Objective:

El Durazno, a village in Guatemala situated high up in the mountains, has access to neither reliable, affordable power, nor water [2]. We propose installing a number of low-cost, easily maintained micro wind turbines, no taller than a person, in order to power an electric pump to draw water from further down the mountain. These turbines would form a small wind farm with the sole purpose of providing enough power for the water pump to operate long enough each day to draw the village's daily required amount of water.

Background:

The nearest source of potable water is down the mountain quite a ways, so currently they have to haul buckets of water up from that place or collect rainwater in order to have water for drinking and washing [2]. The lack of easily accessible electricity means that the solution is not as simple as setting up an electric pump and reservoir tank to store the water: electricity must be generated there as well in order for this to work. The reason that this must be a specially designed turbine when wind turbines of this scale exist [1] is that the people of this village are not engineers nor would any of them have the technical know-how to maintain such turbines, let alone get the parts up to their remote village. Additionally, our turbines also have to endure the weather conditions of the tropics, a much different task than the relatively calm weather most of North America usually has.

Physical Design:

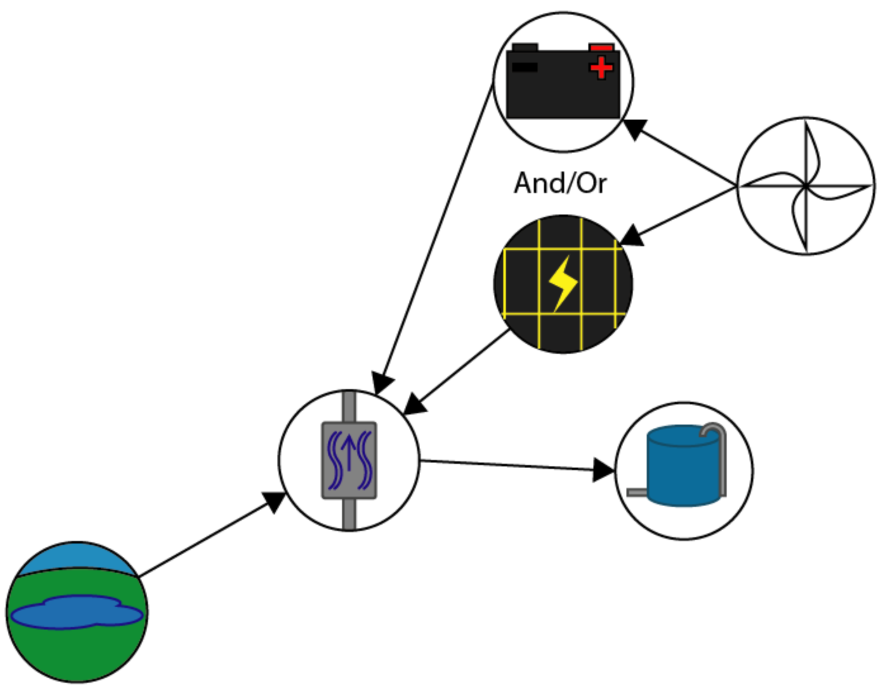

Figure 1: Wind-powered Pump Physical Diagram.

High-level requirements list:

i. Our project must be able to generate enough electricity and power to operate a 373 W, 127 V pump
ii. The pump should be able to operate for at least 8 hours a day so that the village would have access to water for enough time
iii. Our turbine should be made of used car parts as determined by our client
iv. Our project should be easy to operate and maintain so that the villagers could operate and run it even with no engineering support. This means no custom ordered parts from the UIUC machine shop, and the parts we do use must be obtainable via our sponsor in Guatemala or obtained with relative ease by the villagers in other means.

Block Diagram:

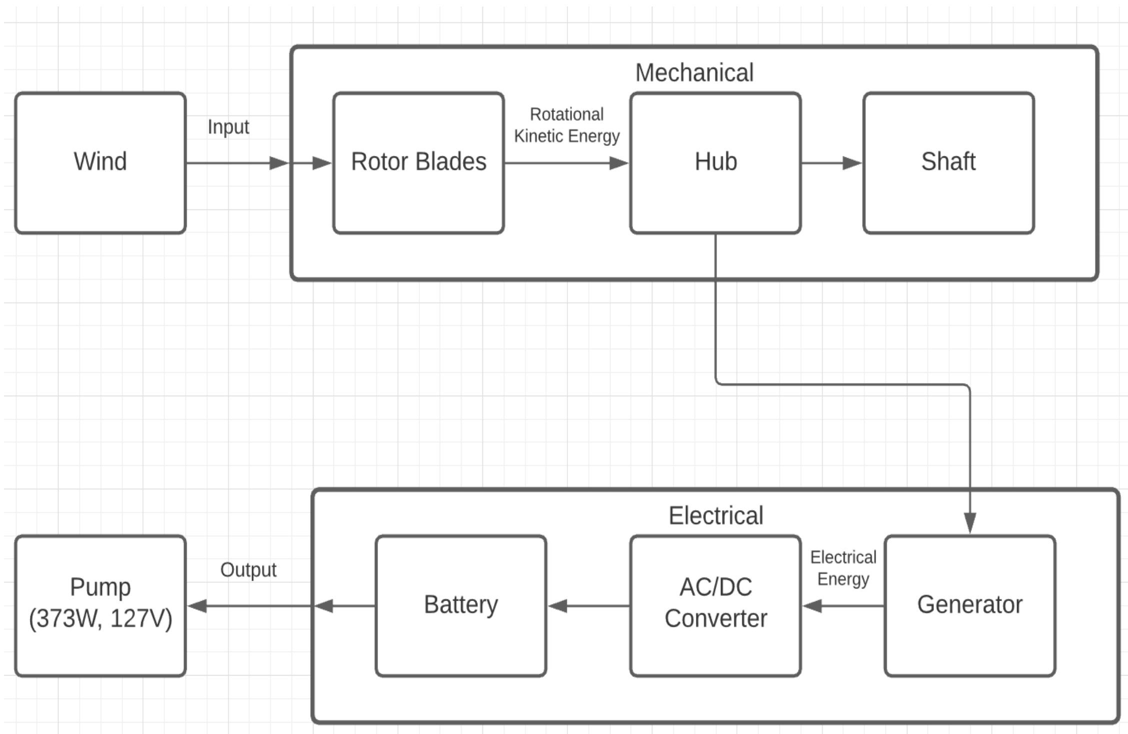

Figure 2: Mid-Level Block Diagram of Wind-powered Pump System

Functional Overview:

Mechanical System [2]

Rotor Blades:

The blades are straight with bent ends made from a used car's door side panel. As the rotor blades spin due to the wind direction, the hub they are attached to moves the shaft of the system. The turn clockwise or anti-clockwise and can operate even in the maximum wind speed at our site location.

- Requirement 1: The blades are aerodynamically shaped to turn easily in the force of the wind.
- Requirement 2: They are placed circularly so they do not oppose each other's movement

Plastic Hub Cover:

We are using a Toyota wheel hub or bicycle wheel hub that connects the turbine vanes together. The hub rotates along with the rotor blades and steering column creating a synchronous movement. This movement is what provides the rotational energy for the system.

- Requirement 1: Wide enough to interconnect steering column, rotor blades, and brackets.
- Requirement 2: Sturdy enough to withstand the changing wind speed

Shaft:

The shaft is a steering column to which the hub and blades are attached to. It spins and provides the appropriate balance to keep the system intact. The column is closed on either ends with PVC pipe caps or plugs. By drilling the cap, steel tube and column, we put a bolt and secured the column with a nut.

- Requirement 1: The steering column representing the shaft should be long enough to centrally connect all components of the turbine
- Requirement 2: It should be resistant to spin and requires greasing often to prevent this fiction.

Electrical System

Generator:

Our generator would either be an alternator of a used car (120V), a DC motor of (24V, 100A), or an Air Conditioner Blower (5V).

- Requirement 1: We are operating a 373W, 127 V Pump. The Motor has to be smartly connected in series with other motors so we don't have initial current or three phase issues
- Requirement 2: The machines have to operate long enough reliably to keep the motor running.

AC/DC Converter 1:

This converter takes in the AC output of the generator and converts it to DC to store in a battery. We would need to design these converters by ourselves using soldering, PCB design and knowledge in power electronics.

- Requirement 1: Tolerate wide AC input: wind speeds range from 9-13 miles per hour, meaning generated voltage can vary very quickly

- Requirement 2: Heat and weather resistant: El Durazno is experiencing a hurricane. This converter should not only output 12V to the battery, but should also do it reliably

<u>Battery</u>:

A 4000W energizer battery available to residents in El Durazno. It turns 12V to 110V and can be hooked to the pump to run when it's energized. We are still calculating how often we can charge this battery using our AC/DC Converter so it can continuously operate the pump.

- Requirement 1: Affordable and readily available for plug and play use. No extra configuration needed.
- Requirement 2: Should not add drastically to the cost of energy production.

<u>Pump</u>:

We are using a 373 W, 127 V pump from Pretul that is readily available to the residents of El Durazno. Our goal is to be able to run this pump for at least 1 hour so the residents do get water from long distances.

- Requirement 1: Pump can connect easily to battery and can move the required volume of water

Risk Analysis:

Our greatest challenge would be producing power from the generator machine. As the mechanical components are mostly built, what is left is piecing together the current and voltage calculations of each subcomponent of the electrical system to make sure they are compatible.

We will need to test the machine and review its data sheet to decide if it can produce the necessary power we need to run the pump. Based on that, we can set the parameters of the AC/DC converter and know whether we need a gearbox connecting the shaft to the machine.

Lastly, we are researching to identify whether the system can be connected to the grid to operate. We are learning about Guatemala's government policies and working with knowledgeable people to determine this. Using a self excited induction machine is an alternative, but it may not be available easily in used cars.

Our entire electrical system depends on which appropriate motor we can use and building and combining the remaining components with the motor.

Ethics and Safety:

The people in the village would be in direct contact of the turbine. The operation and the maintenance of the wind turbine will be undertaken by the people so we need to make sure that the turbine is easy to maintain and operate. Furthermore, we have to ensure that the turbine is safe to use. The major hazard would be the electrical circuitry in the generator and the wires connecting the pump to the generator. The voltage of the generator would possibly be 120 VDC and it would need to be insulated properly to prevent it from causing harm to the operators. Furthermore, since this would be placed in an outdoor environment and on a mountain, it would also need to be protected from the weather. Different climates can cause the electrical circuits to short circuit or cause other problems. Proper monitoring should also be taken so that the production is not affected by the wind speeds and there are enough hours of operation for the pump. This matches with IEEE ethics code #1 to maintain the safety of the public [3]. We would we working with a team from the ABE department, as well as clients in both Champaign and Guatemala so we would constantly need to correct our design and work on the demands as mentioned in IEEE ethics code #7 [3]. Furthermore, we would also need to adhere to Guatemala national energy laws such as the General Electricity Act [4]. This would have an influence on our design as well as building with respect to things such as tying in the turbine into the grid or having a backup energy storage to ensure that the pump is operational when needed.

Bibliography

[1] "WINDExchange: Small Wind Guidebook", Windexchange.energy.gov, 2021. [Online]. Available: https://windexchange.energy.gov/small-wind-guidebook#parts. [Accessed: 19- Feb-2021]

[2] C. Abbamonte, "El Durazno Final Report", 2019.

[3] “IEEE Code of Ethics.” Institute of Electrical and Electronics Engineers. 2020. https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed Feb 18. 2021]

[4] “Electricity regulation in Guatemala: overview”, Thomas Reuters. 2020. https://uk.practicallaw.thomsonreuters.com/w-009-9340?transitionType=Default&contextData=(sc.Default)&firstPage=true [Accessed Feb 18. 2021]