

Lighting an African School with Alternative Energy

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1. Abstract

Insufficient lighting is an issue in many poverty-stricken nations. Without proper electric lighting, residents of impoverished communities resort to using potentially hazardous light sources, such as kerosene lamps, candles, and car batteries used to light lightbulbs.

Burkina Faso, located in western Africa, is one of the poorest nations in the world, with an annual per capita income of \$440. Our goal is to power a school in Yaba, Burkina Faso because it currently has no electricity.

The power sources that we considered included wind, solar, hydropower, combustion of biomass, and energy-generating playground equipment. After taking efficiency, cost, and sustainability into account, it was decided that Shawn Frayne's invention, the Windbelt seemed most feasible for implementation in Yaba. This piece of technology would be best because it is easy to store, easy to repair, and relatively inexpensive.

2. Introduction

Extreme poverty, corruption in the government, and lack of running water are just a few of the problems in Yaba, Burkina Faso. The residents of this area also do not have electricity, which means that their

school does not have lighting. The children attend school in the morning and late afternoon because it is too hot for the children to be in school at midday. At night, the girls have an obligation to prepare dinner for their families and take care of their younger siblings. Since the majority of the village cannot afford proper lighting, town meetings cannot be held at night and children cannot study.

A project like this is normally executed in stages. First, a contact is established with a resident of the area in need. This contact provides the specific details about the problem to the engineers. Next, an assessment of the situation is made through several trips to the area. During these trips, residents are interviewed to determine the major problems in that area and decide whether or not the people need and want the help of the engineers. Then, the design process begins and the plans are laid out to be put into effect. Finally, the team returns to the area in need, implements the design using the labor of members of the community, and teaches the residents of the community how to repair and maintain the equipment.

3. Background

The alternative energy sources initially considered were solar power,

hydropower, wind power, solar thermal power, biomass, and human-generated energy (such as electricity-producing playground equipment). Options for power sources were narrowed down after environmental limitations, complexity of design, cost, and availability of materials were taken into consideration.

Solar power was an option eliminated for economic reasons; the price of one photovoltaic panel averaged \$300. Since Burkina Faso is a poverty-stricken country, the residents would not be able to afford to maintain these expensive panels. Also, the device needs to be simple so it can be repaired by the townspeople with ease, but a solar power system is complex and difficult to repair. Hydropower was eliminated because it is usually used in conjunction with solar power and there is no source of running water in the region.

Methane gas capture involves burning biomass, usually firewood or rotting vegetation; this would not work because there is very little vegetation in Yaba. The vegetation that is there is used for consumption and cannot be wasted.

We narrowed our search down to human-generated energy and wind power. Human-generated energy was eliminated once we learned about the daily routines of the average child in Yaba. Originally the design plan was to use a merry-go-round for the children to play on that would create energy using a turbine. Through our interview with Andrea Kung, we realized that this was impractical because the children do not have any playgrounds or much play time. The girls have to help take care of the family and feed the family and the boys need to help plant and harvest the crops. When the boys are not working soccer is the only recreational activity they participate in.

The final alternative energy source decided on was wind. Wind turbines are

expensive, usually over a thousand dollars each, and are therefore not feasible for implementation in Yaba. The design created by Shawn Frayne, known as the Windbelt, could be a potential solution to these problems with wind power.

The Windbelt is small, and thus easily transported. It has a simple design, which makes it easy to repair. Also, most of the materials are easily accessible and affordable for the residents of Yaba. The device consists of a tensioned membrane that oscillates between two magnets when wind is present in order to produce electricity. Humdinger wind energy (Frayne's company) has three sizes of Windbelts: micro, medium, and large.

The micro Windbelt, as its name suggests, is the smallest model. It requires a minimum wind speed of five miles per hour and can function properly in winds up to twenty miles per hour. Intended to be used as batteries are currently, the micro Windbelt can produce approximately 200 watt-hours (Wh) over a 20 year lifespan [1], which is enough to power a small LED. The micro Windbelt is capable of producing a maximum of 40 milliwatts in 10 mph winds [1]. It generates AC power that can be converted to 3 volt DC power. Also, the micro Windbelt is small enough to fit in a person's hand. Even though this model of Windbelt is easily stored and does not require as much material to build and maintain, it does not produce enough electricity to feasibly power fluorescent light bulbs.

The medium Windbelt, which ranges from 1-3 meters in length, is the best model that could be used in the school. It has an output of 5 Watts. If multiple medium Windbelts and ample energy storage could be implemented, they could reasonably power fluorescent light bulbs. The main problem with this model of Windbelt is that it has not been fully developed. Therefore,

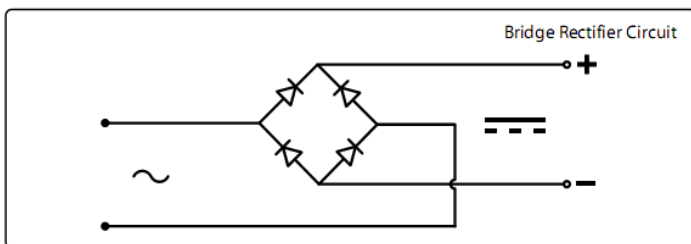
the costs of implementation and maintenance are currently unknown.

The large Windbelt, which is 8 meters in length, would not be a practical power source because it could not be easily stored.

The school has ten rooms that need light, each 75 meters squared. If two lightbulbs are installed per room, 20 total lightbulbs would be needed. Assuming that each bulb requires 40 watts, we would need to produce 800 watts. Therefore, we would need to implement 160 medium Windbelts, which produce 5 watts each.

The Windbelt produces power through a series of steps. When wind blows across the membrane, vibrations are created through a phenomenon known as aeroelastic flutter, the same phenomenon that caused the collapse of the Tacoma Narrows Bridge. The membrane then moves the cantilever, causing the magnets to oscillate. The oscillation of the magnets induces a current through the coil; this current travels through the coil and to the circuit board. However, the Windbelt produces alternating current, and the lightbulbs run on direct current. Therefore, we used diodes in the circuit board to control the flow of the current (see figure 1).

Figure 1



A bridge rectifier unit, shown above, converts AC power (coming from the left) to DC (the + and - output on the right) using diodes (represented by triangles). [2]

After passing through the circuit board, the current travels to a capacitor which smoothes the current to create a direct current to the load.

4. Design Decisions

The Windbelt was invented to light LED lamps and radios in the homes of the less fortunate in Haiti. We believe that this alternative energy source will be feasible in an area such as Yaba because it has a cool, windy season lasts from November to February and some wind during the hot season.

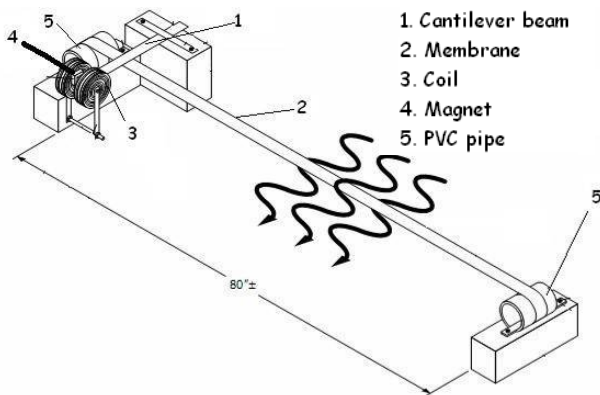
In choosing a source of energy, availability of materials must be taken into account. Many energy sources use materials that are costly for people in third-world countries to maintain. Many are also very difficult to upkeep and repair after they are installed. Our prototype of the Windbelt was constructed using metal coil, PVC pipe, wood, aluminum brackets, sheet metal, carriage bolts, nuts, screws, magnets, and a tight membrane. All of these materials can be bought by the village for maintenance purposes.

Yaba is a village that suffers from poverty and crime. This is why the source of electricity implemented would need to be small and easy to store. The school does not have proper security because its aging security guard is not physically able to stop thieves. In Yaba, it is rude and disrespectful to fire an elder, so the school will not get a new security guard. In fact, the school has already considered installing solar panels on the roof of the school, but decided not to because they might get stolen. Therefore, the Windbelt that we would implement would have to be easy to carry. The smaller the Windbelt is, the less power it produces. However having an easily stored Windbelt that generates less electricity would be better than a more powerful Windbelt that could possibly get stolen.

Constructing a Windbelt is not a complex or time-consuming project. The first step in constructing the prototype was assembling the two belt mounts with blocks of wood that should be cut to be 2"x2"x5" and use the aluminum brackets to attach the PVC piping to the wood blocks on either end. The wooden blocks should be about 80" apart to anchor the belt mounts. Next, the belt was loaded onto each belt mount with tape while turning the PVC pipe to ensure there was enough tension. Then, the cantilever was assembled using 2"x3.5"x4" wooden blocks, aluminum brackets, a piece of sheet metal, screws, and two magnets. Then, the cantilever was anchored so that the strip of metal lay across the belt and the magnets were 2" from the belt and the cantilever was taped to the belt. Finally, the coil was assembled using cooper wire, aluminum brackets, and a carriage bolt. During experimentation, we determined that thinner wire (30 gauge) induces a stronger current than the thicker wire (26 gauge).

The final product was a Windbelt approximately 6.75 feet in length. However, length can be increased or decreased to test the efficacy of the Windbelt.

Figure 2



Wind blows across the membrane, making it oscillate. The oscillating Windbelt makes the magnets vibrate and induces the wire to create a current. [2]

Since the majority of the electricity is generated during the day and the lightbulbs are used at night, energy storage is necessary. The two main sources of storage that are available to the people of Yaba are car batteries and dry cell batteries. Car batteries are less expensive, but have to be replaced more frequently than dry cell batteries. Even though dry cell batteries are more expensive than car batteries, they last longer and can store more energy. Therefore, using dry cell batteries would be a more feasible energy storage method.

5. Engineering Analysis

In the original Windbelt design, Mylar-coated taffeta tape was used as the membrane to oscillate between the magnets and generate power. In our design, we changed this membrane to packing tape because Mylar-coated taffeta tape is not readily available to the residents of Yaba. Packing tape is easier for the villagers to find, even though they may have to travel to another town for it.

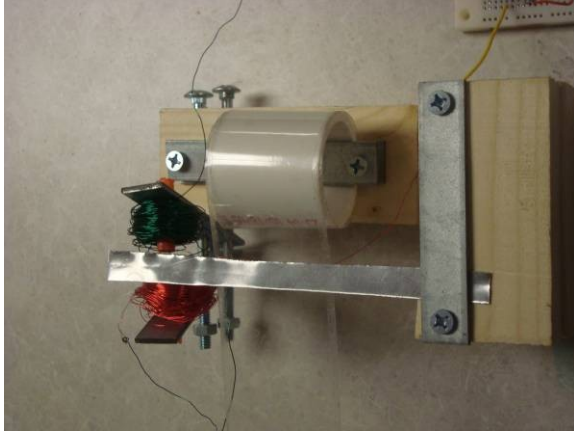
The Windbelts that will be implemented in Yaba will be slightly different than the original idea and our prototype. Our prototype is the size of the medium Windbelt, but with the power similar to that of the micro and was built to power an LED light bulb for demonstration. The medium sized Windbelt would need to be implemented, rather than the micro Windbelt, to meet the energy needs of the school.

After testing our prototype we discovered that it produces very low voltage; it generally produces less than one hundredth of a volt. This is not even close to enough voltage to power a small LED.

Several alterations may be made to try to improve this system. The mylar-coated taffeta tape could be used (as it is supposed to be) in place of our tape. Generally speaking, the entire device would need to be much larger. Hopefully, this

would produce a higher voltage. Unfortunately, this will add to the cost because the use of more material makes the Windbelt more expensive to create.

Figure 3



Top view of the prototype. On the bottom-left are the red and green coils. The oscillating cantilever beam is located between the two coils.

Figure 4



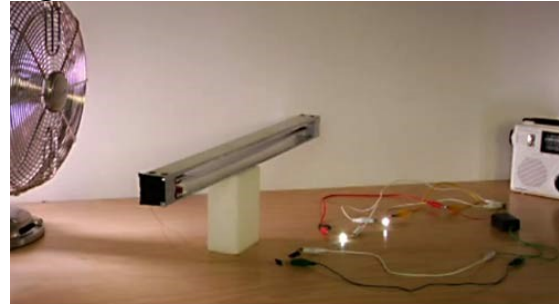
Side view of the prototype. PVC pipe is mounted between two metal brackets.

6. Related Works

Our prototype was based off of Shawn Frayne's invention, the Windbelt, which was developed to power lights for destitute people in Haiti in place of Kerosene lamps, which are potential fire hazards. Frayne's invention has a simple design and is inexpensive to make. His idea

of harnessing energy from wind blowing across a membrane was inspired by the collapse of Washington's Tacoma Narrows Bridge. Although the prototypes are simple, some have still produced 40 milliwatts of energy with only 10 mph winds, "making his device 10 to 30 times as efficient as the best microturbines" [1].

Figure 5



Above is a picture of the Windbelt being used to light several LEDs. [1]

7. Conclusion

Based on our analysis of Yaba's climate and people, it would be most feasible to implement the Windbelt to generate electricity to light the school. With the average income being well below the poverty line an inexpensive form of energy would have to be implemented. It also needs to be easy to maintain and repair. The Windbelt meets all of these requirements.

To possibly cut down the number of Windbelts that would need to be used, we could work with the community to allow the Windbelts to be kept outside at all times. This would require an increase in security for the school, which poses a problem; we would have to respectfully convince the existing security guard that he could use some extra help. We could also consider funneling the wind to increase wattage output.

Providing lighting for the school can greatly improve the lives of the inhabitants of Yaba; they can hold classes at night or start school earlier in the day.

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