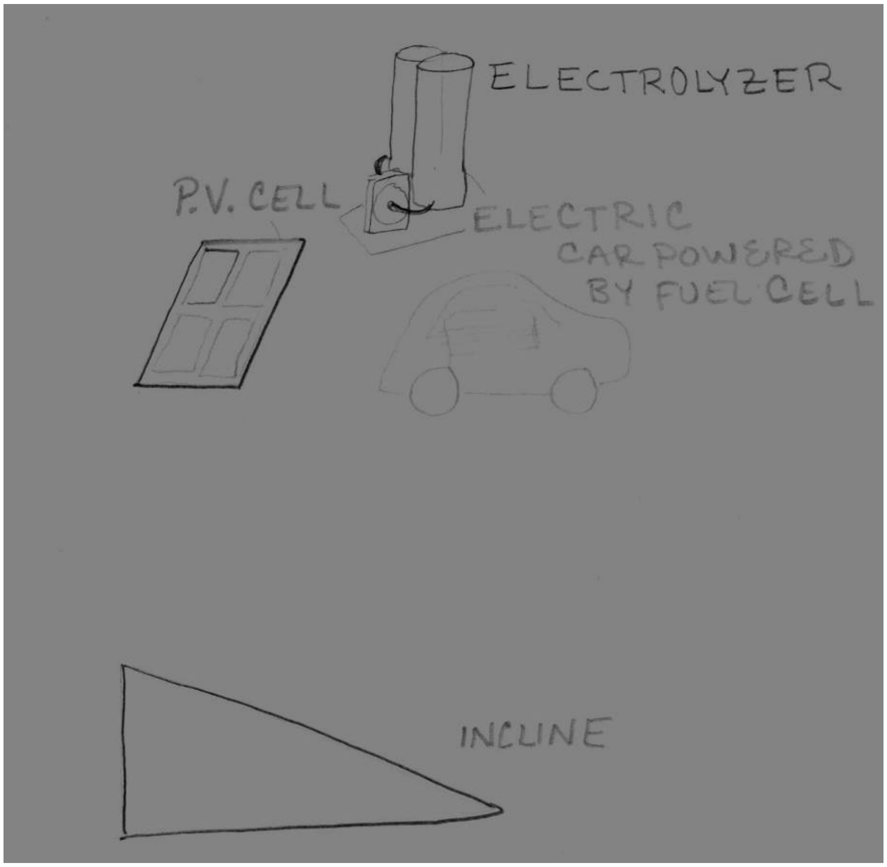

Figure 13- Contents for Hydro-Racers box. (Leopardi 2010)

3.3.3 **Course-Directed Curriculum**

This box would contain curriculum focused toward specific subjects, one for chemistry, one for physics and one for mathematics.

The Course-Directed Curriculum box (Figure 14) would include information for the instructor of each specific curriculum. This allows for the information to be a bit more in depth. Course-Directed Curriculum includes background information for each topic that will be taught, a short history, and some supplemental learning materials for the students.

The chemistry curriculum involves informing the students on biodiesel and other bio-fuels. The background information here would include a history of various bio-fuels, their part in today's society as a renewable energy resource, economic feasibility and overview of the chemical reaction process of biodiesel. Students are then instructed by the teacher on the safety warnings of using the chemicals to produce biodiesel. Working in teams (lab benches or about 4 students) students react a small amount of biodiesel from recycled vegetable oil. After the finished product is made students use a fatty acid test to determine how far to completion the reaction went. This will reinforce the reaction rate concept that they learn in their course.

The physics curriculum includes background information on how energy is converted from the sun's light energy, in the form of radiation, to electrical energy, then to chemical energy stored in a battery, using a PV system. The curriculum includes visual aids such as a power point to demonstrate these conversions. Students then work in small groups (around 4 students), to wire up a scaled down version of a P.V. energy generation system. The students would use this to power LED light bulbs and measure the energy output.

The math curriculum gives students background information on multiple renewable energy technologies. Students are instructed on how to compute efficiencies. Students then individually calculate efficiencies of the different technologies given input/output information and compare, while taking turns at stations watching as the teacher demonstrate technologies to small groups at a time. Stations would include a PV cell to power a light bulb and a wave simulator in a fish tank.

3.3.4 **Minis**

For this alternative solution the box would contain information and background on four to five renewable energy technologies as shown in Figure 14. These would include: PV systems, fuel cell systems, wave energy systems, Windbelt energy generation systems, and Kite energy generation systems. This curriculum is expected to take three to five days based on the length of the class periods. The first day will be an introduction to the technologies through a PowerPoint presentation. After the PowerPoint the class breaks up into teams and do a more in depth study of the specific technology which they have been assigned. It will be left to the teacher to decide if groups get to choose their technology or if the teacher will assign them. This will conclude the first day.

Once the teams have researched their technology, they will build miniature models of the technologies. This could take two to three days. The materials and some basic instructions for the building of these technologies will be provided as well. These models will be used to power either a radio or a LED bulb. Students will use multi-meters to measure the voltage and current that is traveling through the wires that are connected to their renewable energy technology. They will then do some basic calculations to find the power output. The students will then give a little overview to the class of what they did to build their model. They will then compare their calculations to determine which the most efficient technology was.

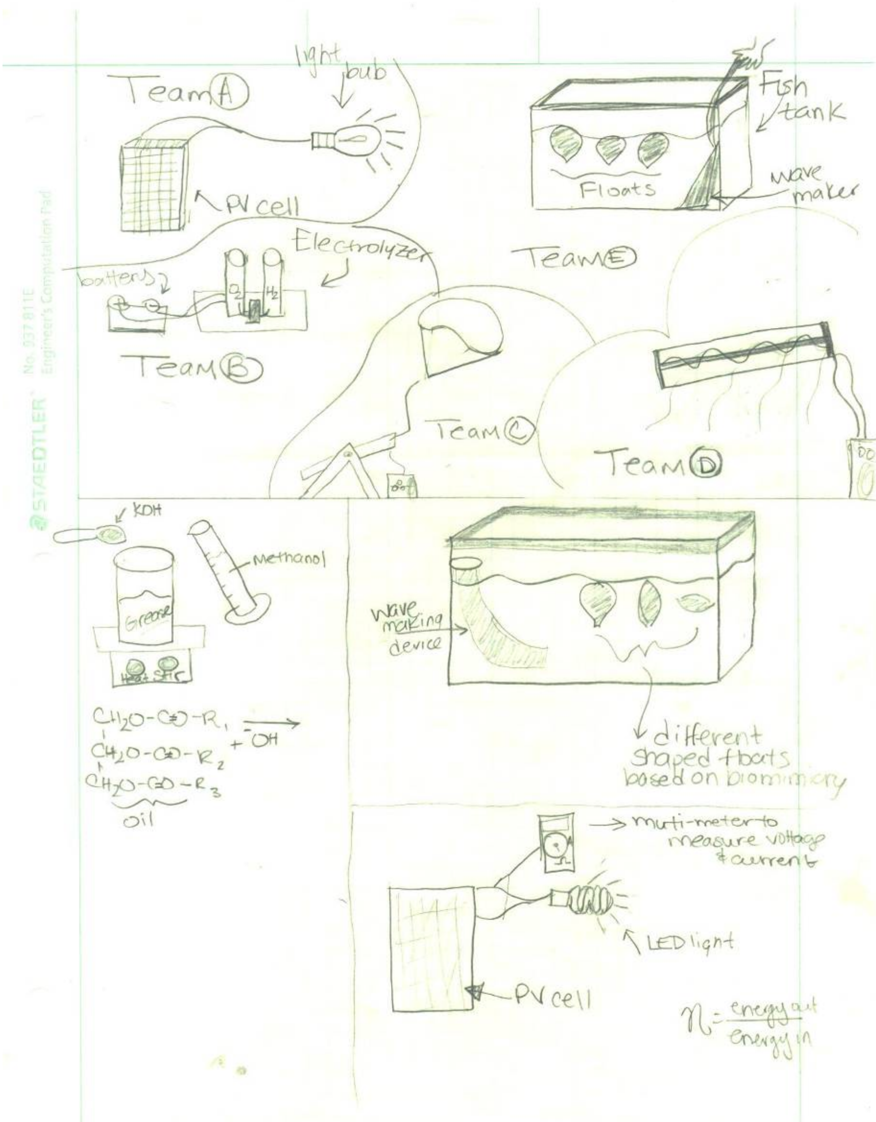

Figure 14-Hand written designs for Minis (top) and Course directed curriculum (bottom). (Johnson 2010)

3.3.5 **Hydrogen Balloon Demonstration**

The Hydrogen Balloon Demo intends to teach one of the many different uses and applications of wind energy, while showing the ability to use hydrogen gas as battery.

To start the demonstration a general PowerPoint on renewable energies. After the PowerPoint will be a small open-ended class discussion about renewable energies. The teacher then uses the provided electrolyzer to produce hydrogen gas. When enough hydrogen gas is accumulated it is put in a large balloon (Figure 15), which is then fitted atop a prefabricated balloon chassis and affixed turbines. The volume of gas must be buoyant enough to overcome the weight of the flight structure.

By measuring the amount of power required to make a given volume of hydrogen. The students can calculate efficiency of the system, therefore making a mental link to the transfer of energy that has just taken place (electrolysis= E+2 H_2O=2 O_2 + H_2). The process of electrolysis transfers energy in the form of electricity into chemical energy as hydrogen gas. This is a somewhat valid means of storing energy because the hydrogen can either be combusted or run through a fuel cell, once more transferring the chemical energy accordingly.

Once the hydrogen is collected and placed in the flight balloon, the balloon is affixed to the flight chassis and sent skyward. When aloft the turbines on the chassis will begin to turn, collecting wind energy. The electricity will then be sent down the wire to the ground where the voltage and current are to be measured. When the balloon has stabilized the group can hook up their device of choice to the leads connecting the floating balloon to the ground.

After calculations are completed and the model has fully demonstrated the somewhat flexible constraints of wind energy the balloon will be once more returned to earth. Whereupon the hydrogen gas within the balloon will be collected and can be used to be run through a fuel cell recombining with oxygen, forming water and electricity once more. the fuel cell could be used to again calculate efficiency of the system, therefore helping to put the total feasibility of hydrogen into focus.

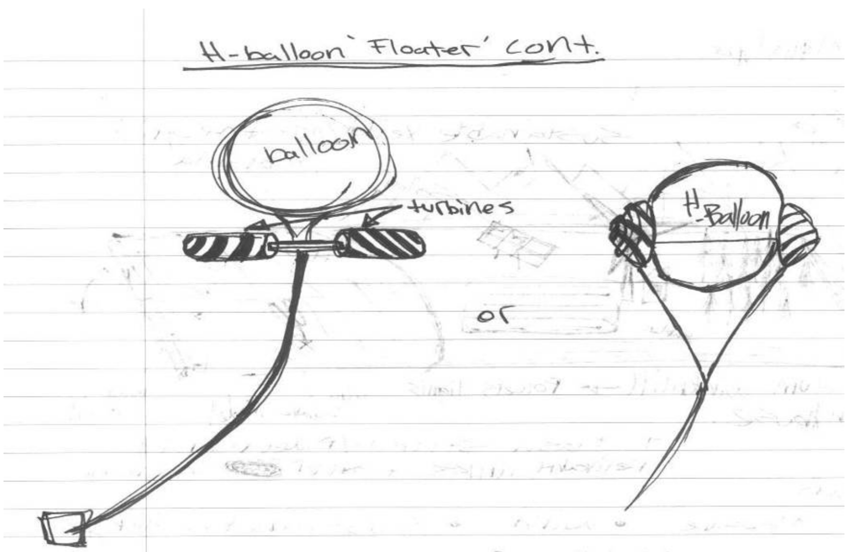

Figure 15-Design for Hydrogen Balloon Demo. (Theobald 2010)

3.3.6 **Diorama-rama**

The educational diorama is a prefabricated miniature model like the one in Figure 16. This model will be used to show a conceptual application of various renewable energies to help affirm and visualize technologies brought up in the given PowerPoint. It is also intended to show a fictional situation in which all of a persons energy needs could be met by themselves, allowing better coexistence with nature without sacrificing comfort or technology.

The wave pool (Figure 17) is set up with a simple hand powered wave pump and models of wave energy designs, which will be floating Styrofoam visual representations to help visualize the motions being captured by the actual designs.

The other half of the diorama will contain a small cabin with a Light-emitting diode (LED) housed inside, small representations of PV cells and a small wind-turbine that will actually make a small amount of energy from being cranked manually which will power the LED mounted in the house.

This solution includes an accompanying PowerPoint presentation, but because of the nature of the model this PowerPoint would be much more thorough to compensate for a lack of more hands-on work.

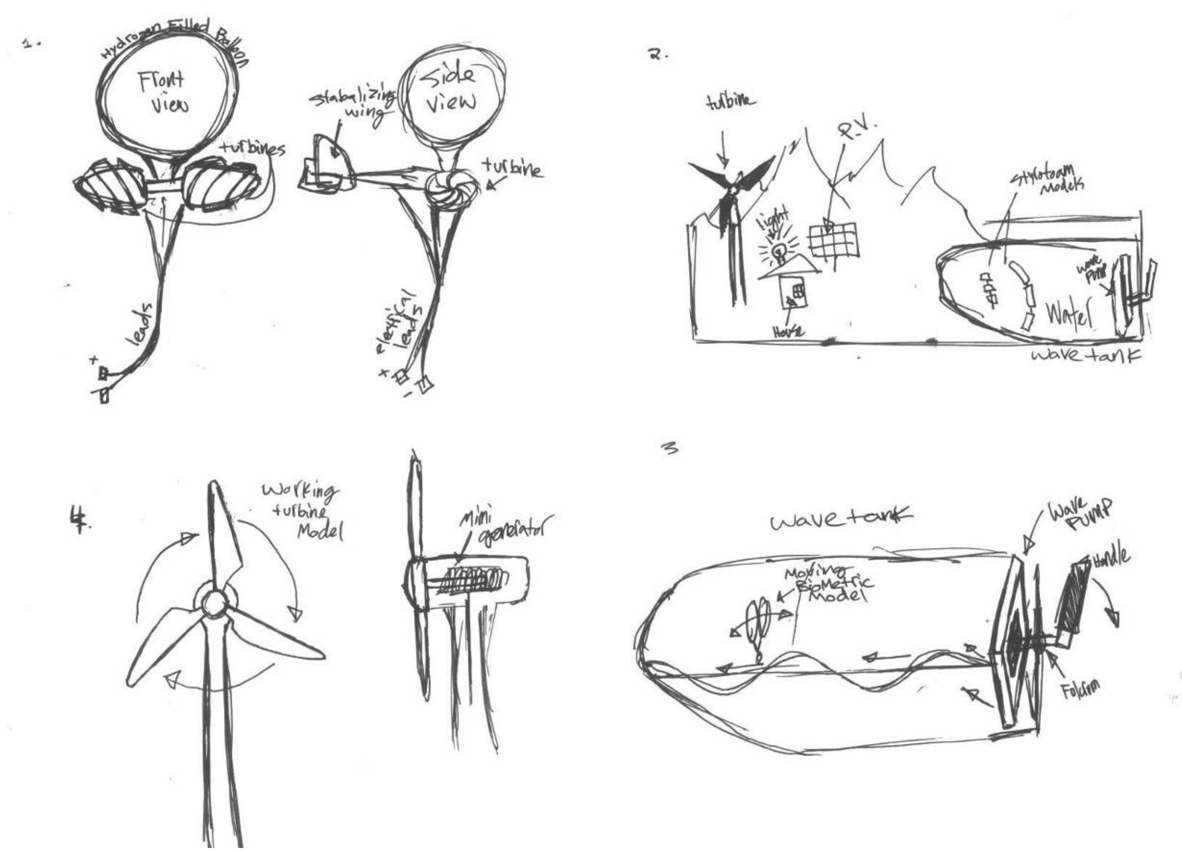

Figure 16-Part 1 of Hand written designs or Diorama-rama. (Theobald 2010)

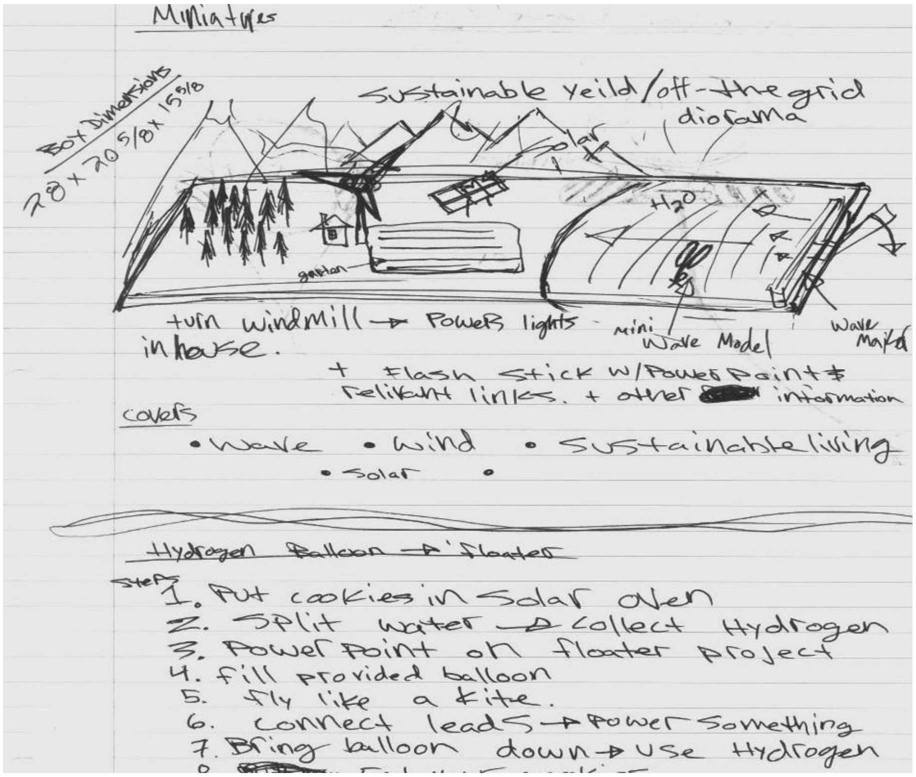

Figure 17-Part 2 of hand written designs of Diorama-rama. (Theobald 2010)

3.3.7 Human Renewable

This curriculum composes of different ways renewable energy can be conceptualized. Students will be participating in large-scale processes of different technologies like windbelts, PV, Wave Energy, and Fuel Cells. This box would also contain actual renewable technologies that students would then use to reinforce the concepts they learned.

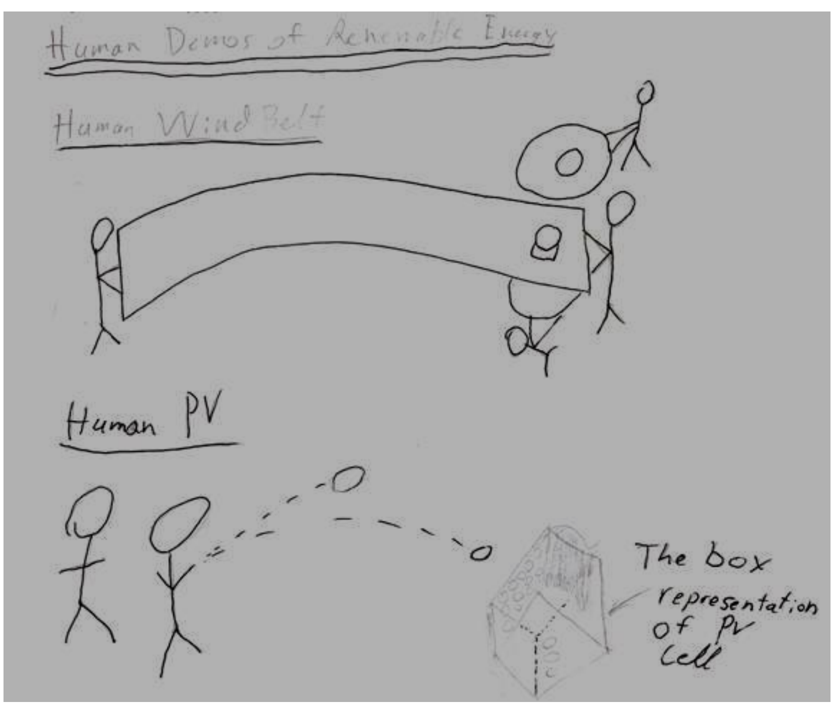

Figure 18- Part 1 of hand written designs of Human Renewable. (Pineda 2010)

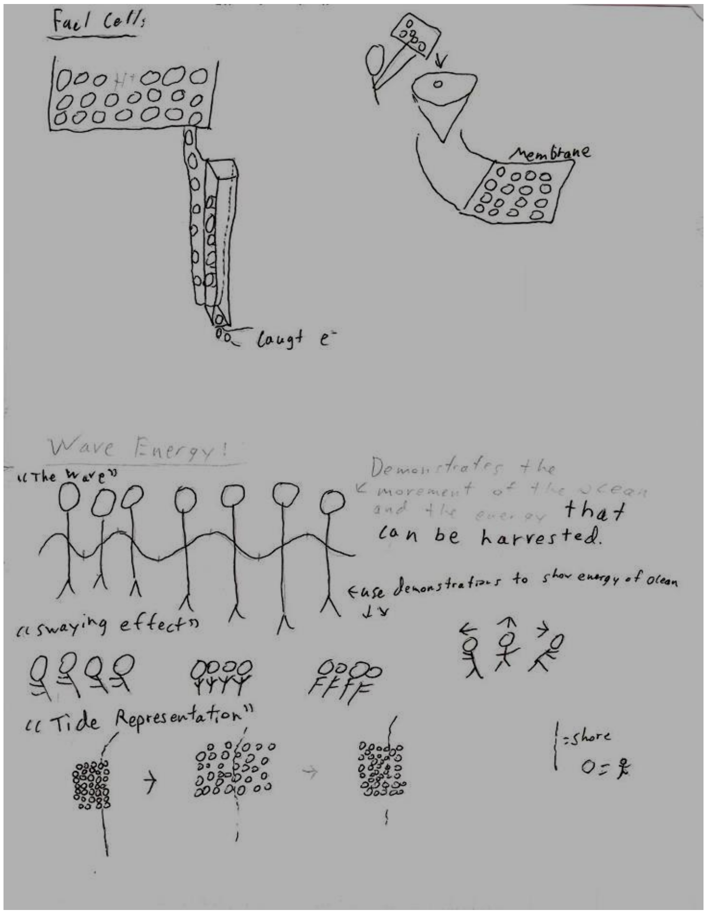

Figure 19-Part 2 of hand written designs of Human Renewable. (Pineda 2010)

3.3.8 **Energy in a Cinch: Windbelts**

In this curriculum, students will have a chance to compete against each other in groups to see who can make the most efficient windbelt. They will first be taught how a windbelt works in a PowerPoint and then they will be shown a base design of a windbelt to get an idea of what theirs should look like. The students will have a range of items to choose from to build their windbelts and will be able to test their designs. This curriculum will take 3 class periods, with a recommended 15 minute period each day to build and test.

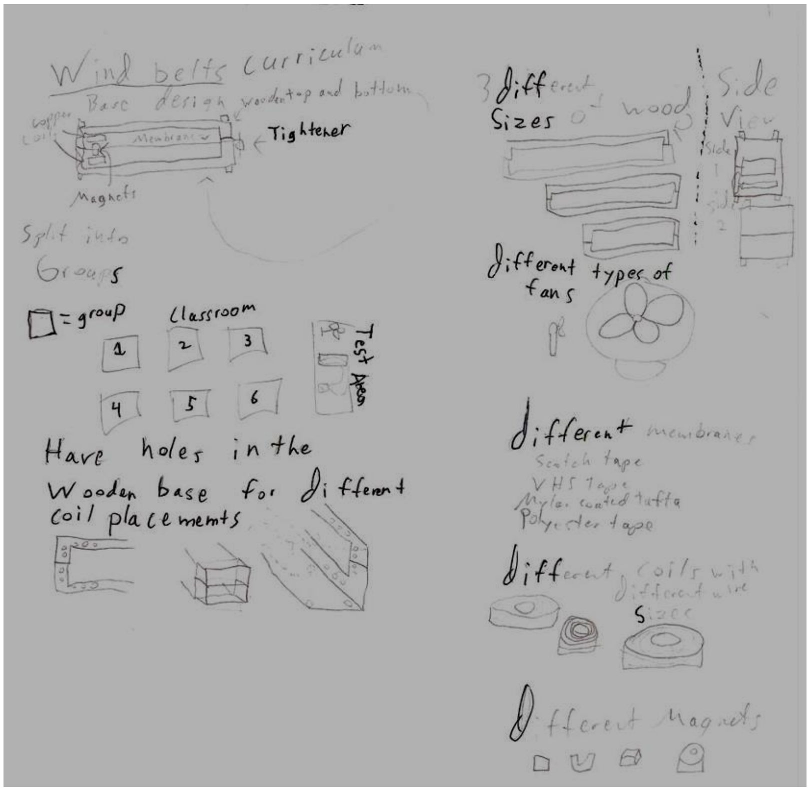

Figure 20-Hand written design for Energy in a Cinch:Windbelts. (Pineda 2010)

4 Decision Phase

4.1 Introduction

Section four describes the decision process used to determine which alternative solution from section three is the best fit for criteria from section two.

4.2 Criteria Definition

Level of Student Engagement: How physically or mentally involved students are while using the kit.

Ease of Use: The curriculum must be simple enough for High School Students to use and comprehend. The hands on portion of the experiment must be able to be conducted during a fifty minute class period.

Transportability: The curriculum must fit completely within box and be able to be lifted and moved by a teacher.

Cost: All materials used for building the curriculum must be under $400 total.

Durability: The components of the curriculum must hold up under use by up to 35 students twice a month for a year, components must be reliable and work during each use.

Pertain to Humboldt County: Information presented will be pertinent to renewable resources and projects around Humboldt County.

Safety: All components of the curriculum must be safe enough for use by students ages 14-18 under a single teachers supervision.

Take Home Knowledge: Students will finish the project with information on how renewable resources can benefit their community, as well as an understanding of what renewable energy is.

Aesthetics: Has an organized, professionally finished and well thought out design.

4.3 Solutions

There were eight possible solutions considered in the decision process:

- Build it, Fly it, Kite it
- Hydro-Racers
- Course-Directed curriculum
- Minis
- Hydrogen Balloon Demo
- Educational Diorama
- Human Renewable
- Energy in a Cinch: Windbelts

These solutions are described in detail in section three.

4.4 *Decision Process*

Team Aero and the RCEA weighted the criteria from 1-10 based on relevance to the project. The scores given by Team Aero and RCEA were averaged for a final decision weight as shown in Table 2.

Table 2-Criteria weights

Criteria	Student weight	Client weight	Final decision weight
Level of student engagement	10	8	9
Ease of use	7	9	8
Transportability	8	7	7.5
Cost	8	8	8
Durability	9	9	9
Pertinent to Humboldt county	7	8	7.5
Safety	9	10	9.5
Take home knowledge	10	9	9.5
Aesthetics	7.5	8	7.75

Table 3- Delphi table of the alternative solutions

Criteria	Weight	Alternative Solutions: Human Power	Course Directed Curriculum	Hydro-Racers	Kites	Hydrogen Balloons	Windbelts	Minis	Team Comparison Project
Level of Student Engagement	9	35 / 315	40 / 360	40 / 360	42 / 378	45 / 405	45 / 405	42 / 378	32 / 288
Ease of Use	8	40 / 320	30 / 240	30 / 240	37 / 296	30 / 240	35 / 280	32 / 256	45 / 360
Transportability	7.5	45 / 337.5	30 / 225	40 / 300	35 / 262.5	35 / 262.5	35 / 262.5	25 / 187.5	25 / 187.5
Cost	8	50 / 400	30 / 240	10 / 80	32 / 256	20 / 160	32 / 256	25 / 200	35 / 280
Durability	9	40 / 360	35 / 315	25 / 225	37 / 333	35 / 315	40 / 360	30 / 270	27 / 243
Pertaining to Humboldt County	7.5	40 / 300	35 / 262.5	45 / 337.5	47 / 352.5	47 / 352.5	47 / 352.5	42 / 315	35 / 262.5
Safe	9.5	50 / 475	25 / 237.5	40 / 380	45 / 427.5	35 / 332.5	45 / 427.5	40 / 380	27 / 256.5
Take Home Knowledge	9.5	35 / 332.5	45 / 427.5	40 / 380	40 / 380	35 / 332.5	45 / 427.5	45 / 427.5	37 / 351.5
Asthetics	7.75	30 / 232.5	30 / 232.5	40 / 310	40 / 310	37 / 286.75	40 / 310	40 / 310	45 / 348.75
Totals:		3072.5	2540	2612.5	2995.5	2686.75	3081	2724	2577.75

4.5 *Final Decision Justification*

Team Aero used the Delphi method to determine the final project from the solutions listed in section three. The final criteria weights are shown in Table 2. The alternative solutions were scored from 1-50, based on how well they met each criterion. By multiplying the criteria weight by score from 1-50 a criteria score was found. Then by summing all the criteria scores, a final score for each solution was found. The Delphi method is shown in Table 3.

Energy in a Cinch: Windbelts received the highest total score. The Energy in a Cinch: Windbelts kit is inexpensive and engaging to students. The curriculum includes building and the taking measurements. This solution is safe, as it contains no chemicals or dangerous components. This project will aid in the students "take home knowledge" as this is an active participation demonstration that is based on what the students accomplish and create through trial and error. This topic is pertinent to Humboldt County, which was weighted strongly by our client, because wind is a major renewable resource in Humboldt County.

Through testing of the *Energy in a Cinch: Windbelts* kit, it was found to be more effective and hands on project if students had the opportunity to work in smaller groups. Based on these results, the curriculum of the box was altered so that students could be put in teams of two or three to build and test one half of a windbelt and one coil.

5 Specification of Solution

5.1 *Introduction*

Section 5 describes the *Energy in a Cinch: Windbelts* solution. This section also gives a cost analysis of the solution and instructions regarding the implementation and maintenance of the solution.

5.2 *Solution Description*

The *Energy In A Cinch: Windbelts* curriculum is a three day curriculum that will provide teachers with materials to aid in teaching high school students about renewable energy. Included in the box is a PowerPoint presentation, which can be printed if no projector is available, that will provide background on renewable energy, a working model windbelt (Figure 21) and close up view of coil in Figure 22, a table top fan, a multi-meter, 12 wooden bases, four of each size, pre-cut Mylar coated taffeta belts, twelve copper coils and 30 neodymium magnets. The box will contain three different-sized bases and three different sized coils. The fan is included to provide a source of wind for the classroom setting.

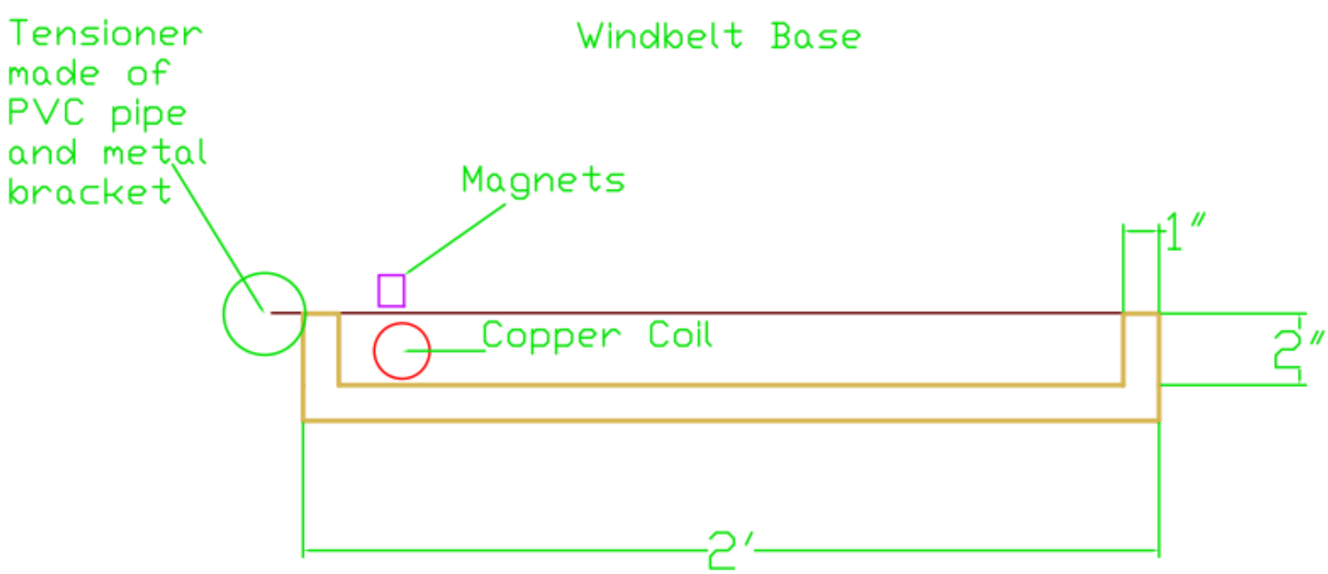

Figure 21- CAD Schematic of the Model windbelt. (Johnson 2010)

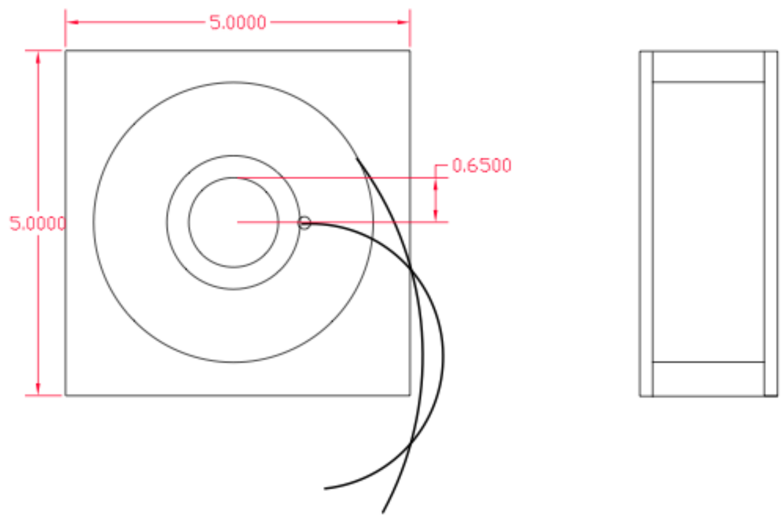

Figure 22- CAD drawing of coils used for model windbelt. (Theobald 2010)

A windbelt consists of a piece of thin, non-elastic Mylar tape stretched between two points on a base. At one end of the base, magnets are placed on either side of the tape. These magnets rest between two copper coils attached to the base. A prototype windbelt is shown in Figure 23. Windbelts generate electricity as the wind moves the tape or “belt” up and down creating aeroelastic flutter. This flutter causes the two magnets to oscillate, which in turn disrupts the magnetic field of the copper coils creating a current. This process is called induction. A hand wound copper coil and magnets, attached to the prototype are shown in Figure 24. Aerolastic flutter can be seen in Figure 25. This flutter happens when wind causes a surface to produce sinusoidal vibrations. The oscillation of magnets between the coils creates AC current. By using diodes, connected together to form a rectifier, this AC current can be converted to DC, which can then be used to power LEDs and other small electronic devices.

Figure 23- Prototype windbelt, shown here in two halves. The bottom half has the belt attached. (Leopardi 2010)

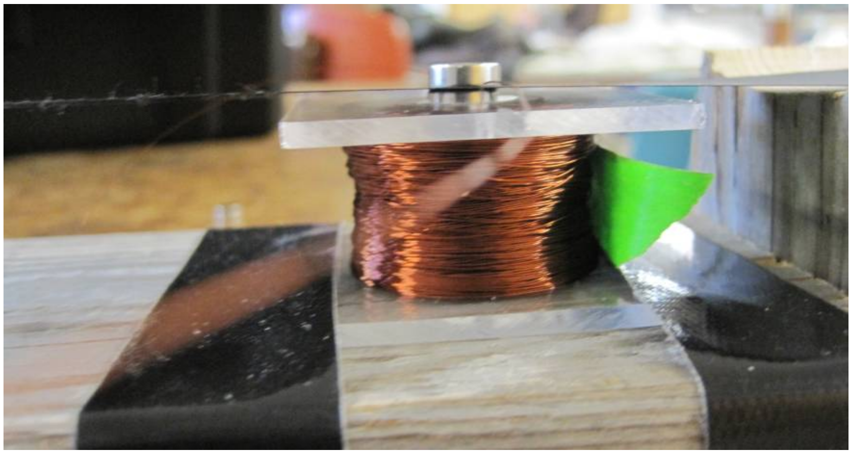

Figure 24-Copper coil and neo-dyminium magnets used to generate current. The coils used in the project are hand wound. (Leopardi 2010)

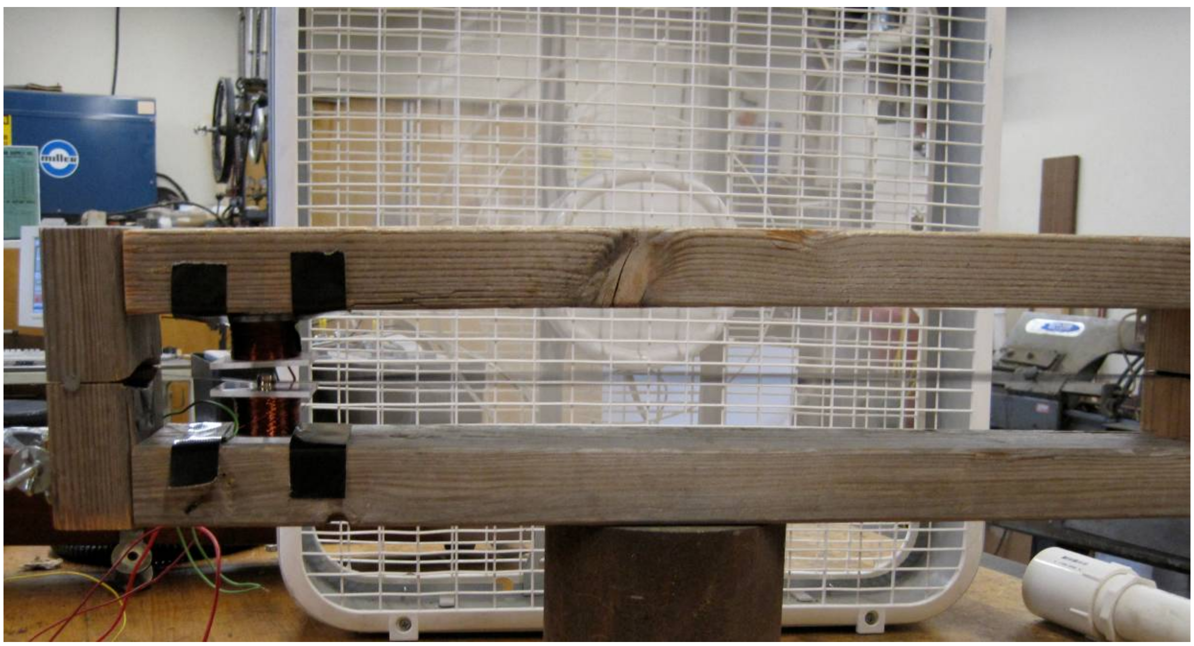

Figure 25-Picture of belt in areoelastic flutter. (Johnson 2010)

Day one of this curriculum will begin with the teacher giving a PowerPoint presentation, or if no computer is available a printed version of the PowerPoint will be handed out. This presentation gives a basic background of solar, micro-hydro and wind as renewable energies. The presentation will explain what a windbelt is, how they work, what their use is around the world and how they are relevant to Humboldt County. The teacher will give a demonstration of with the model windbelt of how a windbelt works. The demonstration will also allow students to see all of the components to the windbelt. On day two students will be given instructions on how to assemble a windbelt. The class will be split into twelve teams of two to three students and given one half of a windbelt base, one belt, one coil and two magnets. Students will attach the belts to the bases and be asked to test the movement of the belt in front of the fan to see how the belt moves and reacts to tensioning. The teams can then experiment with placement of magnets and coils, as well as tension of the belt to see what placements and tuning are most efficient for the size of base and coil they are testing. On day three teams will use a fan and multi-meter to measure voltage output for the windbelt. The students can make adjustments to the coil angles, placement of magnets and tension of Mylar tape to achieve the greatest voltage, which will be measured using a fan and multi-meter included in the box. Teams will be challenged to see if they can produce 0.1 Volts, 0.3 Volts, 0.5 Volts or greater. Teams with same size of base can also combine to make a complete windbelt with two coils and experiment with the results they get. The teams will then come together to present the finished windbelts. They will give a description of the building process and an explanation of adjustments they made. Students will also have the opportunity to try to power an LED light by hooking up the windbelts through the rectifier. Complete teacher and student instructions can be found in Appendix B and C.

5.3 Cost Analysis

5.3.1 *Design*

The design cost of the box consists of the total number of hours of work put into the design by all team members. The hours are organized by phase; the number of hours per phase is located below in Figure 26. The total design cost is 234 hours of work.

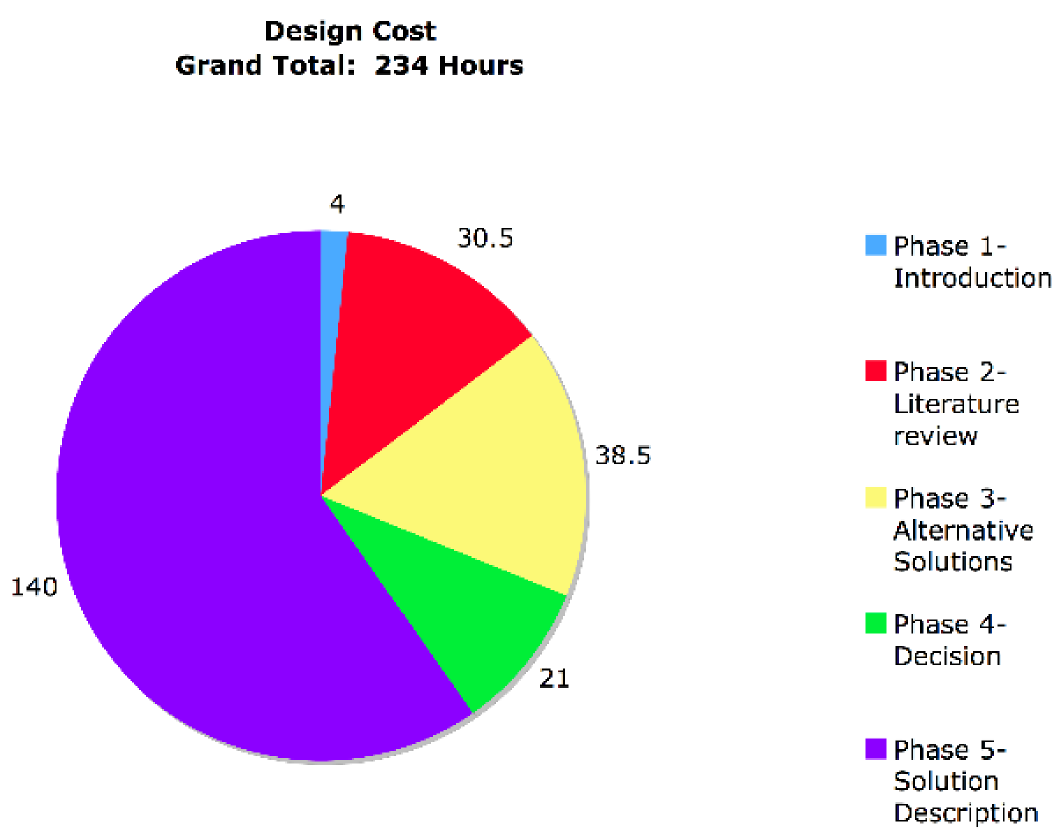

Figure 26-Design cost in hours

5.3.2 ***Implementation***

As specified in the criteria of the project there was a maximum implementation cost of $400, this includes $75 per design student and $100 given by RCEA. The cost of all materials needed for *Energy in a Cinch: Windbelts* are listed in Table 4. The table contains an actual and retail cost of all materials. The total cost was $216.79. This is $183.21 less than the $400 allotted.

Table 4- Table of Materials Costs. The total cost for all materials came to $216.79.

Item	Quanity	Our Cost	Retail Cost
Magnets	1 set of 30	$16.01	$16.01
Mylar coated Taffeta Tape	5 yards	$8.80	$8.80
1 x 3 lumber	29 feet	$15.38	$15.38
Copper wire	1 large spool	$0.00	$15.00
Copper wire	2-3 packs/1 spool	$34.00	$34.00
Multi-meter	1	$29.99	$29.99
LED lights	1-20 pack	$2.99	$2.99
Bread board	2	$23.90	$23.90
Spools	14	$0.00	$10.00
Dowels	28	$0.00	$5.00
Epoxy	1-25 mL tube	$4.99	$4.99
Epoxy	1-10 oz tube	$4.79	$4.79
Flash drive	1	$8.00	$8.00
Tackle box	1	$9.80	$9.80
Various nuts and bolts	numerous	$5.04	$5.04
Batteries	1-4 pack	$4.49	$4.49
Boxes	2	$22.00	$22.00
VHS tape	1	$1.09	$1.09
Diodes	12	$4.95	$4.95
Capacitors	2	$3.00	$3.00
Shims	1-14 pack	$2.49	$2.49
Screw driver	1	$4.99	$4.99
Sand paper	2 sheets	$2.50	$2.50
Alligator clips	4	$2.60	$2.60
Gorilla tape	1 roll	$4.99	$4.99
PVC pipe	2	$0.00	$10.00
Total price		**$216.79**	**$256.79**

5.3.3 ***Maintenance***

Energy in a Cinch: Windbelts is designed for a class of 30-35 students. After each use students will be responsible for disassembling the windbelts and putting the coils, magnets and Mylar tape back into the tackle box for the next class to use.

The teacher will use the checklist provided in the kit to make sure all components have been returned after each use. This should take about ten minutes per use. The RCEA should also use this checklist when the kit is returned to them.

It is projected that the batteries of the multi-meter will need to be changed once a year.

The total projected maintenance cost is $85 per year. Table 5 shows the itemized maintenance costs.

Table 5- Maintenance costs

Maintenance	**Cost**	**Frequency**	**Cost per Year**
Change batteries	$4.49	Once a year	$4.49
Gorilla Tape	$4.99	Twice per year	$10.00
Using Checklist of items	$10.00/hour	4 hours per year	$40.00
Cutting Mylar tape for belts	$10.00/hour	3 hours per year	$30.00
		Total Maintenance Cost	**$84.49**

5.4 *Implementation Instructions*

Teachers must begin by reading the provided outline of the presentation on renewable energy and practice using the model windbelt. If no projector is available in the classroom the slides can be printed and used paper or overhead projector transparencies. The outline provides the teacher with background on the renewable energy technologies, which will be presented to the class and the talking points to accompany the PowerPoint.

The presentation introduces the students to renewable energy technologies, as well as the background and concept of a windbelt. Once the students have been introduced to the ideas, a short discussion should take place to answer any questions or talk about their thoughts on renewable energy and windbelts. After the discussion the teacher will demonstrate how the windbelt works, and show its components on the provided model. The teacher will be asked to use the tabletop fan and the LED light connected to a rectifier to show that power is produced.

The students will then be broken up into twelve teams. Each team will be given a one half of a windbelt base, one coil, two magnets and a strip of Mylar coated taffeta. The teams can then begin to assemble their own belt. Once the components are put together properly the teacher will come check the set up. The student-assembled windbelts will then be tested using the tabletop fan to provide wind, and the multi-meter to find the power output. If a voltage registers on the multi-meter, the windbelt can be hooked up to the rectifier, which is connected to an LED light. The LED requires about 1.7 volts to light up.

5.4.1 *Maintenance Instruction*

In order to insure that all components of the curriculum are returned after each use, a checklist of included items should be reviewed each time the box is returned to RCEA. This checklist can be found in appendix D. The batteries of the multi meter should be checked each time it is returned as well. To cut more Mylar belts from the roll, clamp the included clear cutting jig firmly to a table. Cut the large roll to about 26 inches. Align Mylar properly, push edge of tape against white rail and slowly pull the Mylar in the direction the arrow is pointing, making sure to keep the edge of the Mylar against the white rail. Pull in one direction while cutting. The proper alignment can be seen in Figure 27.

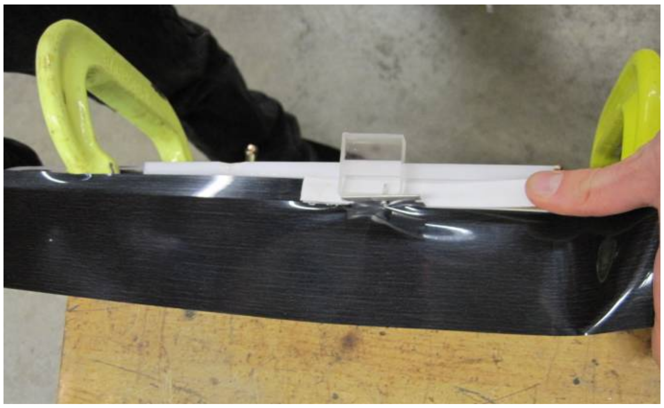

Figure 27- Cutting jig used to make thin belts. (Johnson 2010)

5.5 ***Prototype Performance***

The model windbelt is two feet long, four inches tall, consistently produces 3.3 volts of Alternating Current and can power an LED. This is the final model that will be used by teachers to demonstrate a working windbelt. The model can be seen connected to the rectifier with a LED in Figure 28.The students who tested the project gave positive feedback and were excited about building, adjusting and testing the windbelts as seen in Figures 29 and 30.

Figure 28- Model windbelt to be used in classrooms. (Johnson 2010)

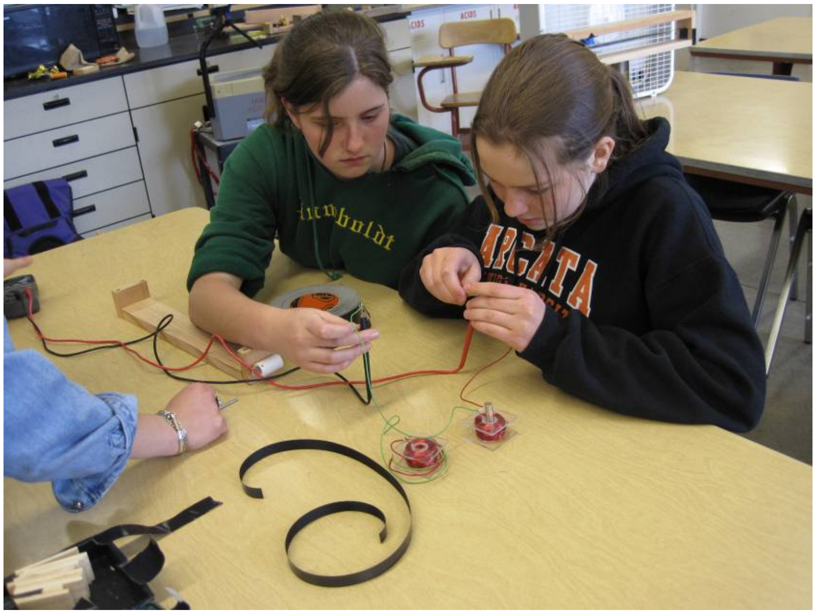

Figure 29- Students testing coils. (Leopardi 2010)

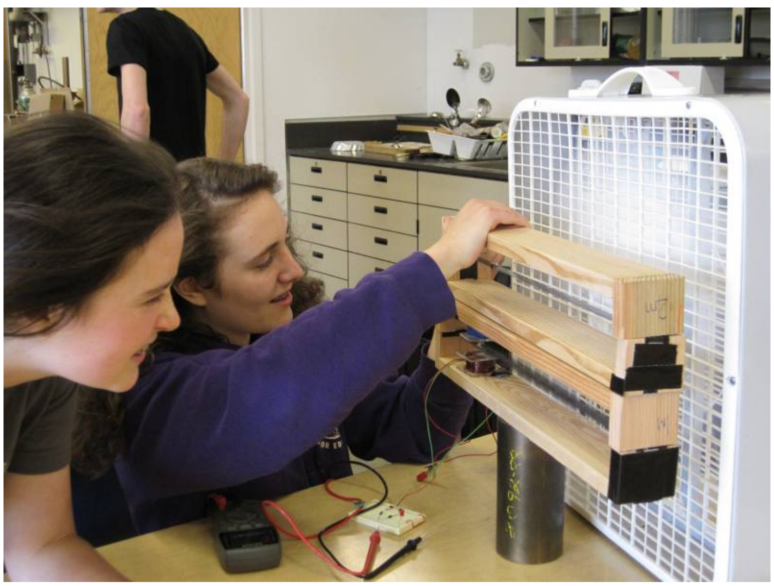

Figure 30-Students testing belt tensions. (Leopardi 2010)

The final design of *Energy in a Cinch: Windbelts* fits the criteria that were defined to meet the projects objective statement. The curriculum is hands on, engaging to students and they will leave the class with knowledge they gained from participating. It is safe, and easy to use for high school age students when following the provided instructions. The topic is relevant to Humboldt County because wind is an abundant resource in Humboldt County. All of the components fit into the two totes that were provided by the RCEA to be transported. Figure 31 shows how all of the components fit into the totes, and Figure 32 is a digital rendition of how the bases fit.

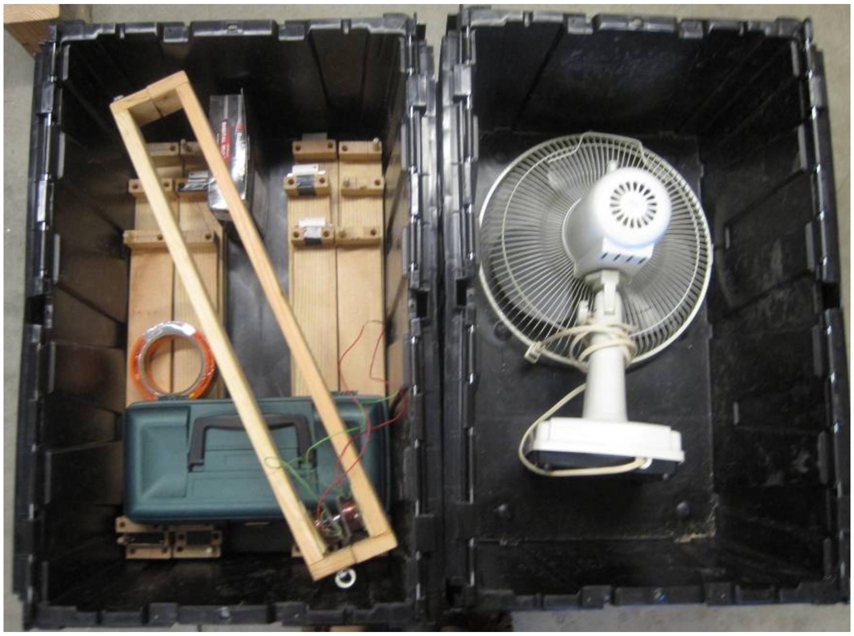

Figure 31- ***Energy in a Cinch: Windbelts*** **kit packed into totes, ready to be transported. (Johnson 2010)**

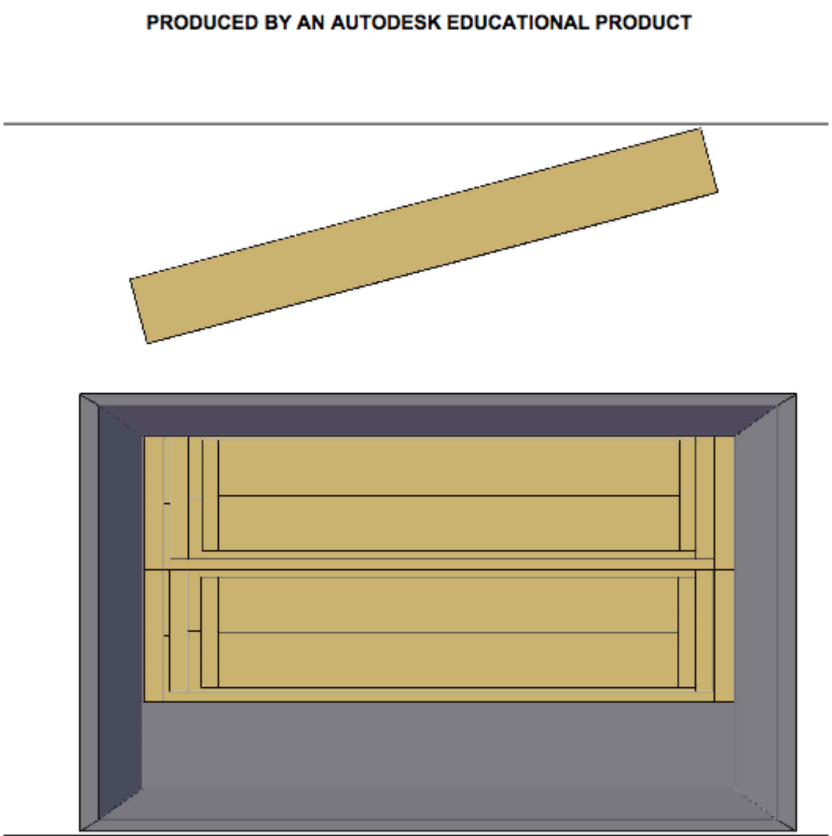

Figure 32- CAD of bases in tote box and model base to the side. (Pineda 2010)

Appendices:

A. References

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B. Teachers Instructions

Make sure that all parts are in the box using the checklist provided.

Day one:

There is a flash drive provided that has visual aids and background information on various renewable energy technologies. Use this as an aid to introduce students to the topic of renewable energy. The final slides go into wind energy, and windbelts.

Using the tabletop fan and the pre-assembled model show students how the windbelt works. The belt may need to be tuned using the tensioner and the tensioning mechanism. The fan can be moved until the belt is oscillating most efficiently, this can be determined through the use of the multi meter or the ability of the belt to light the LED. Usually, the windbelt must be placed on an object so that it is a little over one foot from the table and angled slightly towards the fan. To connect the windbelt to the rectifier the two red wires from the coils must be connected using an alligator clip and the two green wires connected to the leads with alligator clips. Refer to the included visual aids that show how the energy is converted from kinetic to electrical.

Day two:

After a demonstration of how the Windbelt works, break the class up into teams. There are twelve bases for building Windbelts, so size groups accordingly. Show teams the assembly instructions that are provided on the flash drive. Give each group a windbelt base. Allow students look over instructions and start building. Address questions and refer to power point or other background information as needed. Teams should have various sizes for bases, various size of coils used, and various material used for the belt.

Day three:

Once wind-belts have been assembled, teams should take turns using the multi-meter to measure the output from their windbelt. They can also hook the windbelts to a rectifier, which is connected to a LED light to try to power it. Have students keep track of the voltage so they can compare between groups. Once all groups have tested their Windbelts, facilitate a class discussion about how the winning team got the highest voltage. If there is time the windbelts can be connected to one another to achieve higher voltage.

C. Students Instructions

The bases to the windbelts have been pre made and provided in the kit.

With your group discuss which “belt” material are the best fit for your base.

Follow the assembly instructions that are provided by the instructor.

Once you have constructed your windbelt have your instructor check it over. It will be stored for the next class period.

Your instructor will show you how to use a multi-meter, if you haven’t already used one. Using the multi-meter and the tabletop fan, measure the power output of your windbelt. Keep track of the voltage that is measured so that it can be compared later. Make adjustments to the angle of the coil, the tension of the belt and the speed of the fan to increase the voltage.

Then, having your instructor help with the wiring, hook up the Windbelt to the rectifier, which has a LED attached. Run the fan on the wind-belt to try and power the LED light.

When each team has measured the voltage from their windbelt compare these numbers to see which team got the highest voltage. Discuss your teams approach to achieving this voltage.

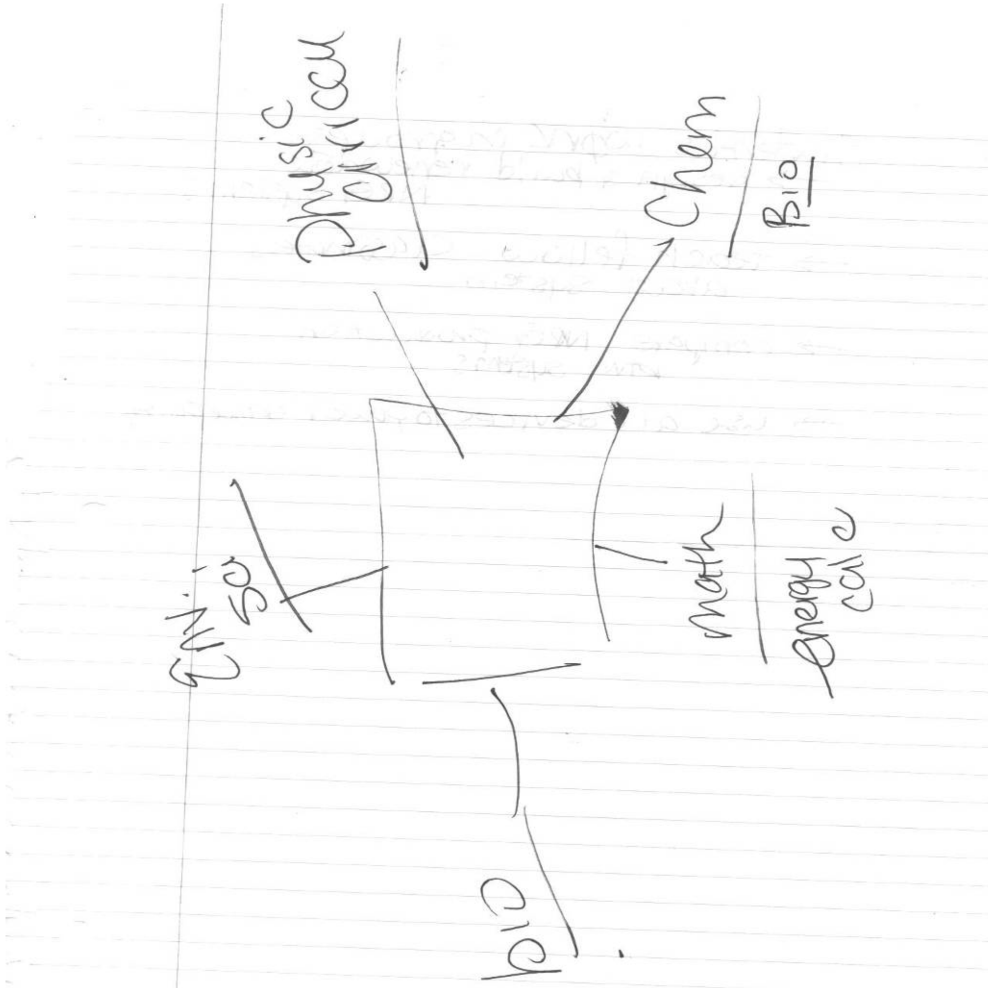
Carefully remove the belt material from the your windbelt base. Also remove the coils and the magnets. Return all components to the correct place in the kit.

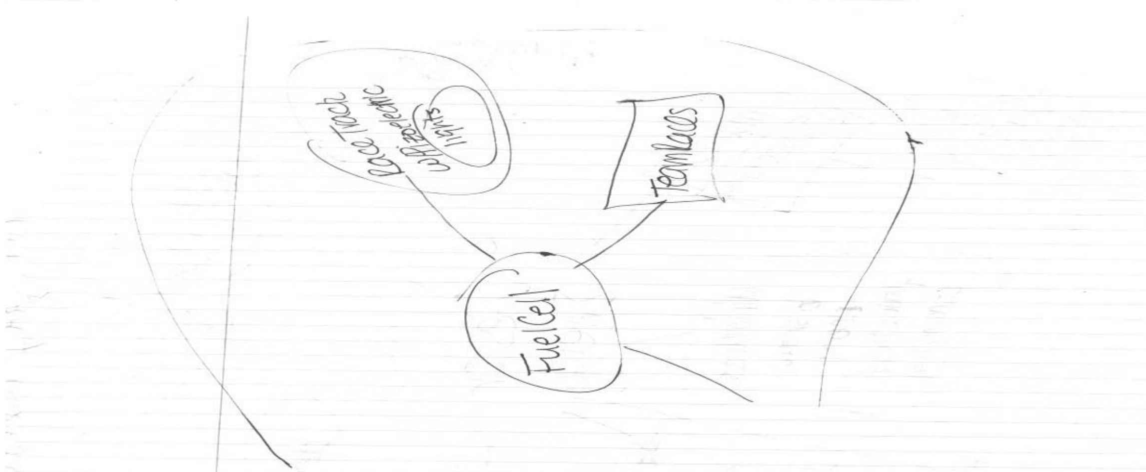
D. Contents Checklist

Contents of Renewable Energy Curriculum Box

Check In	Quantity	Description
	1	Pre-assembled Windbelt (for use by instructor)
	5	Windbelt Base
	10	Copper Coil
	28	Rare Earth Magnet (WARNING: TEHSE ARE VERY STORNG)
	6	Pre-cut Mylar Coated Taffeta Belt
	1	Multi-Meter
	10	LED Light (multiple colors)
	1	Table Top Fan
	1	Flash Drive with Instructional Material
	2	Diode Rectifier
	5	Tensioning Lever
	1	Roll of Gorilla Tape
	1	Small Phillips Head Screw Driver
	1	Belt Cutting Jig
	20	Wooden Shims
	1	Roll Extra Mylar Coated Taffeta Tape
	1	Roll VHS Tape (for experimenting)
	4	Alligator Clips

E. Brainstorm Notes





Students work in groups
→ design & build renewable NRG systems
→ teach fellow classmates about system
→ compare NRG production btw. systems
→ use all devices to power dance party.