HARNESSING ENERGY FROM WATER RUN-OFF

Eh Hsee '24, Daniel Nandsaram '24, Ethan Wilkie '24
Advisor: Dr. Clayton Byers

Abstract:

In the search for sources of renewable energy, this project focuses on utilizing rainwater as an option. A small-scale model consisting of a reservoir, a turbine connected to a generator, and a circuitry was designed to harness potential energy from rainwater. This model was made to determine the efficiency of the proposed system on a small scale. With this system, at a small scale, the data collected suggested that this design was not a realistic source of energy. On a larger scale, for which this system would be better suited, the design still proved lacking, but had potential to serve as a source of energy depending on cost of a realistic application.

Problem Definition:

Renewable energy has become a more prevalent means of harnessing energy as fossil fuels become scarce due to overconsumption over the past years. Thus, the goal of this project is to harness untapped potential energy from rainwater and convert that energy into something meaningful.

Design Requirements:

Time – Approximately 8 month turn-around
Money – A $400 budget is provided.
Usable Flow – The system has limited flow
Energy – Possible energy harnessed is limited by the flow of water
Turbine – The size and variety of turbine are limited by flow
Rotor-Stator Device – Compatibility with turbine & rating matter.
Battery – Voltage must match rotor-stator output
Buildings – testing limited by owner consent

Design Alternatives:

Reaction Turbine		Pelton Wheel		Water Wheel	
Pros	Cons	Pros	Cons	Pros	Cons
-Encompasses a wide variety of different turbine designs -Can operate with a low head	-Specialized turbine would need to be sourced for this project -Typically requires large volumes of water	-Simple design -Can operate with a relatively low volume of water	-One primary usable design -Typically uses large heads of water	-Simplest design of all the options -Least complex in terms of design -Multiple designs to choose from	-Requires very large volumes of water -The water wheel would be significantly larger than other options

Permanent Magnet Generator		Alternator		Induction Generator	
Pros	Cons	Pros	Cons	Pros	Cons
-Widely used in small-scale systems. -Built-in converter to DC -Converts to direct current (DC) -Permanent magnet means no external source needed	-Magnet deteriorates over time. -Voltage regulation needed via additional circuit	-Widely used in small- & large-scale systems. -Converts to alternating current (AC) -Better control over voltage regulation (adjust magnet strength	-Rectifier Circuit needed to convert to DC	-Less maintenance -Can operate over a wide range of speeds -Converts to direct current (DC)	-More expensive -Lower efficiency -Needs external power source to initiate generation

Table 1. Pros & Cons of Rotor-Stator & Turbine Alternatives

Final Design and Implementation:

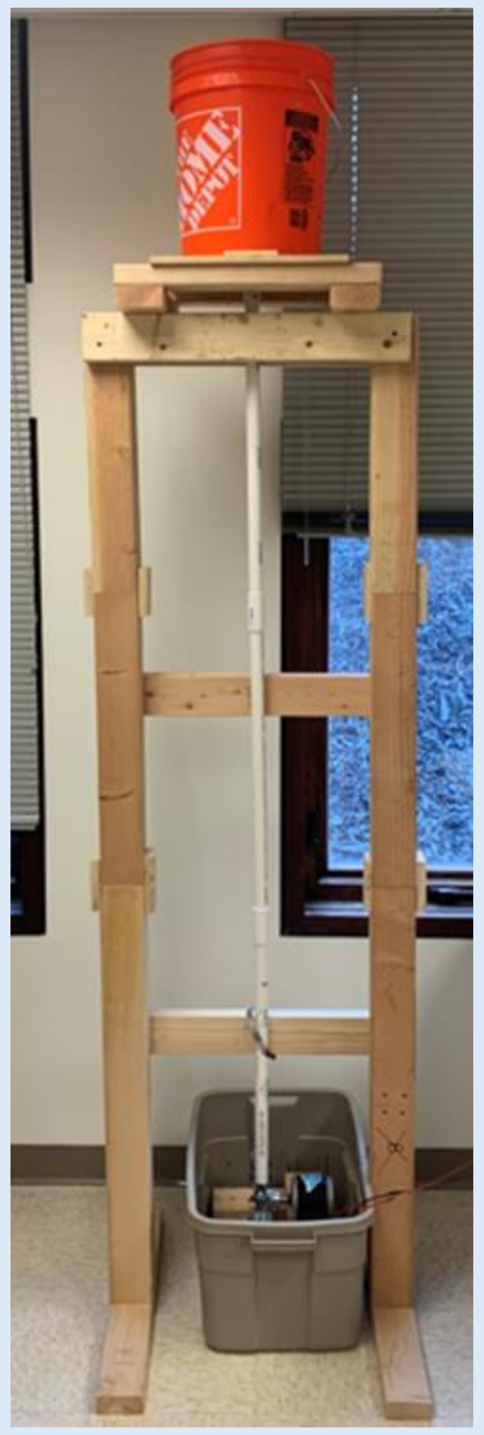

Figure 1, Stand for testing.

The test system consists of:
- A water reservoir in the form of a 5gal bucket.
- A stand holding the reservoir.
- A pipe extending from the reservoir.
- A generator + turbine at the pipe's end.
- A water collection container.
- A connected circuit for measuring voltage and current.
- A siphon for passive drainage of water.

This test stand was used for experiments quantifying flow behavior and the amount of electrical power being harvested by the turbine and generator.

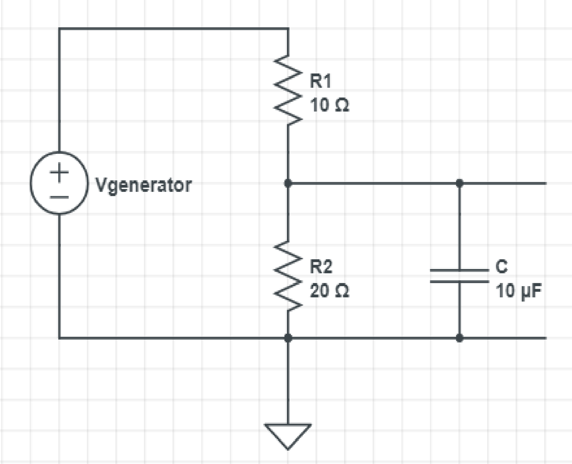

Figure 2, Charging Circuit.

Table 2, results for power measured using the turbine and generator without the siphon.

No Siphon	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Total Average
Average V	1.821	1.676	1.892	1.792	1.812	1.799
Current (I)	0.629	0.579	0.653	0.619	0.626	0.621
Power (W)	1.145	0.970	1.236	1.109	1.134	1.119

Table 3, results for power measured using the turbine and generator with the siphon.

With Siphon	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Total Average
Average V	1.161	1.050	1.050	1.151	1.109	1.104
Current (I)	0.401	0.362	0.362	0.397	0.383	0.381
Power (W)	0.466	0.380	0.381	0.457	0.424	0.422

Table 4, summarized data for predicted vs. measured results for harnessed power, both with and without the siphon.

	Without Siphon	With Siphon
Predicted Power	15.55W	14.13W
Measured Power	1.119W	0.422W
% Difference	92.80%	97.01%

References:

Polansky, Chris. "The Biggest Amazon Warehouse in New England Is Now Open in Windsor, CT." *Connecticut Public*, 3 May 2023, www.ctpublic.org/news/2023-05-02/gov-lamont-cuts-ribbon-at-new-amazon-warehouse-in-windsor-the-biggest-in-new-england.
Simms, Dan. "Compare Electricity Rates in Connecticut (April 2024)." *EcoWatch*, 22 Jan. 2024, www.ecowatch.com/electricity/rates/ct.

Design Evaluation & Iterative Process:

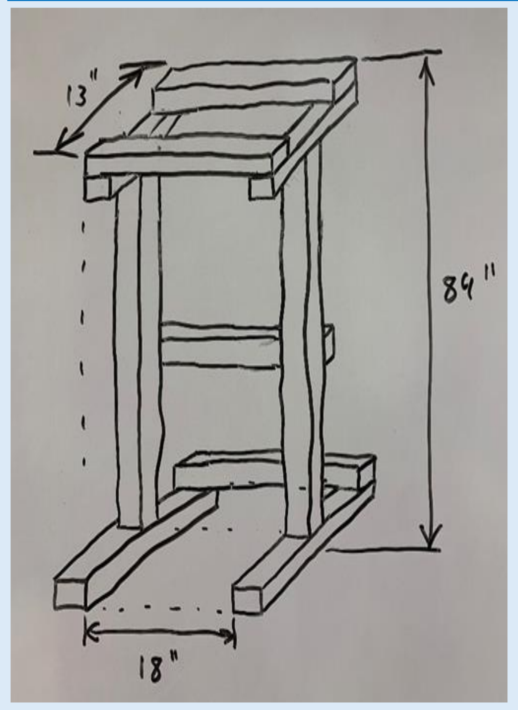

Figure 3, Early drawing for test stand design.

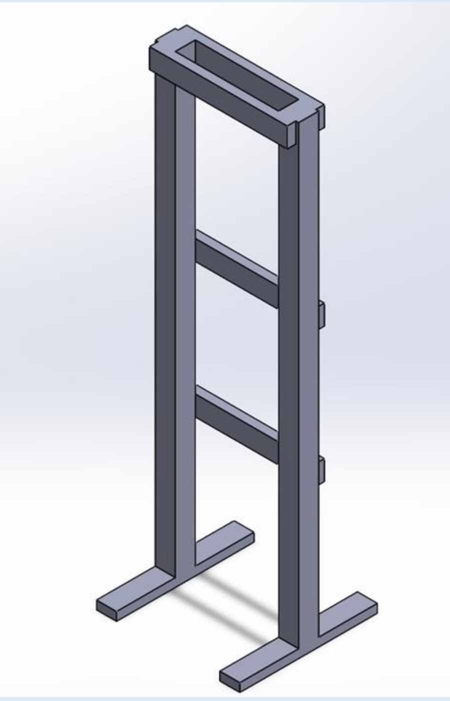

Figure 4, 3D model of stand design.

Figure 5, Final design of test stand.

Figures 3-5 above show part of the iterative design process for designing the test stand for the project, from early drawing to a complete stand.

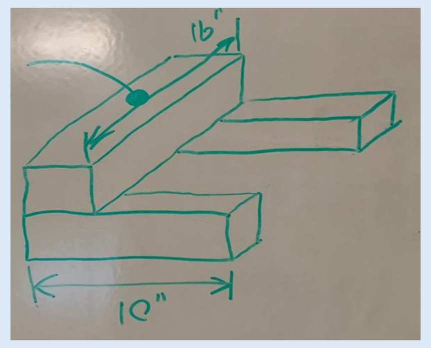

Figure 6, Drawing for turbine stand design.

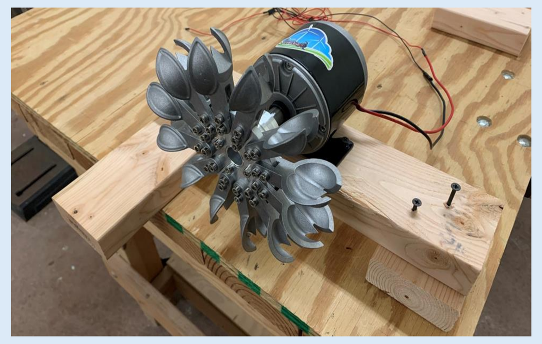

Figure 7, First design for turbine stand.

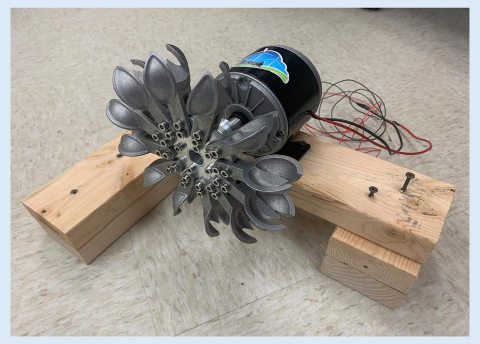

Figure 8, Second design for turbine stand.

Figures 6-8 above show part of the iterative design process for the turbine and generator base, designed to fit in the water collection container and iterated on to allow the turbine enough height such that the water level in the container did not interfere with turbine movement.

Discussion, Conclusions, and Recommendations:

Without the siphon, only 7.20% of the power present in the flow was harnessed by the system. With the siphon, 2.99% of the power was harnessed. Taking the data gathered and applying it to more meaningful applications, the following was determined:

- Using the Amazon Fulfillment Center Warehouse in Windsor, CT, our system would generate 2520kWh (Polansky).
- This would generate $667.82 of electricity (Simms).
- Using Trinity's Math, Engineering, and Computer Science Center, our system would generate 3.21kWh and save $0.85 of electricity.

Our system was ultimately unable to generate enough power and electricity on a larger scale for such an application of renewable energy to be feasible.