

Mechanical and Hybrid Wind-Powered Water Pumps

Problem

Worldwide, 783 million people do not have access to clean water; 319 million of them reside in Sub-Saharan Africa. In this region, the transportation of water from its source to its point-of-use can be arduous to complete using current methods. The men and women in developing communities must exert considerable effort to retrieve the few gallons of water they need to survive. Due to the lack of infrastructure and no external source of energy, new methods to transport the water must be capable of generating their own energy.

Introduction

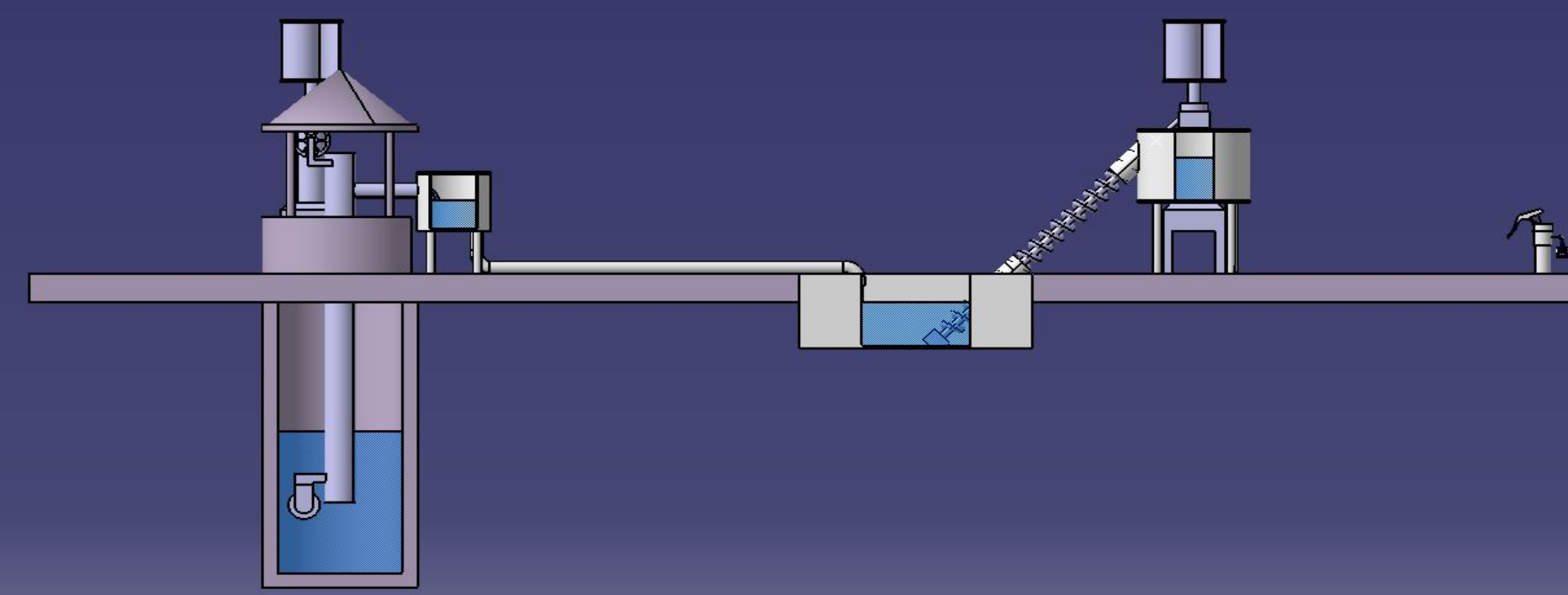
The Archimedes initiative set out to provide water to those without access. Centered on the comparison of a fully-mechanical and a mechanical-electrical hybrid system the project will investigate the effectiveness of each system in its target environment. Considerations such as modularity, complexity, and ease of use have been taken into account with the aim of creating an effective, efficient, easily repaired design.

Deliverables

Deliverables for this project were chosen as a minimal baseline that will be expanded upon as the effect of the system is better understood.

- **5-10 L/min**
The use of the system will determine the flow rate – a irrigation system will require a greater flow rate than a potable water systems. Therefore will need to be more closely evaluated on a case-by-case basis.
- **1 mile Flow Distance**
The flow distance will also be based upon the needs of the consumer, but it was felt a minimum of 1 mile was needed for the system to be feasible.
- **150 ft. Vertical Head**
The vertical head will account for an elevation gradient over a given region. 150 feet was chosen as the beginning deliverable to prove an elevation gradient could be overcome while keeping the initial phase relatively flat. Steeper gradients will be tested in the future.

Mechanical



Starting the Design

The mechanical team designed a pump exclusively using wind power to transport water from the well to where it is needed. At the beginning, a rope pump will be used to lift the water out of the well into the first raised holding tank. From there, it will descend and run through the pipes until it is collected in another holding tank flush with the ground. To lift the water from this tank into the next raised holding tank, we plan to utilize an Archimedes screw. An Archimedes Screw will be employed to raise the water from the ground tank to another raised tank. This section of the system can be repeated as often as necessary to reach the desired distance.

Wind Turbine

The design utilizes the Savonius wind turbine to power both the Rope Pump and the Archimedes Screw. We chose this due to the torque requirements of both pumps and the fact that the Savonius design utilizes up to 15% of the wind energy it captures. With an average wind speed of 6 m/s and a radius of 2 meters for the sail of the turbine, we will put out ~50 N*m of torque which will run either pump.

Rope Pump

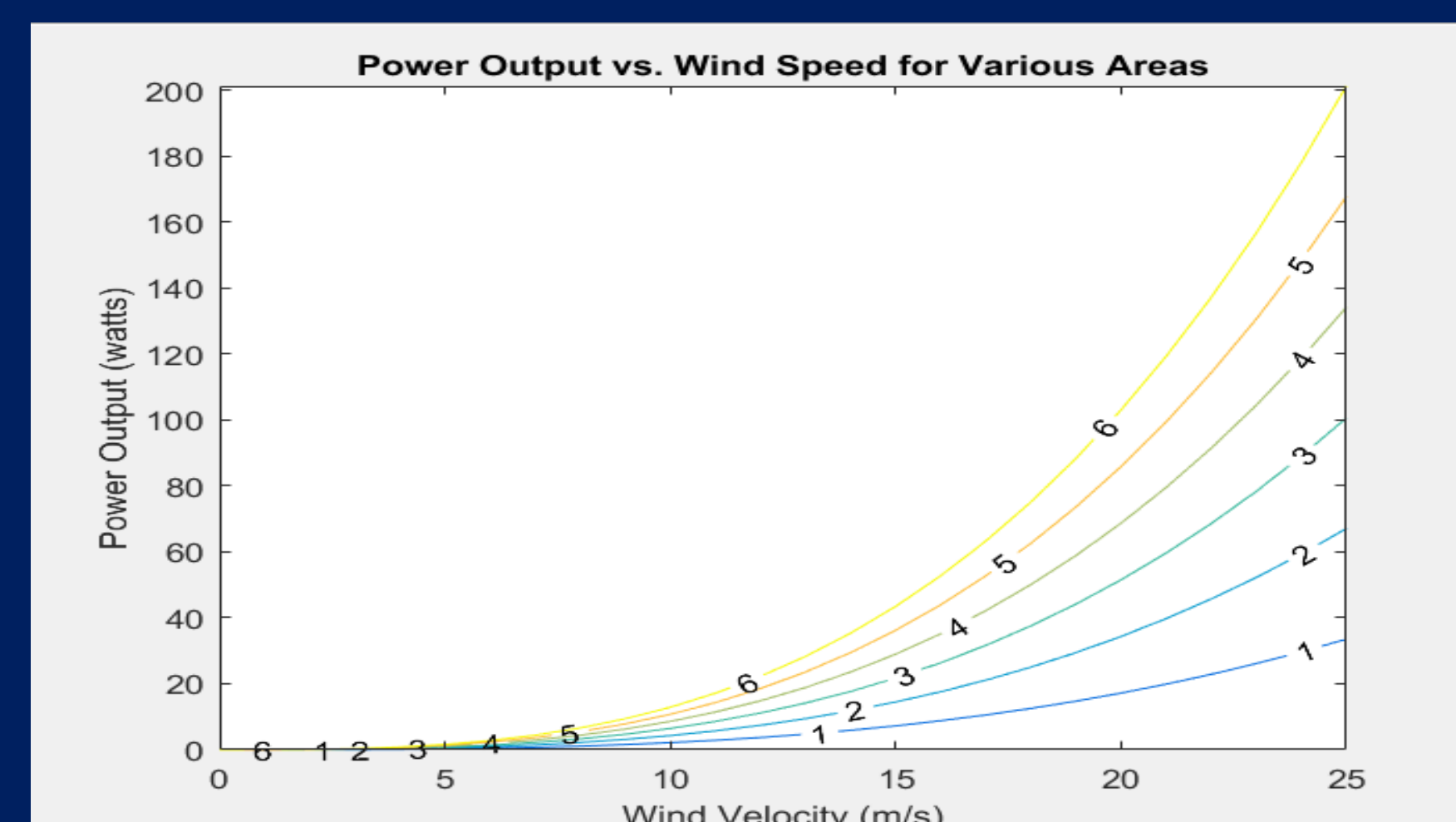
The rope pump was chosen due to its simplicity and its pre-existing use in the target areas. It can be easily integrated with the Savonius Wind Turbine and requires the torque generated by the Turbine.

Archimedes Screw

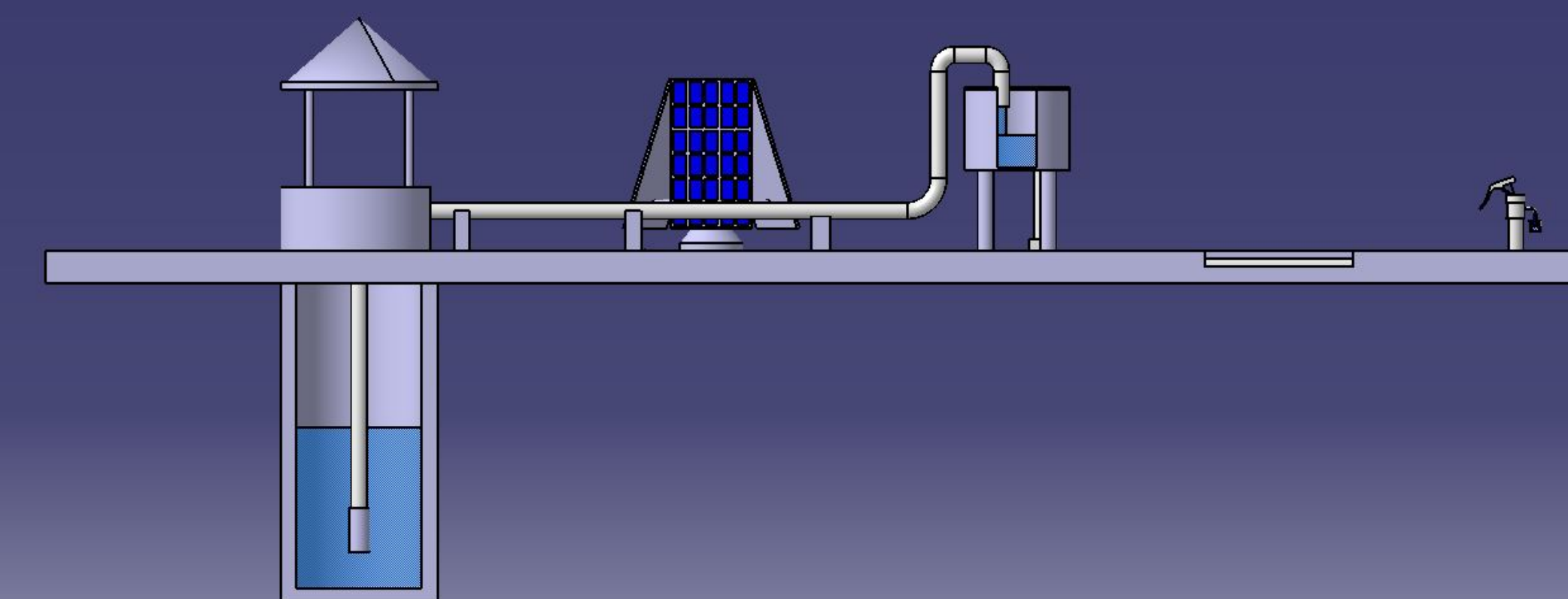
This pump was selected because of its simplicity to build. It is one of the basic structures of engineering and has prior uses in many applications. The design will utilize a 12 foot long screw that will lift the water approximately 8 feet off of the ground into the raised holding tank.

Water Storage

The Water storage design came from the need to maintain the pressure in the piping throughout the system. Each storage container is filled before finally draining through the bottom to ensure that the pressure remains relatively high. This ensures the water can travel the required distance.



Hybrid



Starting the Design

The goal of the hybrid team is to design and assemble a working electric pump system. First, a well pump that could meet the design requirements was selected. Once the pump was selected, the focus was turned to powering the pump system. Originally, wind power was to provide power to the pump but upon a cost analysis between wind power and solar power, it was decided that solar power was the best option.

Pump Selection

The best option for this type of water transport is the well pump. The pump selected is the Red Lion RL12G15-3W2V. This pump has a high maximum head which is needed to not only move the water from the well to the surface, but it also allows for changes in elevation. It provides substantial flow rate that ranges between 10- 20 gallons per minute depending on the pressure. With this flow rate, the pump only needs to run about 1 hour each day.

Battery Bank

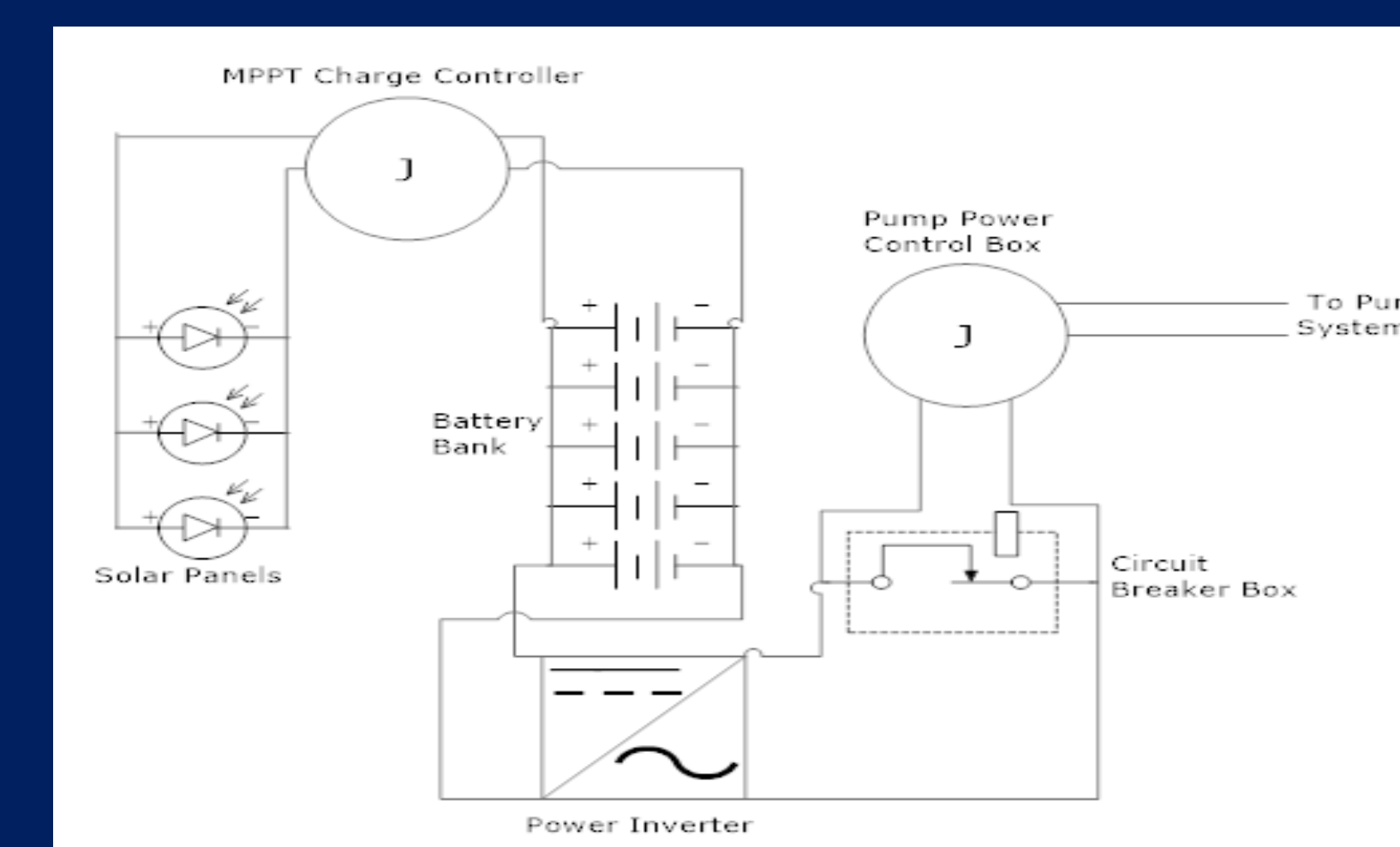
The battery bank consists of 24 12 V deep cycle lead-acid batteries. This was the best option because they are designed to be regularly charged and discharged rapidly. Other types of batteries were considered but the cost of these were often outside the team's budget. The 12 V DC from the batteries is converted to 240 V AC that the pump needs as a power supply.

Solar Panels

It was decided to use 3 100 W Renogy solar panel and a Renogy charge controller to charge the battery bank. These will provide more than enough power to meet the power requirements of the pump.

Pump Operation

The system will use a charged water tank and a pressure switch in order to operate autonomously. The pressure switch will turn on the pump when the water pressure drops below 30 PSI and it will turn off the pump when the water pressure rises to 50 PSI.



Discussion

Although testing has not officially begun, initial observations have shown a stark contrast in the abilities of each of the systems.

Hybrid

The system has potential to be more effective in transporting water, however its cost and maintenance issues show it may not be suitable for the target environment. Theoretically, it has shown to meet and exceed the power and pressure requirements for flow rates much greater than the original deliverables. However, it has yet to be seen whether this system will perform to standards in a physical environment.

Mechanical

The system is still unproven. Theoretically, it should be better suited for the target environment due to its lack of electrical parts. Its reliability is a plus and should be able to consistently provide water as long as there is wind. However, it is still uncertain if the entire system will be capable of producing the required power to transport the water vertically. For this reason, steep gradients pose a greater challenge for this system and will be a significant testing topic in the future.

Future

Testing

As the systems are being assembled, each component will be tested to determine its quality and efficiency. This will be repeated as the systems are assembled in an effort to quantify the efficiency losses through the system.

Post-assembly, the two systems will aid The Garden Project in the transportation of water from a nearby water source to their garden. In this endeavor, it will be possible for the system to undergo further physical testing and modifications to ensure all deliverables are met.

Future Research

Further research will need to be completed on gear ratios and differentials to maximize efficiency and optimize the power transfer from the turbine into the pumps.

More research will also be done to determine and optimize the screw design. Using helix and double helix configurations at different angles to allow for greater flow rates will be the primary focus. While different ways to optimize the rope pump for varying depths will also be looked into.