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From Capstone Student-led Project to Experiential Learning Module: Design and Manufacturing of an Integrated System of Pico-Hydroelectric Generator and Water Filtration

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Introduction

Renewable energy technologies are continuously expanding due to the increased demand for energy. The support for transition from fossil fuel to sustainable energy sources is also ramping up generating the nurturing environment for these technologies [1, 2]. A special area where sustainable energy resources may have an important impact is related to places lacking access to energy resources. Such areas can utilize innovative technologies that offer diverse features useful for specific or niche applications. Renewable energy systems (wind, solar, micro hydropower) can be customized for use in remote locations, as well as combined for multifunctional purposes (e.g., electricity generation and water purification) basic purpose of the technology and to advance technology to address additional needs of stakeholders.

From educational standpoint, the introduction of these emerging technologies within the curriculum for any engineering program is proven to be difficult due to: (1) novelty of the topic (most of the time the topic is barely out of the research lab), and (2) lack of appropriate learning modules, and curricular implementation, among other reasons. Technologies are fast changing, and curriculum doesn't always keep the pace. Emerging topics in engineering were introduced in classroom teaching via faculty-led research spin-offs, student-led research and project-based learning. During the past decade, introducing sustainability into the curriculum was and is a constant preoccupation for educators, as students need to acquire and master in real-time the skills related to emerging technologies such as sustainable energy resources, energy management, green energy manufacturing. Curricular topics related to engineering education in Sustainable Development, whether related to energy resources and energy management, to manufacturing or healthcare, to food or water, are better conveyed using experiential learning and project-based learning [3]. Educational models are often used to display capabilities and limitations of a system, but fail to provide a complete functional integrated system for data acquisition, testing and monitoring.

Combining undergraduate research with capstone design as project-based learning, we developed a multidisciplinary investigative research project culminating with the design and prototyping of device that will later serve as an educational learning module for Renewable Energy course.

The students were required to evaluate renewable energy resources and design an innovative device to produce and harvest renewable energy. The production of energy using a hydroelectric generator was chosen by the design team. Current devices on the market exclude scaled models that share similarities to industrial hydroelectric generators. During the development of this project students explored and employed mathematical and numerical modeling (CFD) to predict the behavior of the physical system. They also developed a scaled model prototype using 3-D additive manufacturing methods.

The hydroelectric module developed by the Drexel University Engineering Technology students served as an educational module for the Green Energy Manufacturing related courses, evolving into an integrated analytical, numerical and experimental approach, and focusing on creating a discovery learning environment in the classroom. The system was placed within a simulated aqueous fluid environment to control fluid flow. The environment allowed for precise conditional control for educational laboratory experimentation measurements and data analysis. This capstone project was implemented to integrate theory with application at interdisciplinary level. The project combined concepts and notions from fluid mechanics, numerical analysis, digital electronics, microcontrollers, and a wide area of mechanical and manufacturing engineering principles. This hands-on approach enables students to become familiar with methods of manufacturing with provided accessibility to a mechanical laboratory. Such projects encourage students to investigate methods of subtractive and additive manufacturing. This includes equipment for rapid prototyping such as 3D printing, CNC, and engraving.

This paper describes the development of the integrated Pico-hydroelectric system and water filtration, and its adaptation to an experimental learning module. We also detail the level of attainment of the Student Learning Objectives for the capstone project described and the newly developed learning objectives for the laboratory activities created around this experiential module.

Design and development of such capstones projects are evaluated across three consecutive quarters of the academic year. Students submit proposals with detailed information of their design approaches. During the second term (quarter), a working prototype is presented with a progress report. The final term requires a presentation and report including data on performance and recommendations for future work. The students are evaluated through oral presentations and written reports by all faculty members and representatives from industry and outside educational institutions Individual student contributions are included within the evaluations. The capstone project simulates a real-world problem that prepares students for industry[4], [5].

Curricular Context

Senior Design is a core course and degree requirement for BS in Engineering Technology (ET) at Drexel University, College of Engineering, and it is a sequence of 3 courses, 3 credits each, quarter based. The senior design sequence is a mandatory degree requirement for all our ABET[6] accredited BS majors in engineering and engineering technology of the College of Engineering. A particular requirement for ET major capstone design sequence is the development of a functional working prototype as a validation of their design endeavor, presented at their final presentation at the conclusion of the spring quarter. The senior design sequence begins in the fall quarter and is finalized with proposal presentation and written report, and is continued during winter quarter and completed during the spring quarter.

Senior design projects are multidisciplinary in nature; involving students specialized in mechanical and electrical engineering technology. Historically, senior design projects topics undertaken by ET major students are from three main areas, with renewable energy making the 50% of the total, healthcare and manufacturing about 40% of the total number of Senior Design topics. However, most of the topics do incorporate advanced manufacturing notions and methods as well as sustainability, eco-design and life cycle assessment concepts [5], [7]. Each project must address both mechanical and manufacturing, and electrical engineering concepts, combined with a theoretical model description. Students must also address in their project industrial standards pertinent to their topic of choice, as well as societal and environmental impact of their developed product/process. Our ET students manifested a proven increased tendency in tackling projects that are stemmed from actual global challenges, such as developing new and innovative energy harvesting and management systems, healthcare devices tailored to improve quality of care and life, advanced manufacturing techniques aimed to either enhancing learning and understanding or addressing pressing industrial additive manufacturing demands. Our senior design sequence has been previously detailed in other published works. [5]

Capstone Project Rationale

More than 1 billion people daily go without common resources such as safe drinking water and electricity, while many governments and companies are working towards a planet in which everyone has access to these resources [8, 9]. According to Water.org, 1 in 10 people or 663 million people lack access to safe water. In addition to that, water crisis is the number one global risk based on its impact to society (as a measure of devastation), as announced by the World Economic Forum in January 2015 [9]. Along with a shortage of safe drinking water, there are several other resources that millions of people lack access to daily; one of which is electricity. The ability to flip a light switch on or charge a device is taken for granted in the United States more often than not. There are 1.3 billion people around the world that lack access to electricity; 900 million of those people are from Africa and India alone (Washington Post, 2015). The growing demand for renewable energy sources that can provide people with electricity is as high as ever. Progress has been made to provide more people with power every year, however there are other implications that come along with this. According to an article published by The Washington Post, providing power to these unserved populations will cause a jump in the demand of fossil fuels (Washington Post 2015). Roughly 22% of the world's energy is renewable, and countries such as India have promised to place an emphasis on renewable energy as a method to provide millions of people with power. However, the amount of fossil fuel use and carbon dioxide emissions will inevitably increase as we provide power to unserved populations, primarily using non-renewable energy sources [8]. Understanding the effects of greenhouse gasses and the need for more renewable energy sources is what led our student senior design team to design PHiLTER, an integrated pico hydroelectric generator and water filtration system.

PHiLTER, a pico-hydroelectric generator with a built-in water filtration system simultaneously provides people with these two resources through an innovative, flexible and durable design. Through the use of several integrated systems and feedback controls this green energy manufactured device utilizes the natural forces of rivers and streams to propel a generator and filter water through a multi-stage filtration system capable of eliminating contaminants down to 0.05 microns. With a long-term goal of designing and manufacturing a large-scale system that is capable of producing a net energy generation of 2.5+ kWh per day, as well as 10 gallons of safe drinking water per day, a scale model was constructed to prove design feasibility and scalability. The scale model allowed our senior design team to meet and overcome various technical challenges, from both a design standpoint as well as from an environmental standpoint, and has ultimately allowed us to design a product that is able to adapt to people’s needs and environmental changes. The scale model, which is 23” in length, includes a 6” x 6” intake valve that transitions to a 4” diameter tube which includes a variable volume valve, a four-blade propeller and a pulley that connects to a generator above the system. The variable volume valve inflates or deflates to vary the inside area for which water can pass through and in turn increase the velocity of the water when initial conditions are suboptimal. Through computational fluid dynamic simulations, this design has increased the initial water velocity from 5 feet per second to upwards of 20 feet per second. Furthermore, the scale model could also serve as an educational device for green energy courses. Students can change the water velocity of a pump in an aquarium, where the model is tested, to show the use of feedback mechanisms and how PHiLTER can provide an electrical output to power LED's and charge cellular devices. By simply placing PHiLTER in any moving body of water, the end user will be able to provide themselves and others with these two valuable resources. This product is not only durable and able to adapt to the changing river characteristics, but is also scalable from educational usage, to personal or communal use.

As per students' thought process, when this project first began, it was centered on the idea of using green energy manufacturing to further help those in need. As hydropower is the most commonly used renewable energy source, they we felt that hydropower would allow them to **create a device that would have a big impact on society**. They came with a unique innovative idea of a device capable of producing electricity and safe drinking water simultaneously. They investigated **the feasibility of the project** by generating designs, performing calculations, running simulations, choosing specifications for parts and understanding the flow patterns and rates at various river and stream locations throughout the Philadelphia region. When analyzing data from local rivers and streams in the Philadelphia region, throughout the course of the year, particularly in correlation with the wet and dry seasons, the average discharge rates, river height and river velocities change considerably. In order for the generator to operate there is a required amount of torque necessary to turn the shaft. This torque is generated from the incoming rush of water through the housing intake where it is then used to spin a turbine which is directly connected via a shaft to the generator.

Engineering Design:

By thoroughly evaluating each feature of PHiLTER on an individual basis, for several factors including but not limited to viability, cost, and longevity, students optimized the overall design to improve efficiency, boost energy output and minimize cost. Several models were explored by student team and based on simulations and using additive manufacturing (3D printing) they start building eac component as presented below. Initially, water passed through a nozzle-like apparatus, immediately increasing the velocity of the water. For this part, a square intake lofted to a circular exit, noted in Image 1 below, was justified as the optimal design for several reasons.

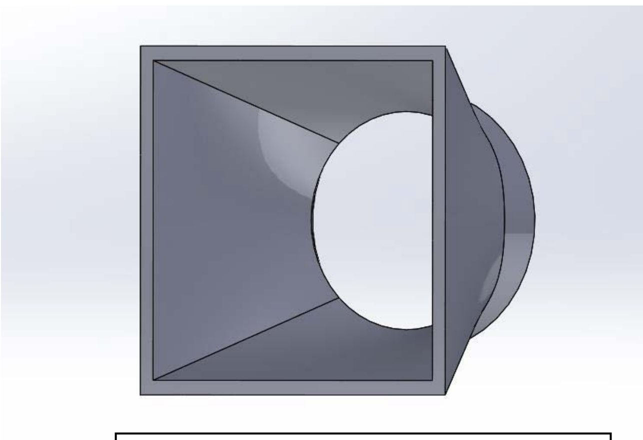

Image 1: Scale Model Intake Design

The square-to-circle part feature is commonly found in HVAC ductwork and is particularly easy to have manufactured at a low cost. Next, as previously mentioned, water enters a circular tube or pipe which will house the variable volume valve, turbine, and power transmissions parts.

This part was quickly analyzed and justified as the optimal part for this requirement. Other options include various shapes such as a square. However, with a circular shaped turbine, to be discussed shortly, this would allow water to pass between the turbine and corner of the square feature and the potential energy of the water rotating the turbine would be lost. Therefore, a circular tube or pipe is the obvious part of choice for this feature because it will allow for minimal clearance between the feature and turbine. When selecting the material for this feature however, there are several options including PVC and various metals. When analyzing these materials, we have chosen PVC for several reasons. First and foremost, PVC has a smooth interior surface that is frictionless. This is important because, unlike metals, there will be no energy loss or loss in water velocity due to friction of the tubing. Furthermore, a frictionless and smooth surface will prevent the water flow from further becoming more turbulent. The final consideration factor is cost and this was analyzed by pricing a schedule 40 8” inside diameter tube or pipe that is 36” in length. PHiLTER aims to be the most innovative pico-hydroelectric generator on the market through the use of a variable volume intake. As discussed in the previous design feasibility study, this will drastically increase the velocity of the incoming water when river flow conditions vary. Through the use of Autodesk Computational Fluid Dynamics (CFD) this design was simulated and justified. However, upon doing more research, experimentation, and talking to industry professionals this design would be hard to implement and may not have as great of an effect as initially believed. When designing this part, the goal was to have a mechanism that could be modulated to adjust to varying flow conditions to maintain optimal power generation. The initial design incorporated the idea of a nozzle, similar to that of the intake nozzle. However, when the nozzle was closed to a smaller area, water would be directed towards the center of the propeller’s core rather than the blades, which in turn would waste energy and make it more difficult to rotate the turbine due to the lack of torque. This would result in fewer revolutions per minute (RPM) and ultimately less power generated. The initial design can be seen in the rendering in Image 2 below.

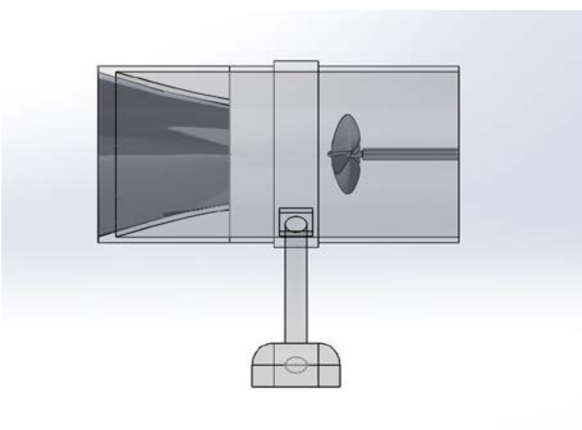

Image 2: Initial Variable Volume Valve Design

In order to overcome these potential issues, an even more innovative variable volume valve needed to be designed. Rather than designing a valve that closed and decreased the internal area in which water could pass through, a new approach was taken. The new design can be seen below in Image 3 where air is injected into the valve's body located in the center of the tube.

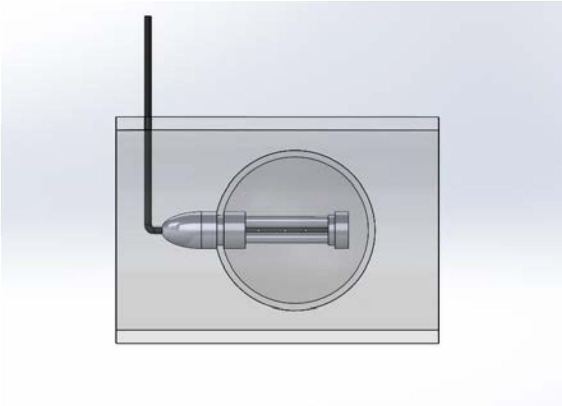

Image 3: Redesigned Variable Volume Valve

This valve is composed of a nose, similar to that of an airplane, to divert water around the body of the valve. From there a latex covering, which is sealed to the end of the nose, surrounds the remaining body of the valve. When air is injected into this body of the valve, the latex inflates and creates a spherical shape. The diameter of this sphere is dependent on the amount of air injected into the valve. This design will create the same effect as a standard nozzle, and the old valve design, by increasing the velocity of the water as the area water can pass through decreases. However, unlike the original design the water will be diverted to the outer fins of the turbine, generating the most torque on the turbine and allowing for the highest RPM. In order to prove this new design worked, and was more effective than the previous design, we simulated this design in Autodesk CFD using the same initial conditions and materials as previous simulations. Results from these simulations can be seen below in Image 4 below.

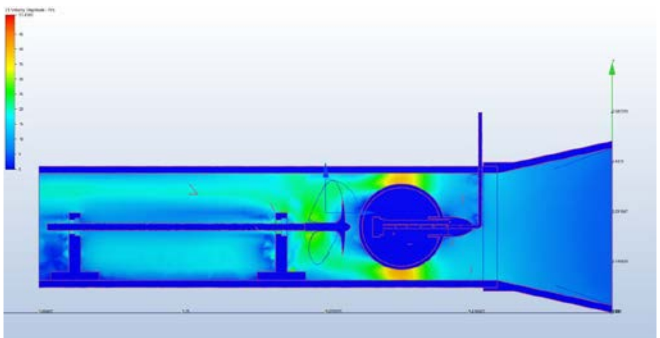

Image 4: Computational Fluid Dynamic Simulation

As seen in this image, water is successfully diverted around the valve and towards the fins of the turbine. As well, there is a significant increase in velocity which solidifies the design as feasible. As we continue to evaluate the overall design of PHiLTER, the next piece is the turbine. For the initial design, we chose a propeller and this will remain the turbine of choice. With zero head, other turbine designs such as Kaplan turbines will not be sufficient for this run-of-river project. The propeller is then connected to a shaft where the motion will then be transferred to a generator above the submerged device. In the initial design of PHiLTER there was a 2:1 right angle gear box that would connect the propeller/shaft to a vertical shaft that is connected to the generator. When evaluating different options for this feature we took into consideration using a pulley system. Upon selecting specifications for a pulley, we could compare the different parts. The first issue with the gearbox was the overall weight of the part and managing to mount the part precisely. On the contrary, the pulley would attach directly to the shaft and a timing belt could be used to connect to the generator. Furthermore, the gearbox was able to achieve a gear ratio of 2:1 at best. However, with the selected pulley system, a gear ratio of 3:1 could be achieved. With a 50% increase in RPM, as well as being lighter and cheaper we have selected to use a pulley system instead of a right-angle gearbox to transfer the motion from the propeller to the generator. Before discussing PHiLTER's water filtration system, there is one more part to evaluate, the generator. After much research, we have confirmed the use of a permanent magnetic generator due to the low start torque, and application in green energy projects compared to standard alternators which have extremely high RPM requirements.

Upon completing the mechanical design for PHiLTER, it was imperative to ensure the water filtration could be implemented into the system. In order to do this, a hole was drilled out of near the rear end of the tubing, right before the water outlet. This would allow the pump to draw water that is passing over the propeller and through the tubing. From there the water is pumped through PVC tubing and through the multistage filtration system. For the full-sized model, water would then be stored in a storage container, monitored for quality and provided to the end user. For the prototype, however, water is replaced back into the test tank to maintain water levels. In order to ensure the filter is working as intended, the tank was filled with tap water and the parts per million (PPM) of the water was tested. After allowing the system to run for several hours the PPM of the tank would be re tested. Results for this test can be seen in the Testing section below. Next, it is equally important to evaluate the parts for the control system. In order for PHiLTER to properly operate the correct parts must be used along with useful coding.

The electrical components for PHiLTER has not changed from the initial design. For the prototype the Raspberry Pi will be connected to a display through the display port, 5V power will be connected to pin 2, and ground will be connected to pin 6. The Raspberry Pi is connected to the Arduino through the USB-A port. The Arduino is connected to the raspberry by USB-B port. The DC AMP meter is connected to the 5V and ground pin in the Arduino. Pins A0 is being used to measure the voltage of the generator. To measure the voltage of the generator it will be using the Code Logic 1 formula**.** The **"**sensorBatteryVoltage" variable is the analog reading from 0 to 1023 that is coming from the generator. After we get the analog reading then the Code Logic 1 convert that analog reading to voltage. Pin A1 is connected to the DC AMP meter module. To measure the amperage of the generator it will be using the Code Logic 2 formula**.** The "sensorGenatorAmp" variable is getting analog reading like the "sensorBatteryVoltage" variable but its is coming from the the Vcc pin on the DC AMP meter module. After the analog reading from the "sensorGeratorAmp", then the Code Logic 2 formula convert that analog reading into amperage. Knowing the voltage and amperage of the generator, we can use the Code Logic 3 formula to get the wattage of the generator. The Raspberry Pi is using Java for the graphical user interface (GUI). The monitor tab will be displaying the amount of voltage, amperage, and power from the generator and the system tab will display three button that will exit, restart and shutdown the system. The Java GUI will read from a text file that has values of the voltage, amperage and power. The Arduino cannot insert the values that it's creating directly to a text file so we have to use the Python language to insert the values coming from the com port to the text file. The system tab they're three buttons that you can press which uses bash script to activate it. The button to the left called "Exit" will exit the program.

The button in the middle called “Restart” will restart the system and the button to the right called “Shutdown” will shut down the system. Initially we were going to use Java and C but we had to download other libraries to read from the com port. The library we downloaded was RXTX for Java. The RXTX library gave Java the capability to read from the com port. It did not work properly with the Raspberry Pi because it was very complicated to install to Java and the compiler that we are using. We found an alternative method instead of reading from the com port directly, we used Python to read from the com port and then insert the values to a text file which will later be read from the Arduino as mentioned before. The GUI got more complex from our last design because we added tabs. On the first tab the user will be able to read the voltage, amperage and power of the generator. On the system tab the user can exit, restart and shutdown the raspberry pi. This is shown in Image 5.

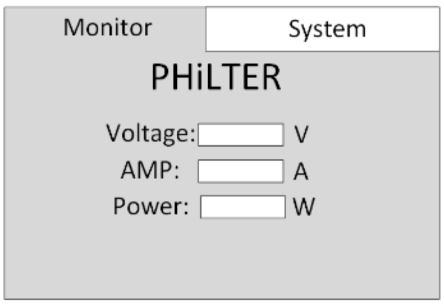

Image 5: GUI Design Concept

The step-up boost converter will convert the initial voltage coming from the DC motor and boost it up to a regulated 5V to be able to charge any power bank or devices such as a cell phone. The boost converter has a regulator built into the PCB (Printed Circuit Board) to restrict any voltage going no higher than 5V which might cause damages to any devices being powered from the USB interface. The usb interface allowed us easy access to any devices by using a usb to mirco usb cable to charge either a cellphone or a power bank. The remaining hardware are the air compressor and two water pumps. Due to the fact that we are making a scale down model of PHiLTER, we are not going to be using batteries as a power storage instead we are using a 12V DC power supply which is generated by the power generator. The two water pumps with adjustable flow speed will be powered through 120VAC wall outlet to mimic the flow of the stream.

Students build a scaled down prototype as educational learning module. This would allow effectively testing and experimenting with features such as the valve to see if there are any ways to improve the feature before implementing it on a larger scale that will inevitably cost more money. Aside from being able to test the functionality of the generator, this scale model could be used for educational purposes. The renewable energy course teaches student about the various types of renewable energy systems through lectures and experiments. However, this course does not currently offer an experiment to teach students about hydroelectric power. PHiLTER could allow for students to measure various inputs and outputs that are typically found in hydroelectric systems.

For this scale model, many of the parts specified were able to be manufactured with a 3D printer. For instance, the intake, propeller, valve, bearing blocks, housing stands and generator stand were all 3D printed and can be seen below in Image 6.

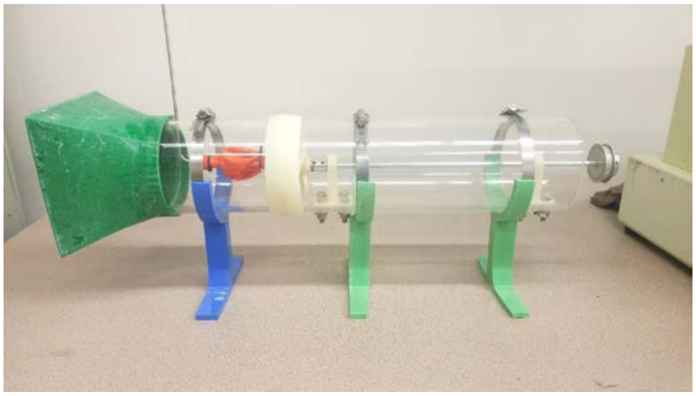

Image 6: Scale Model Prototype

The model was scaled down to have a tube inside diameter of 3.75”, and an intake area of 6”x6”. In order to generate electricity a brushless DC motor was purchased. Although this generator provides low amperage, the voltage is directly related to the RPM. Furthermore, the scale model will be placed in a tank that will be filled with water. An adjustable flow rate circulation pump that is capable of a max flow rate of 895 gallons per hour (GPH) will circulate water through the tank to simulate the moving current in a river. This setup will allow testing of the hydroelectric generator. In order to test the water filtration a pump will be placed within the tank with PVC piping attached to it and directed vertically out of the water. Through the use of two right angle PVC fittings, and a threaded fitting, the filtration straw will be connected to the piping. The pump will push water through the filter, which is above the tank’s water level and back into the tank. By doing this we are able to keep the tank water clean and can test it for various EPA regulation requirements.

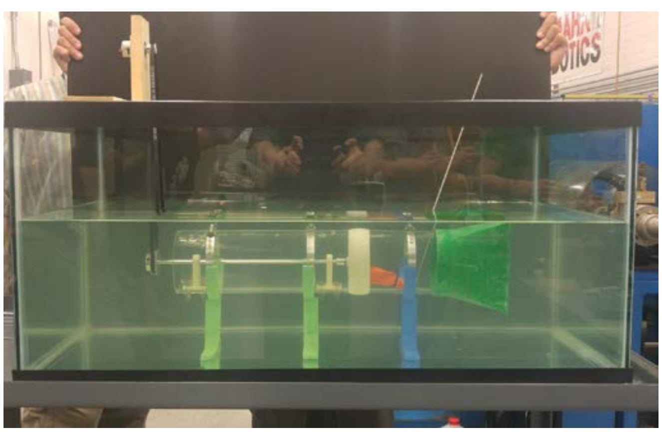

Image 7: Scale Model Setup

By building a scale model prototype we are able to accurately simulate the different features and make any changes as necessary before building a full-size model. As we began initial testing, a few simple changes were clearly evident from watching the prototype function. As water flowed out of the outlet of the main body of the prototype, it contacted our pulley belt. We noticed as it was flowing through the pulley belt, this water was creating drag on the pulley and shifting the belt slightly as it turned. In order to improve this and minimize this effect, we created a pulley guard to divert the flowing water from the outlet around the pulley. The pulley guard can be viewed in Image 9, below. Another obvious change we noticed from viewing the prototype functioning was decreasing the space in between the propeller and the walls of the clear acrylic tube. The total diameter of our propeller was too small, and as a result, we were losing precious energy from the water and drag forces created from the propeller spinning. We increased the diameter of the propeller to be within 0.03 inches from the inner diameter of the clear acrylic tube. This change coupled with the implementation of the propeller guard proved to be simple yet very effective in increasing the overall efficiency of harnessing energy from the flowing water.

Testing and Results:

As we designed the prototype for PHiLTER, it was time to move on to the testing phase. We went with two different method of testing. The first test was doing a control test in the mechanical lab with the fish tank and water pump to determine if the prototype was functional with all its moving parts. We tested the PHiLTER prototype in two different methods. The first method was to determine how much voltage the DC motor could generate with just the water pump shooting the stream into the propeller

The second method was the same test as the first method except the addition with a step-up boost converter. The reason for the second method of testing was to determine the function of the electrical hardware as well as the wiring throughout the prototype.

Using the second method, we were able to charge a cellphone/power bank using the USB interface from the step-up boost converter. The cell phone estimated charge time was roughly 6 hours from empty to full charged. The second test was to do a live test out at the Wissahickon Creek also known as Valley Green. We went to the Wissahickon Creek to do a live testing of the prototype by checking out the scouted area from the previous terms. We went to multiple spots to determine which would be the ideal location to do the live test. When setting up the prototype, we noticed that the water was a bit shallower than what we wanted. We had to make a few adjustments on the site to be able to collect data efficiently. When we tested the prototype in the Wissahickon Creek, we used the same two methods from the previous control lab test. The first method was without the boost converter to determine how much voltage would be gained from using an actual stream instead of an artificial generated one.

In addition to the mechanical power generation testing, our team conducted some water filtration testing to test the effectiveness of our current setup. The tests were conducted inside the prototype tank, using a total dissolved solids (TDS) sensor to measure the number of contaminants within the water before and after filtration. With the tank filled to allow the prototype to be submerged, the water flowed through our prototype and then pumped through our filter from the outlet. The filtered water was then allowed back into the tank, to create a filtration cycle. The initial TDS measurement for the water was approximately

280 PPM. After allowing filtering for 3 hours, the water in the tank read approximately 160 PPM, showing a definitive improvement in overall water quality.

Future Work:

PHiLTER was initially designed to be a full scale, working product that provided people with electricity and safe drinking water. In order to ensure the design would work a scale model prototype was designed, built and tested. Unfortunately, due to time restrictions, a full-size model was unable to be built but an energy balance analysis was done to ensure the product would successfully meet the initial design goals. Furthermore, it is important to note that the valve was installed on the scale model but was not successfully implemented. This is due to several factors, most prominent the material selection and size limitation of the valve. Testing was done with a latex balloon wrapped around a 3D printed valve. This design often let air leak out and the balloon inflated unevenly. The design and concept certainly would work, as it briefly showed promising results on the scale model, if implemented for the full-size model. The full-size model would allow for more durable rubbers to be used that are often used in control valves. As well, modulating the air pressure into the valve would be simpler and allow for a more even inflation of the valve. With that being, the hydroelectric portion of the model did work as designed and satisfies the design criteria and goals. Therefore, PHiLTER can, and should, be implemented on a larger scale. In order to further prove PHiLTER is an effective product, an energy balance analysis was performed. This analysis performs energy production and consumption calculations based on propeller size, river velocity, electrical equipment needs, etc, to determine the total energy output for PHiLTER had a large-scale model been built. All of the formulas used can be seen in Table 1.

cp	0.3		
density	0.0624	Motor	
swept area	113.04	Volts	25
mph	3.41	Amps	6
		Watts	150
Power (watts)	**5.579853**	kWh	0.15
		kWh/Day	3.6
tip speed	0.5	Pump Watts	13.2
Constant	9.549	Pump Total Draw	39.6
		Comp Watts	168
		Comp Total	840
Angular velocit	37.88889	Micro Watts	0.225
		Micro total	5.4
RPM	361.9958		
Torque	0.147269	Total Power Draw (kW)	0.885
		Net Generation	2.715

Table 1: Energy Balance Analysis

The results were calculated based on a water velocity of 5 feet per second and a propeller that is 12” in diameter. This would result in a minimum 0.147 N*m of available torque to spin a generator. This number does not take into account the increase in initial water velocity through the nozzle intake and past the valve. This number could then be compared to the start torque requirement for a Windstream 443541 permanent magnet dc generator which requires 0.044 N*m. Similar generators, such as the DC 540 from

Wind Blue Power, output roughly 25 volts at 6 amps when operating at roughly 300 RPM. Based on the torque calculations, the water velocity would result in roughly 360 RPM. Therefore, we can assume that if a full-size model were to use this generator it would generator 150 watts, 0.15 kWh and 3.6 kWh in a day. In order to correctly run PHiLTER, however, there would need to be several devices drawing power. This includes the microcontroller, inline pump, and air compressor. For this analysis, it was assumed that the compressor runs for a total of 5 hours per day, the inline pump for 3 hours per day and the microcontroller 24 hours per day. All of this would accumulate to draw 0.885 kW per day. This would result in a net energy generation of 2.715 kWh.

Conclusion:

PHiLTER is a two-in-one system that is able to provide end users with safe drinking water and usable electricity, simply from the natural flow of a river. With feedback and automated systems, this design can adapt to conditions, putting out consistent power and drinking water. Over the course of the entire project, various design alternatives for various facets of the prototype were considered and implemented where necessary. By creating a scale model, we were able to ensure design feasibility and simultaneously create useful educational equipment. This project has been nothing short of a learning experience that could ultimately lead to a product to be used in the real world to help students learn and more importantly provide people with electricity and water. PHiLTER is an innovative system that could be used to help generations to come.

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