Harnessing Wind Energy with Recyclable Materials

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Team 03

Progress Report

Document

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Problem Statement

Introduction

The "Harnessing Wind Energy with Recyclable Materials" (H-WERM) design project is a project initiated, and sponsored by Srinivas Kosaraju, a Mechanical Engineering professor at Northern Arizona University, located in Flagstaff, Arizona.

The customer of the design project cannot be specifically identified as an organization or a corporation: the final project design is intended for citizens of third world countries who are in need of relatively small quantities of electrical energy. The energy is intended to be used to provide basic living "luxuries" such as lighting and the use of fan(s)

Needs Identification

Inhabitants of third world countries, whom do not have access to electrical grid network(s) of power production facilities, are in need of electricity.

Project Goal and Scope of Project

Goal Statement: To provide inexpensive electricity to third world country citizens who have limited access to electricity.

Scope: The scope of the goal statement to provide an inexpensive, portable wind turbine system to harness wind energy. The wind turbine system will include both a wind turbine to generate electricity, and a means of storing the electricity generated.

Project Progression

Since the last report, the H-WERM team has worked on several tasks. The group has primarily focused on gathering the materials necessary to construct a design prototype. The team also researched airfoil designs and tested whether PVC piping could be easily formed into an airfoil shape. Additionally, the team generated an alternate design, which is slightly modified from the final design presented in the last report. This design is described in the Final Design II section below.

Blade Design

Tests were performed to see if PVC piping could be "molded" and formed into an airfoil shape. Having an airfoil type blade will improve the efficiency of the turbine, because an airfoil is designed to generate both lift and drag forces, instead of only drag forces, as are generated by a cup shaped blade. The lift forces allow the blades to rotate faster in comparison to the wind speed, which increases the rotations per minute of the turbine, and therefore the power generated.

To determine the formability of PVC piping, pieces of PVC were submerged in boiling water and then removed once the PVC was warm enough to bend under minimal pressure. Once the PVC was removed, it was flattened out, twisted, molded, and cut into an airfoil shape. The results of the testing showed that although PVC is rigid at room temperature, the material is easily bendable once heated.

Given these results, the team researched the optimal blade shapes for small-scale wind turbines. Although the literature available on the topic is minimal, the research yielded the blade specifications listed in Table 1 for an efficient small-scale turbine with low start up speeds.

Table 1 – Blade Specifications	
Airfoil Shape	NC044
Pitch	5-10 Degrees
Angle of Twist	5 Degrees
Taper	Minimal

Based on the specifications shown in Table 1, the team decided to construct a wooden template that will provide the correct pitch and angle of twist if a slab of pliable PVC is pressed on the template. However, forming the NC044 airfoil shape out of the PVC will be much more challenging. The team has considered sanding or cutting the blades to achieve the desired cross-sectional shape, however, the concern with forming the blades this way is that controlling the location of the center of mass of each blade would be extremely difficult using only basic tools. If the center of mass of each blade is different for each blade, the unbalanced system could potentially reduce the efficiency of, or even damage, the turbine. Before a decision is made to cut or sand the blades into an airfoil like shape, more testing needs to be completed.

Final Design I

At the end of the fall semester, the team proposed a horizontal turbine with PVC blades cut to form a helical-shaped propeller for the final design. (See Figure 1, below).

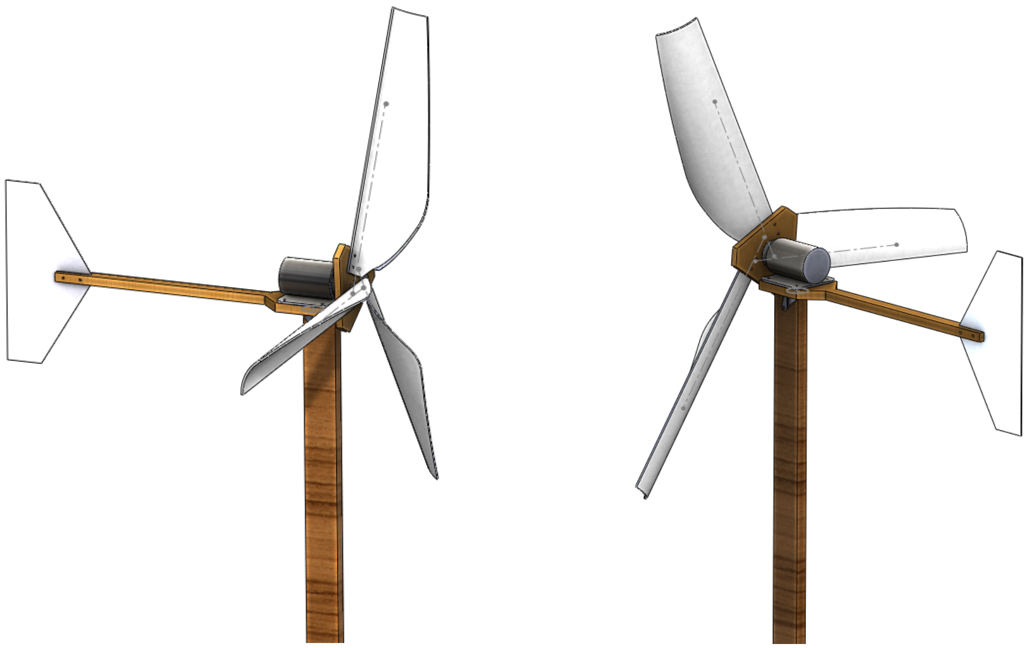

Figure 1: Final Design I

The following sections describe the major hardware parts of this wind turbine design, electrical component specifications, and the design cost analysis.

Major Hardware Components

Turbine Blades:

The wind turbine blades will be constructed by cutting and shaping pieces of Schedule 40 rigid polyvinyl chloride (PVC) pipe to resemble an airfoil shape (See Figure 2, below). This material was chosen because of the availability, lightweight properties, and strength. It is assumed that a standard nominal pipe size of 8.625" diameter with a thickness of 0.332" and length of 30" will be used.

Figure 2: Turbine Blade Shape

Generator to Turbine Blade Interfacing:

The interfacing between the generator and the turbine blades requires several parts to complete the assembly. First, three turbine blades (of equal radial spacing) will be fastened to a wooden block with lag bolts to create the turbine face. To translate the rotational motion of the turbine face to the generator shaft, a PVC device will be used.

The PVC device contains two pieces of PVC pipe fitted concentrically inside of one another other and a PVC pipe cap, which fits concentrically around both the fitted pieces. The PVC cap will be screwed into the back of the turbine face (wooden block), and then a setscrew will be used to connect the cap to the PVC fitted pieces. The smaller of the concentric pieces will be cut such that the generator keway will slide into the newly created PVC hole. (See Figure 3, below). Epoxy will be applied between each PVC piece to improve the strength of the device.

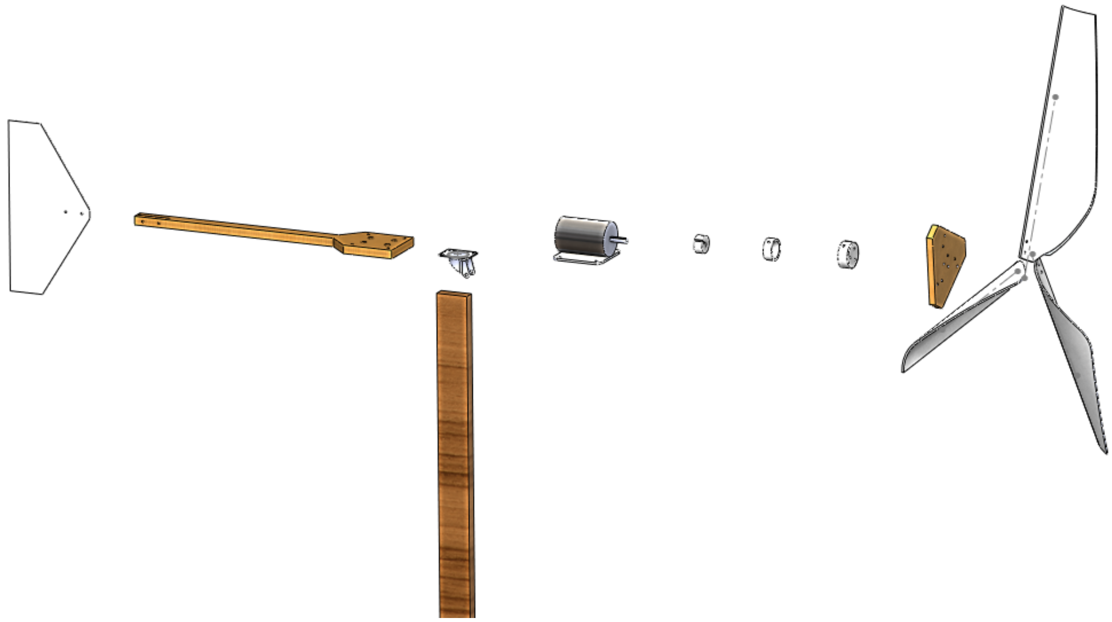

Figure 3: Exploded View of Final Design I

Turbine Horizontal Pivot/Base Design:

In constructing a horizontal axis wind turbine, multiple aspects of rotation were considered. Because wind direction is characterized by varying along the horizontal plane, a weathervane (see Figure 3 above) will be installed on the back of the turbine, which allows the turbine to rotate into the wind. Varying wind directions will require a pivot point that will enable the turbine to rotate. Considering the weight and availability, the design will use a caster wheel to provide the pivoting motion of necessary for the turbine (see Figure 4, below).

Figure 4: Caster Wheel Assembly

The caster wheel will be attached to the pole forming the turbine base, as shown in Figure 5. The rubber wheel will be removed from the assembly and replaced with a wooden 2x4 post inserted between the brackets. A horizontal hole will then be drilled through the wood, and the existing bolt will fasten the caster wheel to the post.

Figure 5: Bottom pivot assembly

Once the wooden post and caster wheel frame have been assembled, a top plate containing the rear tail and the generator will be fastened to the top of the caster plate (refer to Figure 3, above). The existing mount wholes will be used in securing these two plates together. A measurement of wind approaching the turbine from a specific direction can be angled at ±30º from its initial starting position. Knowing this, setscrews will be placed about 90º apart to prevent the turbine from over rotating. (Over rotation can cause multiple problems, such as tangled wires or spiral out of control, ultimately destroying the entire system).

Electrical Components

The following table contains the specifications for the wind turbine electrical components.

Table 2 – Electrical Components

Component Type	Description	Specifications
Appliance	Incandescent Light Bulb	60 W
	DC CFL Bulb	~15 W
	DC Fan	~ 40 W
Battery	Car Battery	12 V, 80Ah, 1 kWh
	Motorcycle Battery	12 V, 6 Ah, 72 Wh
Alternator / Generator*	Bicycle Dynamo Generator	Varied Widely
	Motor Cycle Stator	12 V, 750 rpm, 60 – 90 W
	Car Alternator	~14 V, 2000 rpm

* The final alternator/generator component will be determined based on available parts, which will be selected during the prototype construction phase.

This initial version of the final design was submitted to the client at the end of the fall semester in the team's final report. However, further research led the team to consider other options for the power generation portion of the project. This led to a handful of changes, and a modified design has been proposed.

Final Design II

This design includes many of the elements of the previous design, yet uses a more readily available power generator as well as modified PVC blades.

Design Summary

This design utilizes a motorcycle stator and single shaft to maximize the systems functionalities. A motorcycle stator will be mounted to a block of wood which has a drilled out center hole for the turbine shaft. A 30 inch long turbine shaft will then be pressed into the wooden hole exposing ¼ of the shaft on one side and about half of the shaft on the other. The turbine blades will be mounted to one side of a wooden hub, and the motorcycle flywheel will be attached to the other side of the hub. A bearing will be pressed into the center of the hub, allowing the flywheel to rotate around the stator, thereby generating electricity.

This assembly will then be placed on the shorter exposed end of the shaft, which contains the stator. A clip with a washer will hold the two assemblies together and allow the turbine to rotate freely. Finally, a weathervane will be added to the back of the shaft, allowing the turbine to rotate into the wind, and providing balance to the system. The overall design is shown in Figure 6, and an exploded view is shown in Figure 7.

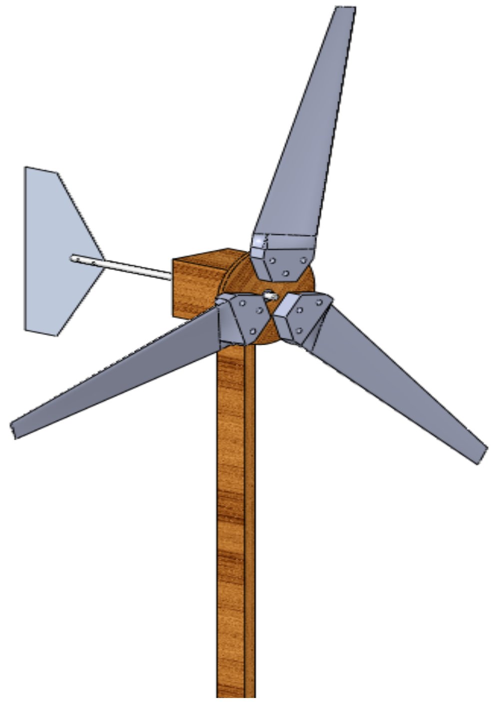

Figure 7: Final Design II

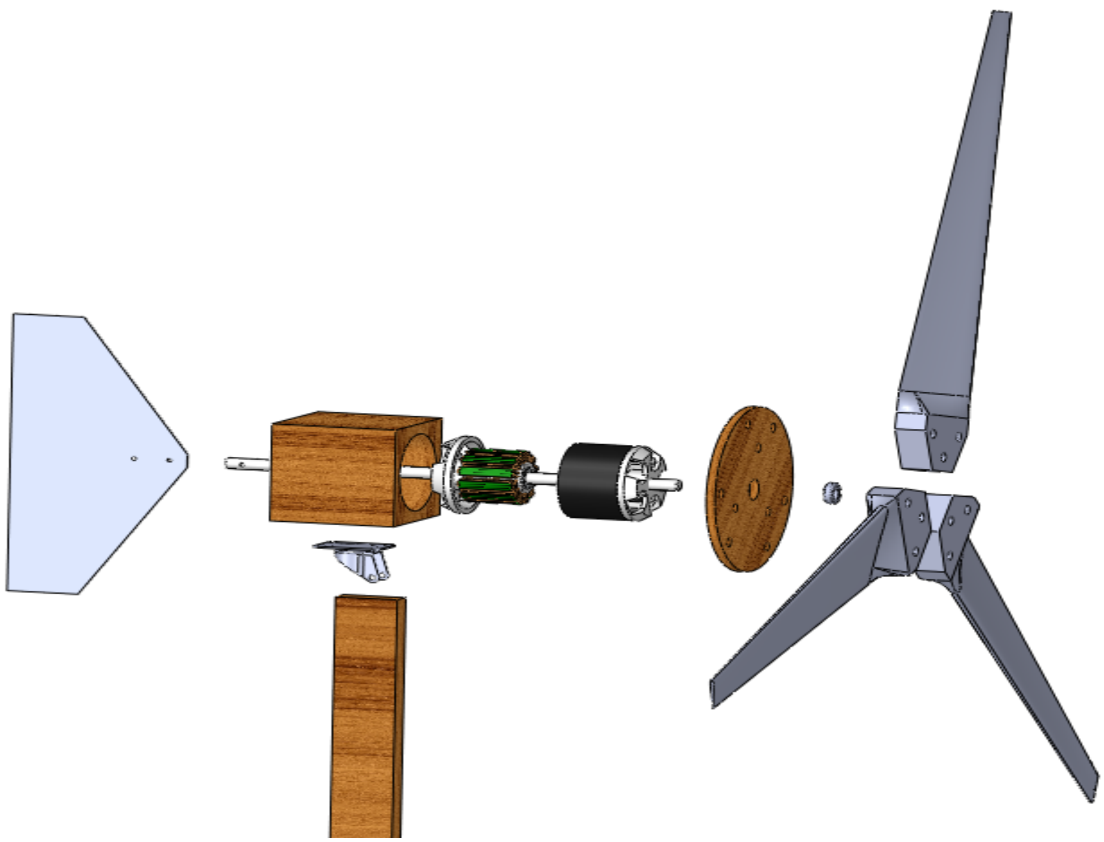

Figure 7: Exploded View of Final Design II

Stator

To convert the mechanical energy of the wind into electrical energy, a motorcycle stator will be used. The stator is made of anywhere between eight to twenty poles connected in a circle and wound by 16 gauge copper wire, as shown in Figure 8 below. A flywheel, which will also be taken from the motorcycle, is a circular metal wheel that contains magnets and rotates about the coiled stator to produce an electrical field. The electricity generated by the stator will be either transferred to the appliances for operations or stored in a backup battery.

Figure 8: Motorcycle Stator and Flywheel

Turbine Shaft

A rigid metal shaft will run the complete length of the horizontal wind turbine, from weather vane to the turbine blades. This provides rigidity to the overall system and allows the flywheel to rotate with the blades about the motorcycle stator. This stationary shaft design reduces moving parts, thus reducing the complexity of the design. The shaft will be made of recycled metal, preferably stainless steel or aluminum to prevent rust, and will be 30 inches long. Its overall thickness will range from 5/8 to 7/8 of an inch to maximize rigidity yet maintain balance. However, the shaft cannot exceed 7/8 due to the standard inner diameter of motorcycle flywheels.

Cost Analysis

Table 3 contains a list of the parts and/or materials used in the final wind turbine designs. Prices were determined based off of cost averages found for each part/material at junkyards and online suppliers.

Table 3: Cost Analysis

Part / Material Use	Cost
Battery *Note that pricing is based off of recycled parts*	$20.00
Generator/Alternator *Note that pricing ranges are defined based off of recycled vs. new parts*	$20.00 - $200.00
PVC Pipe (Turbine Blades, Generator to Turbine Interfacing Component)	Scrapped
Aluminum Cans (Weather Vane)	Scrapped
Lumber – Spruce (Turbine Blade Base, Generator Base, Post)	Scrapped
Circuitry Wiring (DC power adapter for appliances, overall electrical wiring, etc.)	$5.00
Screws, fastenings, etc.	$5.00
Total Cost	**$50.00 – $232.00**

Project Timeline

Figure 9, below, contains an up-to-date Project Timeline for the spring semester. The shaded blocks indicate the time allocated for the associated tasks, while the arrowed lines indicate the team's actual progress on that task.

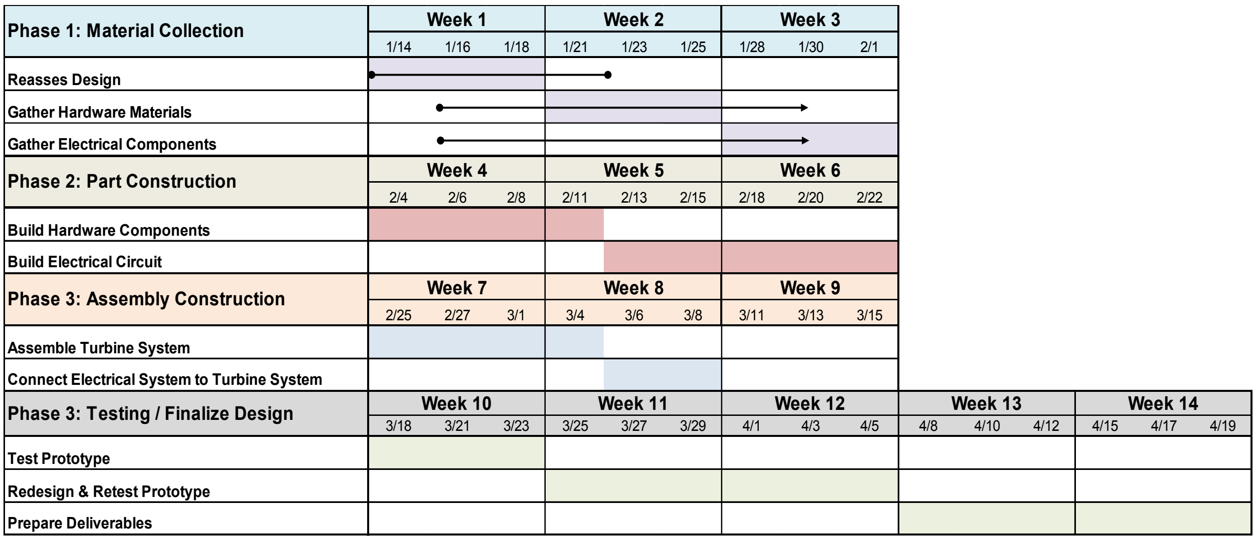

Figure 9: Project Timeline

Currently, the team has collected a number of the materials required for the primary design. These include a caster wheel, PVC piping, fasteners, and scrap pieces of wood. In addition, the team has researched the availability, pricing, and specifications of both the dynamo electric motor and the stator system.

Conclusion

In closing, the team has gathered a sufficient amount of materials, performed an extensive amount of research for the electrical system and for the PVC blade shape, and has developed an alternate design during the past weeks. Based on the current progress of the design, the team anticipates having a prototype for testing by the requested date. During the weeks to come, the team will begin construction on the mechanical elements of the windmill, and will continue to search for the appropriate electrical components of the design.

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Professor David Willey, Northern Arizona University.

Professor Srinivas Kosaraju, Northern Arizona University.

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