ECE 445

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Design Document

El Durazno Wind Turbine

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Group 12

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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 low-cost, easily maintained micro wind turbine, no taller than a person, in order to power an electric pump to draw water from further down the mountain. This turbine would have 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:

El Durazno is a village of about 1,220 people living in 188 households, a relatively small community compared to some towns and cities around UIUC, however this is still over a thousand people without water [2]. According to the report on the project ours is following up on, each household would use about 194.7 L of water daily, and between the households in the village, about 38kL of water would need to be pumped from the sources daily [2]. Their current primary source of water comes from a community leader's property which has a seepage spring on it. Pools of roughly 1-2m^2 are dug and claimed by families for their use. This source is the closest that they have and is still an elevation difference of 200 feet down from the village.

There are plans to connect this source and another one about 173 feet further down the mountain (an elevation change of about 60 feet) to a collection tank for safe containment, protected from contamination [2]. This would give the village better access to more clean, potable water. The only problem is that this collection tank is still much further down the mountain than the village and the whole point is to give them easier access to the water. As the village does not have easily accessible power, this is not as simple as hooking a pump up to the grid and pay the utility [2].

This is where our turbine comes in. It will be powering a pump rated at 373 W, 127 V that will be used to draw water up through galvanized iron piping back to the village so that it can be used. This will operate for 8 hours a day, run via a battery hooked up to the turbine [2]. 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. So our prototype needs to be constructed with easily-obtained materials and be easily assembled with little engineering knowledge.

Physical Design:

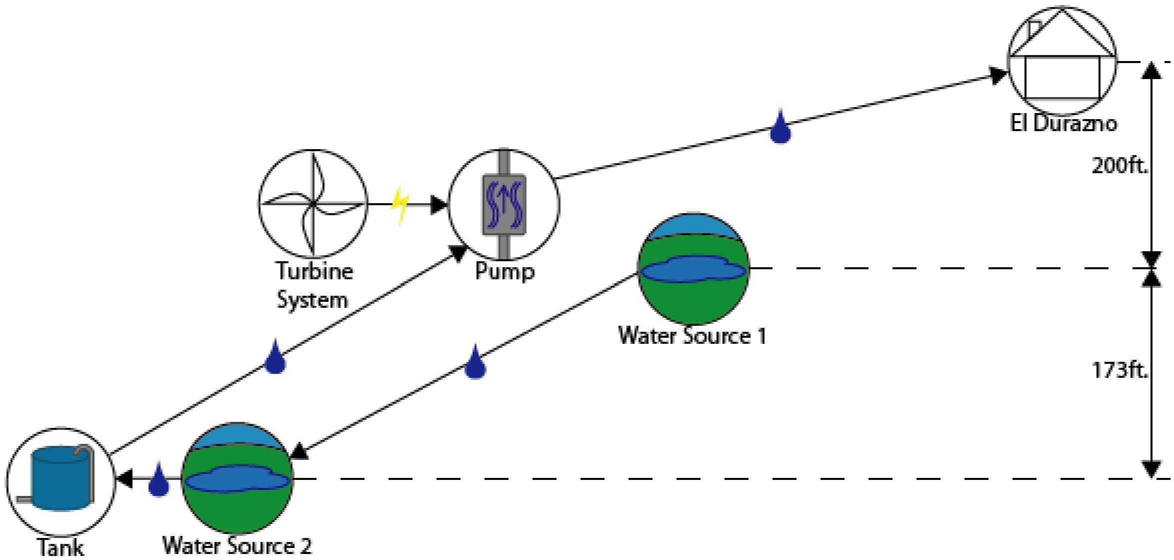

Figure 1: Visual Aid for Background.

High-level requirements list:

i. Our project must be able to generate enough electricity and power to operate a 373 W, 127 V pump via an inverter. The runtime goal for our 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

ii. Our turbine should be made of used car parts as determined by our client

iii. Our project should be easy to operate and maintain so that the villagers could operate and run it even with no engineering support. The wind turbine should be easy to put together, following a set of instructions, without any need for additional wiring or work required. 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. Quantifiably, if we can assemble it in under 30 minutes without having the instructions with us, it should be intuitive and simple enough that the villagers can do it in a reasonable amount of time with the instructions.

Block Diagram:

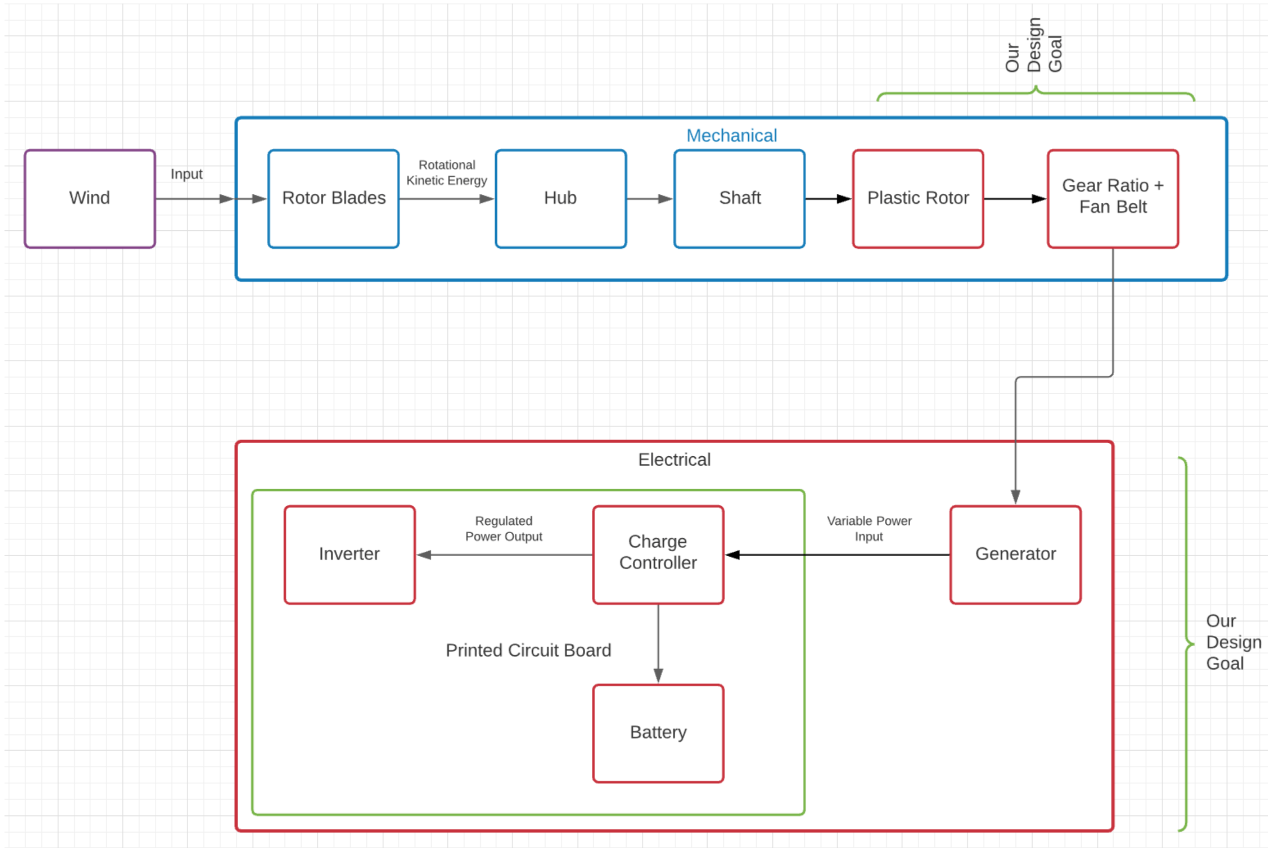

Figure 2: Mid-Level Block Diagram of Wind-powered Pump System

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We have two design goals. One is to complete the plastic rotor and Gear belt ratio with the fan belt by cutting a plastic sheet circularly with holes in the center for shaft and long the periphery for the lugnuts and by stretching the fan belt to connect to gears at a distance. This means the larger gear is attached to the plastic rotor while the smaller gear is attached to the generator.

The second design goal is to complete our electrical system consisting of a generator appropriately running with a charge controller, batter and inverter that are interconnected via a printed circuit board.

As the wind spins the rotor blades, it converts wind energy into rotational kinetic energy, causing the hub to rotate around the shaft. As the mechanical system spins, it moves the coils of the generator around its internal magnetic, converting rotational to electrical energy. This electrical energy passes through a charge controller that produces a steady DC output to charge the battery, while passing it to an inverter to show AC output.

Functional Overview:

Mechanical System

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.

Hubr:

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 moving sideways while spinning and requires greasing often to prevent this fiction.

Plastic Rotor:

With the help of the machine shop, we are planning to perform this operation using an existing plate we have. The brake rotor is Plastic Plate cut in a circular shape to fit the diameter of the previous rusty rotor. It will have the appropriate holes along the periphery to screw lug nuts and a hole in the center to allow the shaft through.

- Requirement 1: The circular plate’s diameter fits the length of the belt appropriately. Lug nut and shaft holes are accurately cut.
- Requirement 2: We can easily fasten a large gear on top of this plastic plate

Gear Ratio + Fan Belt:

Our goal is to stretch the fan belt in order to connect two gears together. The larger gear, Gear A, is fastened on top of the plastic plate while the smaller gear, Gear B, is attached to the DC Motor’s Spindle. This allows low wind speeds to effectively run the DC motor at a high enough RPM to generate power.

- Requirement 1: Gear ratio must be calculated properly using the ratio of the radius of Gear A to Gear B.
- Requirement 2: Proper tight attachment of Gear A to plastic plate and Gear B to motor spindle.
- Requirement 3: Fan belt must stretch to accommodate the size of the gears.

Electrical System

Generator:

Our generators 1 DC Motors (24V, 100A) connected to an AC/DC converter. We are testing the DC motor in the ECE lab to produce a Voltage vs Power Curve in order to understand how we produce power at 800 and lower RPM speeds.

- Requirement 1: The results from test must show promise to use the gear ratio for power generation at El Durazno’s low wind speeds
- Requirement 2: The machines have to operate long enough reliably to allow the charge controller to recharge the battery.
- Requirement 3: Must be able to interface with the Gear B through the fan belt for proper functioning

Printed Circuit Board

Charge Controller:

We are buying Picasoleil’s 12/24 V charge controller that can take an input from 400-600W of power.

- Requirement 1: IP67 weather resistant and reliable to use
- Requirement 2: Affordable and easily wirable to batter, generator and inverter.
- Requirement 3: Attachable to a PCB

Inverter:

This inverter should prove we can produce an AC output using the charge controller. It takes voltage input of 12 to 24 V along with a 400-600W power range.

- Requirement 1: Tolerate wide AC input: wind speeds range from 9-13 miles per hour, meaning generated voltage can vary very quickly
- Requirement 2: IP 67 Waterproof and can survive hurricanes in El Duazno
- Requirement 3: Attachable to a PCB

<u>Battery</u>:

A small lithium ion rechargeable battery available to residents in El Durazno. It turns 12V to 110V at 600mAh and proves our ability to store and energy.

- 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.
- Requirement 3: Attachable to a PCB

3.1: Requirements & Verification:

Requirements	**Verifications**
Rotor Blades 1) The blades are aerodynamically shaped to turn easily against the average wind speed 2) They are placed circularly so they do not oppose each other's movement	**Rotor Blades** 1) Blow a fan or leaf blower at low, high, and medium to check rotation of blades. 2) We can use the data sheet of the leaf blower to know specific wind speed
Hub 1) Wide enough to interconnect steering columns, rotor blades, and brackets. 2) Sturdy enough to withstand the changing wind speed	**Hub** 1) Blow a fan/leaf blower to see how well the hub rotates with its attachments

Shaft 1) The steering column representing the shaft should be long enough to centrally connect all components of the turbine 2) It should be resistant to spin and requires greasing often to prevent this fiction.	**Shaft** 1) Visual inspection: by looking closely we can see if the shaft is well connected to components 2) Using a leaf blower we can check the shaft’s strength in rotating with its components
Plastic Rotor 1) Plastic Plate cut in a circular shape to fit the diameter of the belt 2) Ensure Large gear is attachable to plate 3) It must appropriate holes along the periphery to screw lug nuts 4) Has hole in the center with the same diameter as the shaft	**Plastic Rotor** 1) Take old brake rotor to machine shop to use as reference for precise cutting of plastic plate 2) Insert the shaft through the rotor hole to ensure appropriate diameter 3) Screw in lug nuts to make sure the brake rotor appropriately accommodates nuts they fit in well and tightly
Gear Ratio + Fan Belt 1) Using Wb = Ra/Rb * Wa, we need to accurately calculate the gear ratio using the ratio of radius of Gear A to to radius of Gear B 2) Find those gears online 3) This allows us to convert low wind speeds to DC Motor power generation	**Gear Ratio + Fan Belt** 1) Attach the belt to Larger Gear A with adhesive tape 2) Attach the belt to smaller Gear B with adhesive tape 3) With machine shop help, ensure accurate distance between gears 4) With machine shop help, ensure Gear A rotation causes Gear B rotation and hence DC Motor Power generation via multimeter measurement 5) Fan Belt is stretchable to accommodate gear sizes 6) Visual inspection of gear ratio

Generator 1) 2 DC motors (24V, 100A) should be able to connect in series to provide 4800 W. 2) Operate long enough reliably to keep the 4000W battery charging 3) Mechanism for shaft to spin DC motor 4) Goal is to see how much time is needed to extract 2400W from the 24V, 100A DC Motor	**Generator:** 1) Using a dynamometer or similar device, we can run the generator with a sensor and braking motor to record a Voltage vs Power Curve 2) Using machine shop help, test equipment can be set up
Charge Controller 1) Bought online: PicaSoleil 12V/24V, 400-600W, with IP 67 rating	**Charge Controller** 1) Can be tested in the circuit to see if it charges battery properly and steps down voltage to the inverter 2) Verify power output regulation using multimeter 3) Fits on PCB
Inverter: 1) Tolerate wide AC input: wind speeds range from 9-13 miles per hour, meaning generated voltage can vary very quickly 2) Heat and weather resistant: El Durazno is experiencing a hurricane. 3) Converter’s goal is to step down 48V from DC motors to 12V for battery input while transferring 4800 W power reliably	**Inverter:** 1) 12V - 110V inverter bought online 2) Can be tested to verify if AC output is being produced 3) Fits on PCB

Battery: 1) Affordable and readily available for plug and play use. No extra configuration needed. 2) Should not add drastically to the cost of energy production.	**Battery:** 1) Shopping, find out similar batteries we can buy here 2) Test batteries to hold 3.7V 600mAh rechargeable battery 3) Fits on PCB

Tolerance Analysis:

Our greatest challenge would be producing power from the generator machine. We not only have to plot the Voltage vs Power Curve by testing the DC motor in our ECE lab, but also we need to harness the motor on the plastic belted circular sheet to run the machine.

According to WorldWeatherOnline.com, El Durazno gets a maximum wind speed of 46 RPM (14kmph) during the months of June to August and receives a minimum wind speed of 18.5 RPM during the months of October to November.

Our goal is to be able to construct a gear ratio, such that we can extract power from the DC motor in this wind speed range.

We need to calculate what are the appropriate limits to our gear ratios, in order to accurately convert the low wind speed into energy produced by the DC motor.

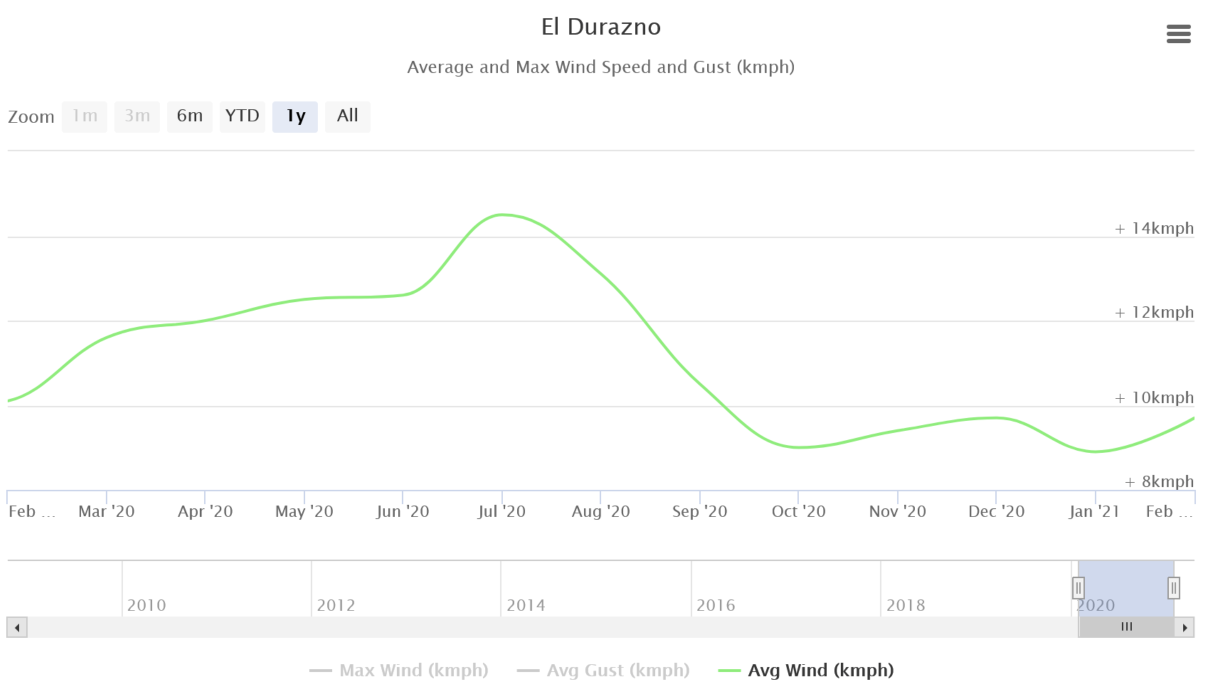

Figure 2: El Durazno's Wind speed Curve WorldWeatherOnline.com

Our DC motor can take the following graphs shape upon testing. We will be able to figure out more upon testing.

Furthermore, our goal is to measure how changes in the DC motor speed affects the AC frequency output of the motor, inverter design and charge controller design. Both the inverter and charge controller need to accommodate the full fluctuation caused by the variable DC motor speed.

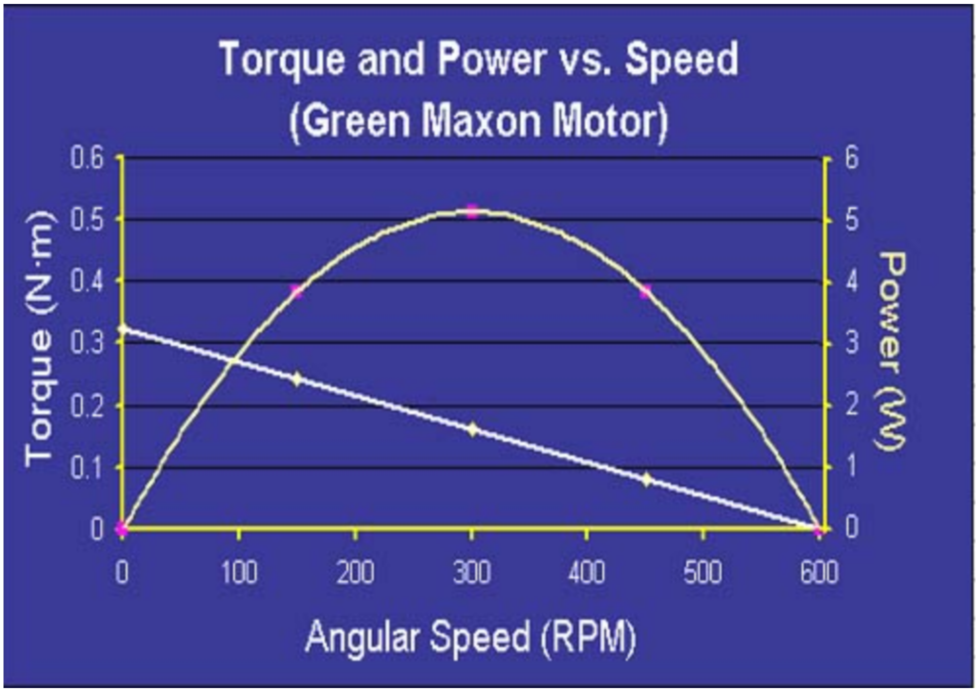

Figure 3: Torque and Power Vs Speed curve from Lancet.mit.edu

Cost Analysis:

1. Labor:

   Manpower: $30/hour * 2.5 * 6hrs/week * 3 students * 16 weeks = $21,600

   Motor testing: $50/hour * 2 hours * 2 people = $200

   ECE Machine Shop: 50$/hour * 2 people * 2 hours = $200

   Welding for Harness: $100/hour * 1 hour = $100

   Total Labor Cost: $21,600 + $200 + $200 + $100 = $22,100

2. Equipment:

Item	Cost
Charge Controller	$35
Inverter 12V-110V	$30
Lithium Ion Battery	$14
Tool kit	$20
Fluke Multimeter	$36

3. Total Cost: $22,100 + $135 = $22,235

Schedule Draft 1:

March 5th:	Design Document Completed
March 8th:	Design Review with Prof. Schuh
March 9th-12th:	Changes to Design Doc + Start Converter Design
March 16th:	PCB Design Completed
March 17th:	Team Evaluation
March 18th:	Order PCB, audit should pass
March 19th-22nd	Motor Choice + Schematic complete
March 22th-27th	Physical attachment of Motor + System testing
March 27th-April 3rd	Insert PCB + test power output + Charge battery
April 3-8th	Finalize Design

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. All the electrical equipment would be properly insulated. Any loose wiring would be removed or taped off to prevent shocks or loss of current.

Moreover, 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]. The turbine will contain grounding down conductors in the blades and grounding down conductors in the turbine to protect from lightning.

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].

Additionally, 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. This project would set up a battery storage as well as have the possibility of letting the sponsor in Guatemala to tie the turbine into the grid, depending on their preferences and interaction with the Guatemalan government.

Bibliography

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