INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

IJARIIT

ISSN: 2454-132X
Impact Factor: 6.078

(Volume 9, Issue 2 - V9I2-1333)

Available online at: https://www.ijariit.com

A proposed pico-hydropower technology applying the modified principle of heron's siphon for renewable electrical energy generation and storage for street lamps in Camias, Porac, Pampanga

Jhaymar Q. Bacani
bacanijhaymar25@gmail.com
Don Honorio Ventura State University, Pampanga, Philippines

Mark A. Gotiangco
markaquinogotiangco@gmail.com
Don Honorio Ventura State University, Pampanga, Philippines

Daryl Lloyd M. Magno
daryllloydmanalilimagno@gmail.com
Don Honorio Ventura State University, Pampanga, Philippines

Christian A. Naguiat
christiannaguiat67@gmail.com
Don Honorio Ventura State University, Pampanga, Philippines

Christian S. Romero
christian.romero1127@gmail.com
Don Honorio Ventura State University, Pampanga, Philippines

Alexander T. Tiongson
alexander.tiongson30@gmail.com
Don Honorio Ventura State University, Pampanga, Philippines

John Vincent G. Tongol, RCE, MEnM
jgtongol.13@gmail.com
Don Honorio Ventura State University, Pampanga, Philippines

Carl Jason A. Coronel, RCE, MEnM
carlcoronel0707@gmail.com
Don Honorio Ventura State University, Pampanga, Philippines

ABSTRACT

Energy affects the economy, environment, and human progress. Due to modernity, energy powers most basic human needs and activities, including illumination, ventilation, movement, and security. Rapid urbanization and energy poverty have led to the need for more, better, and greener resources. This study used pico-hydropower to solve Barangay Camias, Porac, Pampanga's streetlamp system's electrical problem. Data was collected and analyzed to support the study and the power outage in Barangay Camias, Porac, Pampanga. Pico-hydropower concept and design follow. Geometric dimensioning was explained. After designing, prototype construction began. The study's siphon system used a five-gallon water jug and 20mm uPVC pipes. Hydraulic turbines were made using discarded cooling fan alternators. The generator employed a 12-volt DC motor, 3V 1000mAh rechargeable battery, and circuit breaker. Researchers

employed 1.5-V LED lights. The prototype testing yielded 2.6 V. 90mA generates 0.234W. The theoretical power (0.3190W), minimum efficient power (0.1914W), and maximum efficient power (0.2552W) were compared to the generated power. Reverse engineering calculated a 30W LED streetlight design similitude. The pico-hydropower plant prototype generated a 0.234W or 2.6V which is within the average efficient power, proving the design's efficiency and viability.

Keywords: *flowrate, rpm, prototype, efficiency, viability*

1. THE PROBLEM AND REVIEW OF RELATED LITERATURE AND STUDIES

1.1 Introduction

Energy is vital for sustainable human development and is interrelated to the economy and environment. Due to modernization, energy has been the central power for most basic human needs and activities, particularly for lighting, ventilation, mobility, and security. However, issues like the need for more sufficient, high-quality, and environmentally friendly resources have emerged due to rapid urbanization and energy poverty.

Over the course of the last few decades, there has been a discernible rise in the use of energy on a worldwide scale. According to Dong et al. (2020), the consumption has greatly grown, increasing from 8,588.9 million tonnes of oil equivalent (Mtoe) in 1995 to 13,147.3 Mtoe in 2015. This represents a huge increase. Any plan that has as one of its goals the promotion of economic growth that is both egalitarian and sustainable over the entire planet need to place a strong emphasis on assuring energy performance. According to the study of Overland et al. (2022), the insufficiency of energy security is due to the uneven distribution of fossil fuel resources. Generally, fossil fuel power plants generate electricity by burning oil products. The idea of evaporation and sublimation will be utilized in this process; liquid and solid fossil fuels will be converted as steam by burning to drive the turbines that will initiate electricity generation. However, more than this concept of electrical generation is needed to supply the unending growth of urbanization. Thus, most countries currently rely on the capacity to develop other energy resources. The energy resources may become more susceptible as the importation of oil products in third-rate countries continuously grows.

Being part of the third-rate countries, Philippines used 8,134 gigawatt hours (GWH) of electricity in accordance with the recent data provided by the Household Energy Consumption. This is an increase over the previous six years of 1,289 GWH, or 18.8%. This equals an average of 215 GWH annually. The most typical form of energy used by Filipino families is still electricity. Lighting is often powered by electricity, which has consumed 58.33 billion gigawatt hours.

Due to continuous research and studies, renewable energy has been used to generate electricity. With a proper concept of energy conversion, noting that the First Law of Conservation of Energy states that energy cannot be created nor destroyed, and the supply of electricity has increased dramatically. Nowadays, electricity can be generated using the potential energy coming from the sun, coal, and even water. With modernization and advanced technology, various concepts have been successfully studied to solve the growing demand in the field of electricity. In this study, electricity has been generated using water. The idea and principle of modified Heron's siphon have been utilized; thus, the study aimed to design a pico-hydropower machine.

1.2 Review of Related Literature

1.2.1 Electrical Power Sources

Electricity or Electrical Power is one of the vital keys for human development since it can significantly affect a country's economy and overall livelihood. With the rapid growth and advancement of technology, most human activities are related to electrical supply and consumption. It is commonly consumed to run lighting devices, appliances in homes, and even pieces of machinery in factories. Due to its importance and relation to rapid urbanization, problems in electric supply and demand have arisen nowadays.

In the study by Miroshnichenko et al. (2019) entitled "On the Possibility to Solve the Problems of Electrical Power Supply to Autonomous Consumers by Using Renewable Energy Sources" It is stated that one of the most significant issues facing Russian power is related to the electrical supply and distribution of power to users who live in rural areas. The most visible effect of the electrical supply and demand issues is the rapid economic change in the country. This article provides a categorization of the Russian areas based on the degree of centralization as well as the degree of safety regarding fuel and energy sources. Both diesel power plants and renewable energy sources were compared and contrasted. The writers also conducted a comprehensive analysis of the advantages and disadvantages of various renewable sources of energy.

To address environmental issues and utilize energy resources efficiently, research into energy conservation has increased in recent years. Several concepts and types of renewable electricity resources have been researched and used with the help of science and engineering principles. Nowadays, electricity can be generated from different renewable energy sources using different power generators. According to the U.S. Energy Information Administration (2021), there are three significant energy categories for electricity generation: fossil fuel, nuclear energy, and renewable energy. Electricity from fossil fuels is considered the largest source of electricity. The production of steam, which is the first step in the process of generating electricity, requires the usage of fossil fuels like petroleum, coal, and natural gas. In nuclear power plants, steam turbines are utilized to create electricity from nuclear fission in order to harness the power of nuclear energy. Lastly, there are different renewable energies that are used in the generation of electricity. It includes hydro, solar, geothermal, biomass, and wind energy. Renewable energy is used to rotate the turbine to produce mechanical energy that will be used and converted into electrical energy using a generator.

1.2.2 Hydroelectric Power

Various types of energy are used around the world. The idea of a world without energy is unimaginable. Energy is essential to the survival of humans at every stage of their lives. Humans have consumed energy since the beginning of time—daily, the energy demand has increased. Worldwide energy consumption has increased exponentially in recent decades, from 8,588.9 million tons in 1995 to 13,147.3 million tons in 2015 (Dong et al., 2020). The consumption of additional energy is inevitable given the progression of human civilization. Conventional energy sources include coal, petroleum oil, natural gas, nuclear power, and hydropower; fossil fuels account for around 90% of conventional commercial energy consumption (Rahman et al., 2017). In the current global context, conventional energy sources account for 85-90% of primary energy consumption. Unlike developed countries, which are at an early stage of industrialization, developing countries have experienced more significant growth in energy consumption. With this, the world is competing to meet demand with limited energy resources. In terms of installed capacity and global investment flows, hydropower constitutes the overwhelming bulk of the renewable energy that is used to produce electricity across the world. According to the BP Statistical Review of globe Energy 2020 (Zhang et al., 2021) (published in the BP Statistical Review of World Energy 2020), hydroelectricity was responsible for producing 15,6% of the 27,004.7 Terawatt-hours (TW) of power that the globe produced in 2019. Approximately half of the total electricity produced by hydroelectric dams is grid-connected in more than 150 countries. In more than 60 countries, this equates to at least 50% of the total electricity production; in more than 20 countries, it reaches more than 90% (Hancock & Sovacool, 2018). Hydroelectricity is one of the most readily available renewable energy sources that can support human well-being in an environmentally sustainable manner.

In the study of Nayak et al. (2019) entitled "Design and Fabrication of Pico Hydro Turbine," hydropower plant machines were classified into categories based on their capacity to generate electricity. There are four categories: Large Hydropower, Small Hydropower, Micro-hydropower, and Pico-hydropower Machines. Large hydropower is a machine that can generate more than 100 MW. Small hydropower has a generating capacity of 1 MW to 100 MW. The micro-hydropower plant can generate electricity ranging from 5 KW to 100 KW. Lastly, the pico-hydropower plant has a generating capacity of less than 5KW. Pico-hydropower is enough to generate electricity for street lighting and other miscellaneous consumption.

According to Bellen (2017), hydropower has long been recognized as the most developed and dependable of all renewable energy sources. The size of hydropower projects varies from a few kilowatts (kW) for pico-hydropower to many gigawatts (GW) for large-scale projects. Therefore, recent research has concentrated on employing pico-hydropower plants, which require little to no impoundment to move away from conventional hydropower facilities. They leave a less negative environmental impact and cost less to construct and maintain. Pico-hydropower is where "run-of-river" technology is most frequently applied. This technology is prevalent in rural areas with low population densities, especially in mountainous locations with suitable slope and run-off conditions.

One of the most important and major sources of electricity is hydropower. The most recent development in hydropower generation is micro and pico-hydroelectric power. These plants are cheap, convenient, and hygienic for the environment. In the study of Durrani et al. (2019), Low-head screw turbines were used in micro-hydropower plants to produce electricity using sewage water. A single screw turbine connected to the sewage line generates an average power of 1963 watts. It is concluded that the number of turbines, head, and flow rate is directly proportional to the power generation. As the number of turbines, heads, and flow rate increases, the power generation also increases.

Hydraulic turbines or water turbines convert the potential or kinetic energy from the water into mechanical energy, which is then transformed into electrical energy by a generator connected to the turbine. According to the study of Kamran (2023) entitled

"Energy Sources and Technologies," hydropower plants use either impulse turbines or reaction turbines. Impulse turbines rotate their runner using only the kinetic energy of the water. In this type of turbine, the water is ejected from the nozzle or water pipe and thrown into the turbine to initiate the rotation. On the other hand, the reaction turbines use kinetic energy and water pressure. The reaction turbine will be placed under the water and let the water enter the turbine system to initiate the rotation. In application, both types of turbines have pros and cons and can be used based on the hydropower plant's type and design.

1.2.3 Streetlamps

Street lamps, also called street lighting, are lighting systems used on the roadside or suspended to a cable above the road to provide illumination. Lighting is necessary to provide safe, convenient, and comfortable pedestrian and transport movement. In the study of Thiel et al. (2017), the research opportunities and practical difficulties identified by the study established the foundation that must be considered to develop a model of street lighting. The behavior of the public is significantly affected and interacted with by street lighting. The lighting systems in streets, squares, parks, and famous buildings can be considered physical systems, each with its dynamics, inputs, and outputs. The anticipated outcomes are the protection of motorists and pedestrians, the encouragement of sports and leisure pursuits, and, among other things, a decrease in crime at night. However, there are some limitations in the study of Thiel et al. Other databases were not used in the search process, resulting in the portfolio compilation, which only examined six journals.

Street lighting should aim to increase visibility at night without significantly increasing construction costs or energy usage. However, the current street lighting system uses more energy because the lamps are fully illuminated even when no vehicles or pedestrians are nearby. Currently, the energy supply needs to catch up with demand. Jebaseeli et al. (2021) proposed an effective and all-inclusive plan for energy savings in lighting to resolve this. The design circuit used in the study is simple and has flexibility. Necessary controlling actions can be determined depending on the volume of passengers on the road. A further benefit of using renewable energy sources is that the entire system can become self-sufficient, making it more durable and dependable. The three primary techniques used to save energy are the Dawn-Dusk, Reduced Voltage, and Random Cut-off Methods. The three techniques proposed vary in the process. Dawn-Dusk Method is a method that uses sensors to know if there is a need for lighting in the situation. The Reduced Voltage Method is a technique that connects a series of resistors to the motor's lines. The voltage drop that takes place as current travels through the resistors has the effect of lowering the voltage that is present at the terminals of the motor. While the Random Cut-off is a method for the conservation of electrical energy, it does so by momentarily obstructing the passage of electrical current in a certain region during a predetermined amount of time. The use of circuit breakers is one of the most prevalent activities that are performed when utilizing this strategy. The role of a circuit breaker is to offer an interruption function to the flow of current in order to safeguard and save electrical energy. Circuit breakers are electrical devices that are meant to protect and automatically halt the circuit circulation from the damaged component of an electrical system. This concept can methodically take advantage of the streetlight's energy-saving capabilities in well-planned urban areas. Unfortunately, the study made by Jebaseeli et al. was limited to energy conservation. It could not solve the problem according to the energy source supply that can be utilized in street lighting. Hence, it only uses commercial electrical energy.

In one study, Passago et al. (2020) developed a design that utilizes the solar-powered streetlight and electricity generation model. The model uses solar panels with 80-Watt solar cells and 12 V, 45 Ah batteries. The electric poles used in the automatic lighting control system had a height of 6 meters and were spaced apart by 13 meters. Solar cell panels can produce an average voltage of between 12.06 and 14.08 volts, with a charging capacity of 0.79 and 4.72 amps for batteries. The average voltage of the LED was between 10.04 and 11.95 Volts, and the current flowing through it ranged between 0.18 and 1.22 Amps. Thus, Passago et al. conclude that the energy consumption of the streetlamp is lower than the generated energy of the proposed streetlamp. Another study conclusion is the significant value corresponding to the relationship between the voltage and the battery of the solar-powered street lamp. The design benefits the environment by generating high amounts of clean energy. On the other hand, combining manufacturing experience with LED light expertise from the automotive educational institute is a prior requirement for high-volume production and quality standards.

1.2.4 Heron's Siphon

The hydrodynamic device known as Heron's siphon is a combination of hydraulics and pneumatics, despite appearing to be in perpetual motion. However, the principle of the siphon mechanism has been in use for decades in different engineering works, and more data is needed to show how it is performing. A study entitled "Study on Structural Characteristics of Siphon Well Design in a Power Plant" by Dongmei et al. (2019)

described and analyzed the structural characteristic of a siphon well and its primary function. According to the study, a siphon's overall structural characteristics are vital in determining the siphon's needed performance well. During the study, the physical model test was held in the laboratory, having a four-experiment with the outflow of water from the weir at angles of 15, 30, 45, and 60 degrees of intersection. Therefore, taking into account the discharge capacity and the hydraulic flow pattern, a preliminary design for an oblique weir that has an angle of somewhat more than 30 degrees has been drawn up. The siphon well size is calculated during the design process by optimizing and analyzing the design parameters from three perspectives: Economic optimization analysis, Optimization analysis of environmental protection, and Security optimization analysis. The structure is not limited to the function but also proportional to the impacts on the safety and efficiency of the system and the whole operation.

With the Heron's siphon principle, Yu and Wang (2020) proposed a design of an energy generation system using harvested rainwater. In the study, rainwater shows excellent potential to be an energy source, considering that it has a natural kinetic and potential energy source. Also, the relationship between the various parameters of water flow and siphon has been analyzed and calculated using the concepts of fluid mechanics. The study positively shows energy generation using the siphon principle and the rainwater's nature. It enables it to generate average electrical energy for a whole high-rise establishment. Unfortunately, the study is limited to rainwater as a source of water supply. Thus, the occurrence of rain is not determined.

1.2.5 Contributory Works

Typically, funding for pico-hydro projects is restricted to implementation. Projects must be able to support themselves financially after being commissioned. The end-users can only support technical maintenance and repairs with a solid financial foundation. The majority of variables that affect the success or failure of pico-hydropower (PHP) sites are insights from the Philippines 103 projects have weak financial bases due to poor electricity utilization, as the main load is only consumptive. Additionally, problems in customs collection and fund management are regarded as the second most significant predictor of PHP failure, as evidenced by the statistical results. For the same reasons, the researcher concluded that support organizations and implementing agencies should concentrate on villages undergoing economic growth. In relation, while it is understandable for communities to prioritize their basic needs for food, shelter, and clothing, especially in the aftermath of a disaster, they also understand the value of continuing PHP projects because they bring advantages like improvements in education, livelihood, and general comfort and well-being (Bellen, 2017).

Outdoor illumination is a significant energy consumer. Implementing energy efficiency solutions offers the quickest return on investment for reducing energy consumption. The transition from conventional illumination technology to sophisticated lighting solutions has the potential to produce substantial energy savings. According to the research carried out by Shahzad et al. (2018), there is a substantial correlation between the impacts of various renewable energy sources and their influence on certain geographic regions. This correlation was also taken into consideration in the research carried out here. They came to the conclusion that the Sustainable Process Index may be anywhere from 258 to 7760 km2, and the carbon footprint can be anywhere from 930 to 980 tons of CO2 (tCO2) equivalent. They also determined that 48,496 tons of CO2 (tCO2) is comparable to supplying the need for lighting for 100,000 hours. When analyzing these findings, a comparison is made to the Sustainable Process Index and Carbon Footprint generated by high-pressure sodium and light-emitting diode luminaires that were powered by the Saudi energy grid. Using outdoor lighting consumes a great deal of energy. Implementing energy efficiency solutions provides the quickest return on investment in terms of reducing energy consumption. Utilizing modern lighting solutions as opposed to conventional illumination methods has the potential to save a substantial amount of energy. The Sustainable Process Index and the Carbon Footprint are both generated by luminaires that use high-pressure sodium and light-emitting diode technology in conjunction with the energy grid.

The availability and consumption of electricity now influence most human activities due to the rapid growth and advancement of technology. It is frequently used to power lighting equipment, residential appliances, and even factory machinery. Electricity supply and demand issues have recently emerged due to their significance and connection to the rising urbanization of the world. Energy conservation research has grown recently to address environmental challenges and effectively use energy resources. Science and engineering techniques have been applied to investigate and utilize a variety of ideas and types of renewable electricity resources. There are three primary forms of energy to produce electricity: fossil fuels, nuclear energy, and renewable energy. Each energy form has different categories or ways of generating electricity, and hydroelectric power generation is one of them.

Hydroelectric power is one of the oldest and most significant renewable sources that generate power through water flow. Using turbines, water flow produces mechanical energy that will be converted into electrical power using a generator. Unlike other renewable energy, hydropower is the cleanest energy source of electricity. Due to urbanization and pollution, many researchers found more interest in the machine. In addition, hydropower can generate electricity at any time or season, unlike other sources such as solar power plants. Hydropower has four standard categories based on the generating capacity: large hydropower, small hydropower, micro-hydropower, and pico-hydropower machine. With various generating capacities, different parameters are needed to consider when designing a hydropower plant. In this study, the researchers built a possible pico-hydroelectric power with the principle of a modified Heron's siphon for lighting the streetlights. With these, streetlamps which are lighting systems used to provide illumination on the roadside or suspended from a cable above the road, are the main target of the energy generated from the prototype. The researcher adopted the Random Cut-off method with a circuit breaker for the safety and conservation of energy consumption. Lighting is required for safe, convenient, and comfortable pedestrian and transportation movement. Many researchers study streetlights due to their importance. With the modified principle of Heron's siphon, the researchers will formulate and create the prototype needed for hydroelectric power generation.

Despite seeming to be in continual motion, the hydrodynamic device, Heron's siphon, combines hydraulics and pneumatics. More information is required to demonstrate how well the siphon mechanism works, yet it has been used for decades in various technical projects. The researchers utilized the Modified Heron's fountain to produce a continuous flow of water inside the system of the hydroelectric generator. The flow of water was used as the initiator for the turbines to rotate; thus, the generator produced electricity. Unlike the other study and hydropower design, the researchers utilized gravitational force and pressure from the water flow to generate electricity used as the street lamps' power source.

Producing hydropower plants is considerably expensive. One of the reasons for the failure of the production projects of hydropower plants is the financial factor of the projects. Despite its importance, the hydropower plant machine's production and maintenance costs are relatively higher than the other renewable resources. To solve such issues, studies claimed the importance of the power plant with recommendations of priorities from the government and public agencies. The researchers tried to minimize the machine's production cost in this study. Initially, the researchers aimed to produce the pico-hydropower plant using recyclable materials. However, due to the availability of needed materials, some parts of the machines must be bought from trusted suppliers.

1.3 Background of the Study

The Philippines is a third-rate country or a developing country in Southeast Asia. Although electricity access in the country has dramatically improved, with a 97% of urban electrical accessibility and an increase of 12.44% in electricity generation in 2016 compared to 2015, it is still considered poor compared to other countries such as Japan. In more rural places, access to modern energy sources is more limited, hence only some areas have access to electricity. In terms of the nation's overall capacity for the generation of energy, it increased to 21,423 MW (megawatts) in the year 2016 from 18,765 MW in the previous year, 2015. The total energy situation in the nation has improved over the course of the years; nevertheless, the improvement is deemed to be minimal in comparison to the demand as a result of the country's growing urbanization and industrialization (Khanna et al., 2019).

With science and engineering concepts, several ideas and forms of renewable electricity resources have been studied and utilized. Hydropower is one of the concepts of electric generation, which converts the mechanical energy from the water motion into electrical energy. Hydropower uses hydraulic turbines to convert water movement or flow into mechanical energy. Then, the converted mechanical energy will drive the generator to produce electricity. Singh and Singal (2017) claimed that among renewable energy resources, hydroelectric power is the most preferred renewable energy since it can generate electricity in any season or time. Also, it has negligible environmental and social impact compared to other renewable energy.

As of 2016, hydropower constituted 71% of the world's renewable energy supply. Thousands of dams were constructed between 1920 and 1970 throughout the globe, increasing this capacity. In affluent nations, the construction of large dams has ceased, as the best sites for dams have already been utilized, and environmental and social issues have rendered the costs unacceptably high (Moran et al., 2018).

With continuous research about energy generation, modern energy resources use different principles to generate electricity. In this study, the researcher investigated the viability of developing a miniature of a hydroelectric power plant using the principles behind Heron's fountain to produce electrical energy. The Heron's Fountain is a hydraulic contraption that demonstrates the flow of water inside an increasing pressure system. It was designed by Heron himself. Heron's Fountain was used as an example in the research conducted by Gholinejad (2020) to demonstrate the transformation of gravitational potential energy into mechanical energy. In other words, the water inside Heron's fountain continuously flows within the system due to the gravitational force and pressure. Aside from that, Heron's fountain is connected to the First Law of Conservation of Energy concept, which states that energy cannot be created nor destroyed.

The researchers aimed to produce a pico-hydropower design utilizing the Modified Heron’s siphon principle as a possible solution for the lack of electrical supply for the street lighting system in Barangay Camias, Porac, Pampanga. Based on the data collected from the municipality, most of the electrical supply is intended for residential and commercial use. In the data provided by the Engineering Department of the Municipality Hall of Porac, only 90% or 26 out of 29 barangays in the municipality have an electric supply. The electrical supply of the area around Porac is from the Pampanga II Electric Cooperative Inc. in Guagua Pampanga derives power from the NPC Bataan 69 KV Transmission Line. The three remaining barangays, including the Camias, rely only on alternative power sources. Due to that, the community of Camias prioritizes household consumption. Other electrical consumption, such as street lighting, needs to be addressed. Thus, it shows that this study has great significance to the problem.

1.3.1 Study Area

Figure 1.1. Map of Porac, Pampanga (Gonzalez, 2005)

According to the municipal website of Porac, Pampanga (2021), the name "Porac" comes from the term "purac" because of the quantity of purac trees that the first residents of the area encountered; it is thought to be the first town to be formed in Pampanga. In the 1879 map of the nearby town of Floridablanca, the then-Provincial Surveyor Don Ramon N. Orozco referred to this river as the "Poraq River." The name Puraq was changed to Porac on September 16, 1867.

The data that was provided by the Municipal Government of Porac, which is located in the province of Pampanga, indicates that the town has more than 31,000 hectares of land and is the largest in the province. According to David (2021), mountains make up more than half of Porac's land area. The 2017 Porac Municipal Government census lists over 5,000 Aeta families; they constitute the largest Aeta contingent in Pampanga. Porac consists of 29 barangays, of which six are Aeta settlements. Barrio Camias is situated in the ancestral domain of the Aeta Indigenous people (IP) and is mainly administered by Aeta leaders through the barangay, the most fundamental local government level. There are approximately 700 Aeta families (Papa et al., 2021).

In this study, the researchers utilized the Modified Heron's Fountain to produce a continuous flow of water inside the system of the pico-hydroelectric generator. The water flow was used as the initiator for the turbine's rotation and electricity production. Developments in this study and applying the principles of the miniature gave a possible source of electrical energy used for street lamps in Barangay Camias, Porac, Pampanga.

Figure 1.2. Map of Mt. Barundon View Deck, Camias, Porac, Pampanga (google, n.d)

This study's specific location is near Mt. Barundon, which is in Barangay Camias, Porac, Pampanga. According to the Comprehensive Land Use Plan (Chapter 1: Demography) of the municipality of Porac, Camias is one of the barangays in the Porac province of Pampanga. The location is a Native Aeta Community Residence, a remote area in the Porac. In the latest population report of the barangay, there are 347 households. Out of 29 barangays in the municipality of Porac, Camias is one of the barangays with insufficient primary electricity source. Part of the barangay, especially near the Mt. Burundon, prioritized the residential consumption and other consumption, including street lighting, are neglected. Street lighting is essential for the security of the pedestrian and transportation. For tourism, the Camias is famous for its terrain and topography, which is very suitable for bike riding.

1.4 Objectives of the Study

The researchers designed a pico-hydropower system based on Heron's siphon concept for generating and storing electrical energy for street lamps in Camias, Porac, Pampanga. The area is known for its terrain, suitable for bike riding and traveling. Despite that, the area lacks enough electricity and a network of street lamps, which made this study viable and essential for the location. Streetlamps improve the quality of life and promote security in urban areas by artificially prolonging daylight hours so that activity can occur. Additionally, street lighting increases pedestrian, cyclist, and vehicle safety.

1.4.1 General Objective

This study aimed to present an efficient solution for the insufficiency of electricity for the streetlamp system in Barangay Camias, Porac, Pampanga, utilizing the proposed pico-hydropower.

1.4.2 Specific Objectives

The following are the specific objectives of the study:

1. To design a pico-hydropower system based on Heron's siphon concept for generating and storing electrical energy for street lamps in Camias, Porac, Pampanga.
2. To describe the viability of the proposed pico-hydropower system using a prototype.
3. To evaluate the efficiency of the proposed pico-hydropower system using a prototype.

1.5 Statement of the Problem

In the Comprehensive Land Use Plan of the Municipality of Porac, Pampanga, despite having 347 households, Camias is one of the three remaining community barangay with an insufficient primary source of electricity. The barangay is a Native Aeta Community known for being the municipality's tourist and bike-cycling landmark; however, it lacks a proper street lighting system on the roadside. This is due to the need for more electrical power in the area. Part of the community only relies on alternative sources of electrical energy, such as solar power, and just enough for household consumption. Other electrical consumption, such as streetlights, needs to be addressed. According to the study by Vadlamani and Hashemi (2020), streetlights can provide proper nighttime illumination and offer more security to the area it covers. Thus, claiming that the places having street lights have fewer accidents and crime rates. Streetlights are an essential part of the road or the transportation itself. It provides more security for the pedestrian and transport system.

This study aimed to provide an economically and sustainably viable alternative to the insufficient supply of electrical energy for consumption and safety in the mountainous area of Camias, Porac, Pampanga.

Specifically, the following inferential questions are laid down.

1. How can a Heron's siphon-based pico-hydropower system be designed and built to produce and store electricity for street lights in Camias, Porac, Pampanga?
2. How viable is the suggested pico-hydropower system design based on testing?
3. How efficient is the suggested pico-hydropower system design based on testing?

1.6 Significance of the Study

The location of the study, Camias, is a mountainous area near a lake called Camias River. The location is remote for the Native Aeta Community Residence and lacks enough electricity for consumption and security. Lacking the streetlamps due to insufficient electrical power sources, which is beneficial for the security of the pedestrian and transport system, is one of the seen problems of the study. Thus, the researcher designed a pico-hydropower using the modified principle of Heron's fountain for the streetlamps. The researchers decided to engage themselves and contribute to the rising problem.

- **The Community.** The Community would benefit from the study as the main objective was to provide a design of pico-hydro power technology applying the modified principle of Heron's fountain for the streetlamps, which will increase the security of pedestrians and transport systems in the area of Camias. Also, the possibility of providing electrical energy for consumption was considered a sub-objective of the study.
- **Tourism.** The effect of this research can benefit tourists visiting the Community. Since Camias is known as a bike-cycling landmark, the production of pico-hydro-powered street lamps could help them to aid navigation and be cautious of the potential problems that may arise during night travel.
- **Environment.** Camias is mountainous terrain and a residence for the indigenous people. Preservation of nature in the area should be taken into consideration. Thus, pico-hydro power is considered the safest renewable energy source (Durrani et al., 2019).
- **Civil Engineering Field**. With this study, civil engineering, electrical engineering and mechanical engineering students could acquire knowledge applicable to their professional development as civil/electrical engineers. Furthermore, researchers who are aligned in

this field and intend to do similar research would find this study invaluable.

1.7 Scope and Limitations

Due to various factors affecting the study, several limitations are worth discussing. The study focused on designing and building a miniature prototype of pico-hydropower technology by applying the modified principle of Heron's fountain. The study was limited to enough design to light a streetlamp. Any electrical consumption other than a streetlamp was disregarded in the study. The study did not deal with the market factors of pico hydropower technology and electric energy, its building cost, and whether it is affordable. In addition, the study did not deal with the maintenance of the pico-hydropower technology, the water level inside the system, and the water consumption of the siphon.

The production of the prototype was done outside the study location, Camias, to ensure the production process and convenience of the researcher. On the other hand, all the data needed from the area were collected in the location (Camias) and the municipality of Porac, Pampanga.

As part of the study's methodology, a prototype of the pico-hydropower technology was constructed to show the technology's mechanism. Also, the prototype was used for gathering data. According to Zhao et al. (2014), the small experimental prototype can be utilized for data collection of an extensive electrical system using a scalable multi-modular system.

1.8 Conceptual Framework

Figure 1.3. Paradigm showing the systematic illustration of this study

The conceptual framework served as a graphical illustration of the study's methodology and expected conclusion. The study began by identifying the present issue supported by studies, research, and dissertations. The researchers investigated the highlighted issue using the information gathered from the municipality of Porac, Pampanga. Using Heron's siphon concept, the pico-hydropower technology for streetlamps was designed. After the development of the design of pico-hydropower technology, preparation, and material gathering followed. Then, the prototype was developed, and the researchers assessed it and collected data. Lastly, the researchers drew a conclusion based on the information acquired.

1.9 Definition of Terms

The following are terminologies that were beneficial for the research progress:

Circuit Breaker. It is an electrical device that are designed to protect and automatically block the circuit circulation from the damaged part of an electrical system and provide an interruption function to the current flow for protection,

Dawn-Dusk Method. It is a method that makes use of sensors to determine whether the environment requires lighting.

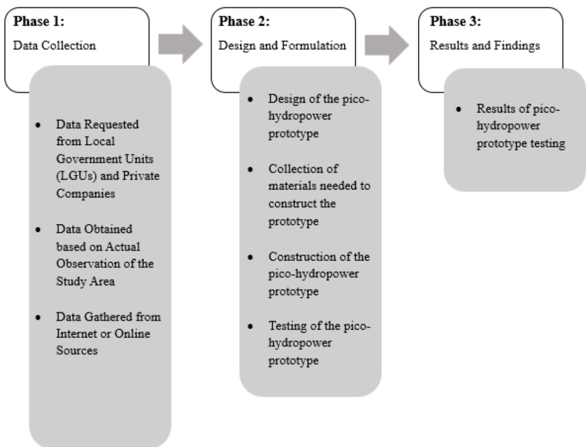
Fossil Fuel. They are one of the most common energy sources that cannot be renewed. We derive the majority of the energy we need by burning fossil fuels.

Heron's Fountain. It is a hydraulic device that illustrates the concepts of pneumatics and hydraulics. A fountain forms when water flows from a system with high gravitational potential energy to one with low gravitational potential energy because of the increased pressure inside the system.

Hydraulic Turbines. They are the main moving parts that employ the turbines and linked generators to transform the energy of falling water into rotational mechanical energy, which is then converted to electric energy. A row of fixed blades on a spinning shaft or plate makes up a turbine.

Hydroelectric Power. The use of falling or swiftly moving water to generate energy or drive machinery is referred to as waterpower. One of the earliest and most significant types of renewable energy, hydropower or hydroelectric power, harnesses the naturally occurring flow of moving water to produce electricity.

Hydroelectric Power Plant. It is a non-conventional power plant that is frequently utilized to produce electricity from a renewable energy source. The reservoir or dam is built at a high head above ground level to produce kinetic energy from water.



Law of Conservation of Energy. It affirms that energy cannot be produced or destroyed. However, it can change from one form to another.

Pico-Hydro Power System. A term used to describe the mechanisms and procedures involved in converting water's natural flow or any other form of flow into energy.

Random Cut-Off Method. It is a method of obstructing the local electric energy at a specific period. It is to conserve energy due to scarcity of supply.

Reduced Voltage Method. It is a method that involves attaching a number of resistors to the motor's wires.

Renewable Energy. It is energy created from renewable resources that never run out, such as the sun and wind. Transportation, space and water heating and cooling, and electricity generation are all possible with renewable energy.

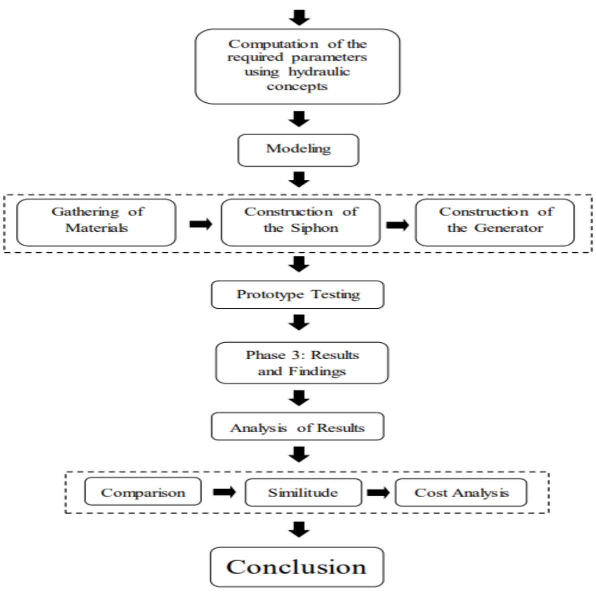
Revolution per Minute. It is a measuring unit, commonly written as RPM, for the number of revolutions of an object to its own center. In this study, the RPM was used to describe the revolution of the mechanical components of the design pico-hydropower plant.

Siphon. When a hill or high-level ground separates two reservoirs, a long-bent pipe is used to transport liquid from one reservoir at a higher height to another reservoir at a lower level.

Urbanization. It is the emigration of people from rural areas to urban centers. The phrase also describes the rise of urban regions or the extension of cities.

2. METHODOLOGY

2.1 Methodological Framework



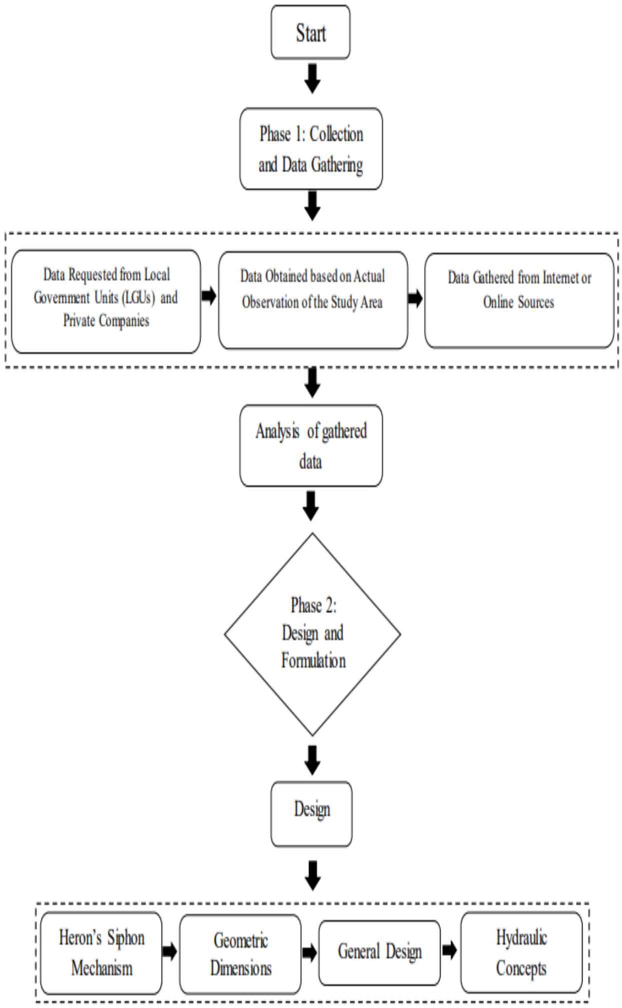


Figure 2.1. Methodological Framework

The research framework enables a thorough evaluation of the study's credibility and feasibility. In a research study, the research methodology describes the particular methods or stages used by the researchers in order to sort, identify, process, and analyze the topic's data.

In this study, the researchers designed a pico-hydropower system based on the modified Heron's siphon concept to generate and store electrical energy for street lighting in Camias, Porac, Pampanga. Streetlamps improve quality of life and promote safety in urban areas by artificially lengthening daylight hours and increasing safety for pedestrians, cyclists, and vehicles. Furthermore, the study provided an efficient solution for the insufficient electricity for street lighting using pico-hydropower.

The study began with phase 1, the collection and data gathering. During this phase, the data collected from the municipality of Porac, researchers' observations, and related studies were analyzed and used to support the current issue and study investigation. Next is phase 2, the design and formulation phase. This phase was divided into two sections, the design and modeling sections. Under the design section, all the concepts, theoretical ideas, and principles were discussed. Also, the computation of the needed parameters was done in this section. In the modeling section, all the general procedures for building the prototype were enumerated, from the collection of materials up to the actual construction. Lastly is phase 3, the result and findings. In this phase, the prototype was tested, and computations for the results were made. All the results were discussed and concluded in this phase, including the comparison between the theoretical and actual results. Also, the cost analysis of the prototype and similitude (increasing approach) were discussed in this phase.

2.1.1 Research Design

The study was quantitative in nature. Quantitative research is a study based on scientific methods. It is a study that uses numerical data and scientific inquiry to solve the problem of the study (Sheard, 2018). In quantitative research, variables can be manipulated and controlled. Furthermore, in most cases, it is in a theoretical structure (Surucu & Malakci, 2020). According to Williamson et al. (2018), it is the type of research used for studying technological and social innovation. It is chosen to approach the study in a way that the research will be entirely adequate for collecting and analyzing its data. The approach that will be conducted is the Experimental Approach which, according to Boporai et al. (2020), is a methodological approach that uses one or more variables and data to produce causal conclusions and test theories through the scientific inquiry of experimentation and innovations. In an experimental approach, the study will focus on designing new ideas, theories, and innovations. The emphasis is on designing the experiment so that you can collect appropriate data and analyze the data to draw valid conclusions about the research topic.

The study was inductive research. It is a method that can generate new theories and ideas from the analyzed and evaluated data (Gioia, 2013). According to Soiferman (2010), an inductive technique is a type of methodology that makes use of an exploratory approach, which is a type of research strategy that is utilized to study a problem that has not been properly defined. This research approach is used to determine whether or not a certain issue exists. For this kind of study, a researcher will start with a broad concept and then utilize the existing research as a means of locating new problems and concepts that might become the subject of further research.

In this study, the researcher focused on designing a pico-hydropower using the principle of a modified Heron's siphon. Based on the data collected, the design of the pico-hydropower system utilizing the modified principle of Heron's siphon was carried out. The researcher began the study by collecting important points from the related studies, research, and dissertations. The researcher also collected data from the Camias, Porac, Pampanga.

2.1.2 Research Locale

Figure 2.2. Barangay Camias, Porac, Pampanga (google map, n.d)

In this study, the researcher designed a pico-hydropower using the modified heron's fountain to provide an efficient solution for the lack of street lighting in Camias, Porac, Pampanga. The role of the modified Heron's siphon was to produce a continuous flow of water inside the system.

The specific location of this study was within the vicinity of Mt. Barundon, Camias, Porac, Pampanga. Camias is one of the barangays in the municipality of Porac, province of Pampanga. The location is a Native Aeta Community. The area is known to be a tourist and bicycling spot. However, the road in the area lacks street lighting, which is essential for security during night hours. This shows one of the significances of the study. In addition, the area is near the Camias River, which will serve as the study's water source for hydroelectric power.

2.2 Data Collection

The study gathered vital information for the thesis-development procedure. The data were separated into three primary categories: Data Requested from Local Government Units (LGUs), Data Obtained Based on Actual Observation of the Municipality Area, and Data Obtained from the Internet or Online Sources.

2.2.1 List of Data

2.2.1.1 Data Obtained from Local Government Units (LGUs) and Private Companies

The researcher gathered these data directly from the Engineering Department of the Municipality Hall of the Porac, Pampanga.

- **Household Population Data** - It was used for describing the demographic situation of the Camias, Porac, Pampanga.
- **Power supply and Demand Report** - Data was needed for describing the power supply and demand of the Barangay Camias and the whole municipality of the Porac.
- **Electricity Access Data** - This data was needed to describe the power supply and demand of the Barangay Camias and the whole municipality of Porac.

2.2.1.2 Data Obtained based on Actual Observation of the Study Area

These data were gathered through observation. The researchers visited the location of the study, Camias, and observed the actual situation of the locale.

- **Availability of Streetlamp** - This data was needed to identify and validate the problem regarding the street lighting in Barangay Camias.
- **Availability of Electricity** - This data was needed for describing the power supply and demand of the Barangay Camias and the whole municipality of the Porac.

2.2.1.3 Data Gathered from Internet or Online Sources

These data were gathered from trusted online publishers and secondary sources. These were used as additional ideas in the design and production of the Heron's siphon based pico-hydropower plant machine.

- **Related Literature** - This data was used in identifying the required quantitative parameters of the pico-hydropower machine. Specifically, it was used to determine the required standard hydraulic head, flow rate and physical dimension, which was necessary for the overall design.
- **Philippine Electrical Codes** - This data was used as standard parameters in making street lamps.

2.2.2 Research Ethics

For ethical considerations, the study did not force any individual nor assemble the data requested. The study provided consent to ask permission to conduct and collect data needed for the research process. The researcher ensured that all the transactions and communication was done legally, voluntarily, and willingly without using force to secure privacy rights. The research's results were used for academic requirements and were not used for personal purposes. For the preservation of human and animal rights, the researchers refrained from engaging in any activity that could cause damage to other humans and animals.

2.3 Data Analysis and Evaluation

2.3.1 Design and Modeling

This section was divided into two subsections: Design and Formulation. All the principles and related ideas were identified and discussed for the design. Also, the initial general design for the proposed pico-hydropower technology was discussed. All the general procedures for constructing the pico-hydropower prototype were enumerated for the modeling.

2.3.1.1 Design

A. Heron's Siphon Mechanism

Heron's siphon is a technology that uses siphonage, a type of force due to the difference in the hydraulic head primarily caused by atmospheric pressure and gravitational force. In Gholinejad's (2020) study, Heron's siphon was used to demonstrate how gravitational potential energy can be converted into mechanical energy. In other words, gravity and pressure cause the water inside the Heron's siphon to flow continuously within the system. In this study, the researcher used the heron's siphon mechanism to produce mechanical energy that initiated the rotation of turbines. The turbine was connected to a power generator, which produced electricity.

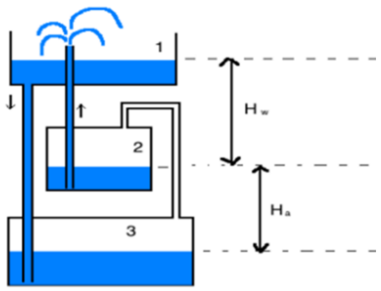


Figure 2.3. Heron's Siphon Mechanism (Course Hero, 2020)

B. Geometric Dimension

From the term itself, geometric dimensions are the actual linear measurement of an object. According to

Yu and Wang (2020), the most crucial part of designing a siphon is determining the proper dimension for the head and diameter of the inlet and outlet pipe. The difference in water level in the system of storage pipes determines the gross head, which is ultimately influenced by flow velocity, volume flow rate, generation capacity, and efficiency.

For the hydraulic turbine, the type and dimension of the turbine is needed to produce the required mechanical energy of the hydropower plant. According to the findings of the research conducted by Matlakala et al. (2019), the diameter of the impeller in a hydraulic turbine has a significant impact on the angular acceleration of the turbine as well as its ability to convert mechanical energy. The angular acceleration of the impeller in the presence of a constant force is exactly proportional to the diameter of the impeller. What this translates to is that the angular acceleration that can be produced with a constant flow speed will be greater if the diameter of the impeller is increased.. In this study, since the heron’s siphon produces uniform flow velocity, the researchers used the principle to increase the revolution per minute produced by the hydraulic turbine.

C. General Design

Figure 2.4. General Design of the pico-hydropower Prototype

The general design of the pico-hydropower plant was divided into following parts.

C.1 Siphon

The researcher used a five-gallon water jug and unplasticized polyvinyl chloride (uPVC) pipes for the siphon. As shown in Figure 2.4, the siphon has three containers (two whole five-gallon water jugs and one cut-in-half five-gallon water jug) connected with the vertical pipes(uPVC). Containers were interconnected using uPVC, which serves as the path for the water to flow during the mechanism.

For the initial water level of each container, the top container (C1) had full water, the middle container (C2) had nearly full water, and the bottom container (C3) had no water at all. During the mechanism, the water in C1 was expected to flow downward to C3. This increased the pressure inside C2 and C3. Due to the pressure, the water was pushed upward from C3 to C2 and from C2 to C1. The cycle or flow of water was expected to repeat itself until it reaches the limit due to the nature of the siphon.

C.2 Hydraulic Turbine

The researcher utilized impulse turbines for the purpose of this investigation. An impulse turbine is a type of turbine that relies only on the kinetic energy of the water to revolve its runner. The hydraulic turbine was installed in C1, right below the uPVC pipe, which was the point at which the water was expelled from C2. Because of this, the turbine began to whirl. The mechanical energy is created as a result of the spinning of the turbines, which converts the potential energy in the water. Gholonejad (2020) suggests that the gravitational potential energy of water may be turned into mechanical energy due to the fact that water flows so quickly.

C.3 Pulley and Belt System

Pulley and Belt will be utilized to increase the rotational speed output of the turbine. According to Jaber and Ali (2019), a pulley and belt system is a rotating machine that can transfer loads from one pulley to another with the aid of the Belt. The system commonly comprises two or more pulleys, and a belt connects each pair. Each pulley has a purpose; one is the driving pulley connected to the system's rotating mechanical components, such as turbines. The Belt is driving the other pulley due to the rotation of the driving pulley.

In most cases, the driving pulley is larger than the driven pulley. This is to have multiple gaps in the required revolution of each pulley that will cause the multiplication of rotational speed in the driven pulley. In this system, the rotation speed of the driven pulley is inversely proportional to the rotational speed in a constant force. This means that the smaller the diameter of the pulley, the faster the rotational speed.

In this study, the researcher will be using a 5 inches diameter driving pulley and a 0.8 inches diameter driven pulley. The two pulleys were interconnected using a rubber band acting as the V-Belt. Thus, it produces a ratio of 1:0.2 for the rpm generation.

C.4 Generator- Motor

A DC motor generator was attached to the turbine. The generator then used the mechanical energy from the turbines to create electricity. The turbine's rotational speed served as the basis for the generator. Simply multiplying the torque and rpm (in radians) generated by the hydraulic turbine will yield the voltage equivalent of the rotational speed measured in revolutions per minute (rpm).

In this study, the researchers used a 12V motor generator with a speed rated at 2200 rpm to 3000 rpm.

C.5 Battery

The generator was connected to the battery or power supply, which stores the electricity generated by the generator. The battery was dependent on the voltage and current that the generator produces and the battery or power supply safety measures. As per, Pasago et al. (2020) created a concept using the electricity production model and solar-powered streetlights. The model uses 12 V, 45 Ah batteries and solar panels with 80-Watt solar cells. With a charging capability of 0.79 to 4.72 amps for batteries, solar cell panels may generate an average voltage of between 12.06 and 14.08 volts. In this study, the researcher used 3 V 1000mAh rechargeable battery.

C.6 Circuit Breaker

The study utilized the Random Cutoff method for the conservation of electrical energy. One of the practices under this method is using a Circuit Breaker. A circuit breaker served as a block-off device for the flow of electricity during daytime. In addition, Circuit breakers are electrical devices that are intended to prevent damage and automatically block the circuit circulation from the damaged section of an electrical system. Additionally, they give an interruption function to the current flow, which is done for the purpose of providing protection. It can give an additional safety factor to the system.

C.7 Connected lights

Light-emitting diode (LED) bulbs rated 2 V were utilized in this study. When compared to conventional lighting, 2 V lightbulbs have a longer lifespan. Solid-state lighting (SSL) has reportedly been employed in various applications, including car headlights, household illumination, industrial lighting, displays, and more, according to Kittaneh and Majid's (2019) study. The SSL provides advantages over conventional lighting in terms of luminous efficacy, energy conservation, physical robustness, and life.

D. Hydraulic Concepts

The following were hydraulic concepts which were essential for the result and findings of this study.

1. Revolution Per Minute (rpm)

Revolution per minute (rpm) is a unit used to describe the rotational speed (N) or the number of revolutions or a cycle that an object completes in a single minute.

$$\text{rpm} = \frac{\text{revolution}}{\text{time (in minute)}}$$

Revolution per minute (rpm) can be calculated by getting the quotient of the revolution or number of turns completed and time needed to complete the revolution.

$$\text{rpm} = \frac{\text{velocity}}{2\pi r}$$

To calculate the rpm of the turbine theoretically, simply divide the velocity of the running water (per minute) to the angular distance of the turbine. The radius of the turbine is multiplied to 2π to convert from linear distance to angular distance.

$$P_T = \tau \times N$$

In solving the theoretical power generated using the rpm and torque, which produces angular velocity to the object, simply multiply the torque power to the calculated rotational speed of the object.

Rotational speed (N) is an important unit needed to be considered in designing a power plant. According to Quaranta (2019), rotational speed is one of the primary important concepts to be considered to achieve the required good working condition and efficiency of the design hydropower plant. The higher the rotational speed which means the higher rpm, the higher the power generation of the hydropower plant.

2. Flow Rate and Hydraulic Head

Flow rate (Q) is the rate of motion of water in a given set of time or is simply defined as the volume of water per unit of time. It is often measured in cubic feet per second (cfs) or cubic meter per second (cms).

$$Q = V \times A$$

wherein;

V - flow velocity

A - cross sectional area

Flow rate can be calculated by multiplying the flow velocity by the cross-sectional area of the medium. This will give you the flow rate. One way to think about flow velocity is as the amount of distance covered in a given amount of time. The flow velocity of the water can be measured using a simple method. The most common method is placing an object into running water in a known dimension and measuring the time needed to reach the specific location (Pasalli & Rehiara, 2014). In this study, the researchers utilized the “Bucket and Stopwatch Method" to determine the flow velocity of water from the siphon. Bucket and stopwatch method is the most suitable method to be used in determining the flow rate of small catchments (Wijayawardhana, 2021). In relation to that, this method is the most commonly used method for determining the flow velocity for the micro and pico hydropower plant since both types of hydropower plant only required low flow rate. In this method, the flow velocity will be determined by taking the time (in minutes) needed to fill the bucket with the water from the system (Heron’s siphon).

Head (H) is the vertical distance from the base surface of the water due to the gravitational force and is often measured using feet (ft.) or meters (m.).

According to Susato and Stamp (2012), the average flow rate needed for the hydropower plant varies based on the hydraulic net head of the system. For the pico hydropower having a gross head of less than 3m, the average flow rate needed is less than 0.03 cms. The hydraulic head of the system has a direct bearing on the average flow rate that is required, and this bearing is inversely proportional to the hydraulic head.

3. Theoretical Power considering flow rate and hydraulic head

Theoretical Power (P_T) or hydraulic power is the assumed electrical power generated of the pico-hydropower due to the flow rate and hydraulic head due to the gravitational energy. According to Pasalli and Rehiara (2014), the formula to be used in calculating the theoretical generated power of a pico-hydropower is;

$$P_T = \rho g Q H$$

wherein;

P_T - theoretical power generated (Watts)

ρ - density of water (1000 kg/m^3)

g - gravitational force (9.81 m/s^2)

According to the Energy Saver website of the United State Department of Energy, the average generated electricity of the pico hydropower is ranging up to 5 kW.

4. Theoretical Power considering rotational speed (RPM)

Theoretical Power (PT) can also be calculated using the rotational speed or the revolution per meter of the hydraulic turbine of the pico-hydropower plant.

$$P_T = (\tau N)(\frac{2\pi}{60})$$

wherein;

P_T - theoretical power generated (Watts)

τ - torque

N – rotational Speed

To calculate theoretical power, simply multiply the torque and rotational speed in terms of radian per seconds.

5. Efficiency Ratio

Efficiency (η) is defined as the ratio of the useful work performed during energy generation. According to Nazari-Heris et al. (2017), efficiency can be calculated using the formula;

$$\eta = \frac{\text{Power}_{\text{out}}}{\text{Power}_{\text{in}}}$$

$$\eta = \eta_h \eta_m$$

wherein;

$\text{Power}_{\text{out}}$ - useful power or power loss

Power_{in}- expanded power or power gain

η_h - turbine efficiency

η_m- mechanical efficiency

Efficiency of a hydropower system can be classified as turbine efficiency and mechanical efficiency.

Turbine efficiency or hydraulic efficiency is the power obtained from the turbine of a hydropower system. Nazari-Heris et al. (2017) claim that the turbine efficiency is due to the rotation of the turbine and the collision of the jet and vane of the system to the water. To calculate the turbine efficiency;

$$\eta_h = \frac{P_R}{P_w}$$

wherein;

P_R - runner power or mechanical power

P_w- water power

Mechanical efficiency, on the other hand, is the efficiency from the shaft and the water. It is the measure of the mechanical system and power obtained due to the mechanical system of the hydro power.

$$\eta_h = \frac{P_s}{P_R}$$

wherein;

P_R- runner power or mechanical power

P_s- shaft power

According to the study of Nazari-Heris et al. (2017), the standard efficiency of a pico- hydropower is around 60% to 80%. Considering the efficiency of the system, hydraulic power and its corresponding energy can be calculated using;

$$P = \eta P_T$$

To calculate theoretical efficient power generated, simply multiply the efficiency factor (60% to 80 %) and theoretical power calculated.

2.3.1.2 Modeling

The following were the steps for the modeling of pico-hydropower technology using the principle of modified Heron's siphon.

1) Gathering of Materials

Materials needed to construct the designed pico-hydropower technology were considered and collected beforehand so that the materials would be readily available in the workspace during the construction. For the Heron's siphon, the study used three five-gallon water jugs for the containers and unplasticized polyvinyl chloride (uPVC) for the piping of the siphon system. For the turbine, the researchers used an impulse turbine. A scrap cooling fan alternator was recycled to form the hydraulic turbine. A 12-volt was used as the DC motor, 3 V 1000mAh rechargeable battery, and a circuit breaker were utilized for the generator. For the lights, the researcher used LED Lights.

2) Construction of the Siphon

The researchers began by preparing the materials needed for the study. All the materials were prepared based on the finalized design. For the container, the two five-gallon water jugs (19 inches in height) remained as the middle and bottom container, while the remaining five-gallon water jug was cut into half that served as the catchment and upper container. The containers were interconnected using uPVC cut into 35 inches for the output pipe and 18.2 inches for the pipes connecting a transparent hose. After preparing the materials, the researchers assembled all the materials based on the design.

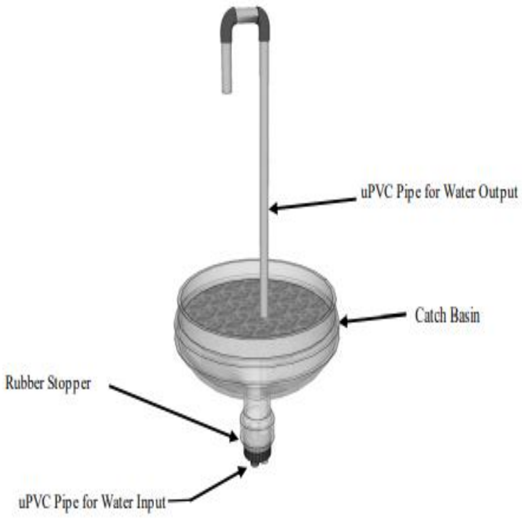


Figure 2.5. General Design for the Upper Part of the Siphon

The upper part of siphon C1 was built using a water container cut into ¾ of its size to form the catch basin of the siphon, uPVC pipes connected with a clear hose, and a rubber stopper to close the opening of the container. A clear general-use neutral silicone sealant was used as an adhesive for the joints and connections of the parts.

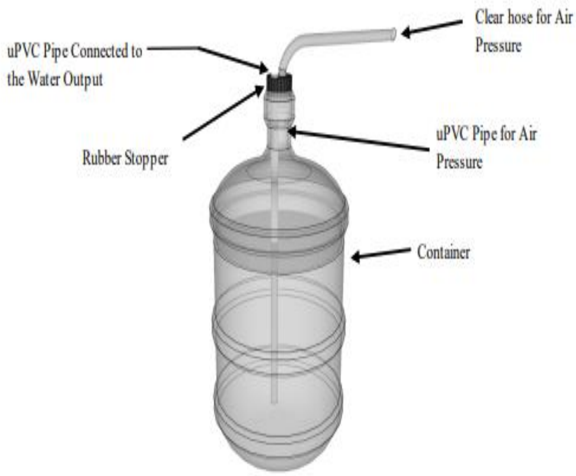


Figure 2.6. General Design for the Middle Part of the Siphon

The middle part of the siphon C2 was built using the whole water container and serves as the container of the water being pushed by the pressure going out to the end of the pipe (output of water), uPVC pipes connected with a clear hose and a rubber stopper for the opening of the container.

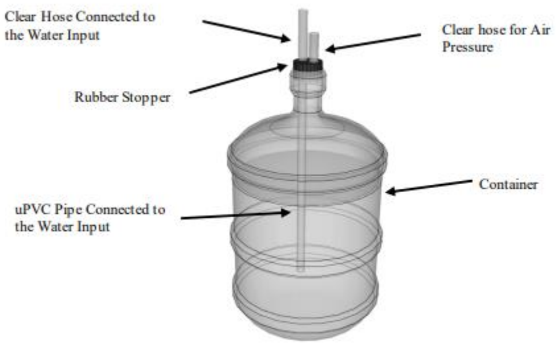


Figure 2.7. General Design for the Lowest Part of the Siphon

The lowest part of the siphon C3 was also built using the same water container as the C2 having the same uPVC pipes connected to a clear hose and a rubber stopper, as shown in the figure.

3) Construction of the Generator

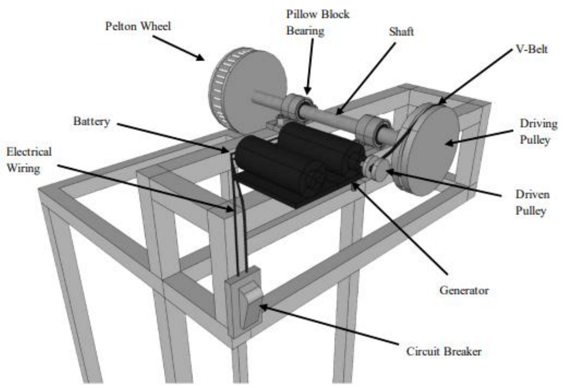


Figure 2.8. General Design for the Generator of the Siphon

In this study, the generator consists of 4 stations, the turbine, Direct Current (DC) motor, the battery, and the circuit breaker. The Pelton wheel was made using a recycled scrap cooling fan alternator fabricated and sealed to prevent leakage of water which possibly cause difference in rotation. As shown in Figure 2.8, the wheel has an impeller with 5 inches diameter and was located in container 1, right below the uPVC pipe connected to container 2. The Pelton wheel was connected to a 4 inches driving pulley which was both connected by an aluminum shaft. The driving pulley was linked to a 0.8 inches driven pulley linked by a rubber band which serves as the v-belt. The two pulleys were fabricated using an engineering plastic to achieve the lightest weight and desired sizes for the pulleys. Also, the driven pulley was connected directly to the 12 volts Direct Current (DC) motor. The DC motor was connected to the rechargeable battery using an electrical wire to store electricity. Lastly, the battery was connected to the loads.

2.3.2 Result and Finding

The effectiveness and viability of Heron's siphon mechanism was tested in this portion of the investigation. Its effectiveness was evaluated by assessing the system's capacity to create energy based on the mechanism's flow rate and hydraulic head. The system's efficacy could be ascertained by measuring the system using the area and speed method. According to Pasalli and Rehiara's (2014) study, the effectiveness of the pico-hydro power plant's machinery might diminish the potency, and the head would be lower by putting the necessary equipment there. They reference JICA's analysis, which estimates that overall efficiency will range between 50 and 70 percent. Then the output is between 14.70 and 20.58 kW. Therefore, higher than 20.58 kW turbine and generator should be selected. Knowing the potential of the river and the mechanism that produced electricity will make the study viable if the system's maximum value is greater than the hydraulic potency's expected value.

3. RESULTS AND DISCUSSIONS

3.1 Flow Rate Measurement

After building the Heron’s siphon system of the designed pico-hydropower plant, the researcher started to determine the flow rate of the water inside the system using the bucket and stopwatch method. It is a method utilizing the required time to fill the specific volume of the container. A 1-liter plastic container was used in this study for the bucket and stopwatch method, and measured the time it takes to fill the container.

Table 3.1. Recorded Data Using Bucket and Stopwatch Method

Trial	Volume (liter)	Time (seconds)
1	1	8.17
2	1	10.57
3	1	9.58

As shown in Table 3.1, the study used three trials to determine the time required to fill the 1-liter plastic container. Upon the process, trial 1 got 8.17 sec, trial 2 got 10.57 sec, and trial 3 9.58 sec. Obtaining the average time of the three consecutive trials by dividing the sum of the time in the number of trials, the average time to fill the 1-liter plastic container is 9.47 sec.

Flow rate is the volumetric flow per specific time unit of the water. Applying the formula of flow rate, the researcher obtained a flow rate of 0.0001056 cms or 0.006337 cmm.

3.2 Flow Velocity and Rotational Speed Calculation

Flow velocity is the flow distance per unit time of the water, and it can be calculated using the relationship between the flow velocity and flow rate. The study used a discharge pipe with a 20 mm outer diameter and a 16mm inner diameter. Applying the formula of flow velocity, which is equal to the flow rate and cross-sectional area quotient, the study obtained a flow velocity equal to 31.520 m/min or 0.5252 m/s.

For the turbine, the study used a 5 inches diameter turbine. The geometric dimension of the turbine is necessary to determine the rotational speed N of the turbine. Applying the formula of rotational speed, the study obtained a rotational speed of 78.4 rpm, say 79 rpm.

The study used pulley and belt systems to increase the rotational speed. The calculated rotational speed was used as the initial rpm for the diving pulley.

Table 3.2. Computation for Pulley Diameter and Rotational Speed

Pulley	Pulley Diameter (inches)	Rotational Speed (RPM)
Driving	4	98
Driven	0.8	490

The study used two pulley systems, one is for the driving pulley, and the other is for the driven pulley. The driving pulley is 4 inches in diameter and connected by a shaft to the turbine at 98 rpm rotational speed. On the other hand, the driven pulley is a 0.8 inches diameter pulley connected to the generator. Using the diameter-rotational speed relationship, the driven pulley is expected to rotate at a speed of 490 rpm. Utilizing the rotation from the driven pulley, the study decided to use a 12-V generator motor, which can cater to rotational speeds from 2200 to 3000 rpm.

3.3 Theoretical Power Calculation and Analysis

The theoretical power of a hydropower plant can be calculated based on the flow rate of the water and the rotational speed of the turbine.

According to Pasalli and Rehiara (2014), theoretical power considering the flow rate can be obtained by multiplying the density of water, gravitational acceleration, flow rate, and the hydraulic head of the system. The study used a 14.06mm or 0.01406 meters hydraulic head. Applying the formula, the theoretical power of the designed pico-hydropower plant is 0.01457W.

Theoretical Power (PT) can also be calculated using the rotational speed or the revolution per meter of the hydraulic turbine of the pico-hydropower plant. In this study, the torque was computed by multiplying the lever arm and the force applied by the flow rate. The researchers obtained a torque of 0.006216. Applying the formula of theoretical power considering rotational speed, with a 490-rpm rotational speed, the theoretical power considering the rotational power is 0.3190W.

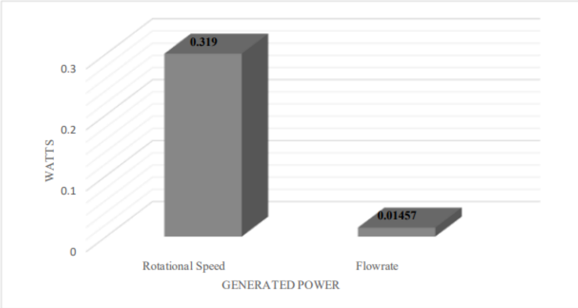


Figure 3.1 Theoretical Generated Power Considering Rotational Speed vs. Flowrate

Synthesizing the data obtained, the theoretical power considering the rotational speed is 0.3190W while the theoretical power considering the flow rate is 0.01457W. As shown in figure 3.1, the theoretical power considering rotational speed is higher than the theoretical power considering the flow rate. Such the 0.3190W governed and used to compare to the actual power generated.

3.4 Applying the Efficiency Factor to the Theoretical Power

According to the study by Nazari-Heris et al. (2017), the standard efficiency of pico hydropower is around 60% to 80%. In this study, the researcher adopted efficiency as minimum efficient power (60 percent) and maximum efficient power (80 percent).

The governing theoretical power is 0.3190W considering the rotational speed. Applying the efficiency formula, the minimum efficient power is 0.1914W, and the maximum efficient power is 0.2552W.

3.5 Prototype testing

After building the entire designed pico-hydropower plant prototype, the researcher starts the prototype testing.

The prototype successfully worked right after the prototype testing. Using the mechanism of the Heron's siphon, the water inside the system could flow with a velocity of 31.520 m/min. As the water has discharged to the turbine, the turbine rotates at 78.4 rpm, approximately 79 rpm. Since the turbine is connected with the pulley and belt of a ratio (1:0.2), the rotational speed has been multiplied and become 490 rpm. The rotation of the pulley initiated the generation of electricity and stored it in the battery. The stored electrical energy was used to light the LED Lights.

In this study, the researchers used a multimeter to determine the actual generated electric power of the designed pico-hydropower plant. A multimeter is a measuring device for the flowing electrical power in a circuit.

Table 3.3. Actual Generated Electric Voltage of the Prototype

Trial	Recorded Voltage (V)
1	2.54
2	2.64
3	2.62

As shown in Table 3.3, the study used three trials to obtain the actual generated voltage of the pico hydropower plant. Upon the process, trial 1 got 2.54V; trial 2 got 2.64V, and trial 3 got 2.62V. Obtaining the average time of the three consecutive trials by dividing the sum of the time by the number of trials, the average actual generated voltage is 2.6V. To convert the volts into watts, multiply the volts by the ampere (Balalola et al., 2022). The average amperes used for this study is 90mAh. Adopting the 90mA, the actual generated power is 0.234W.

3.6 Comparison and Analysis

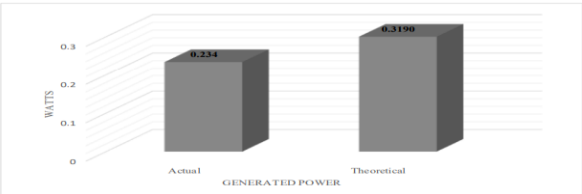


Figure 3.2. Comparison between Actual and Theoretical Generated Power

As shown in figure 3.2, the generated electrical power is lower than the theoretical power. The generated electrical power is 0.234W while the theoretical power is 0.3190W. By analysis, the theoretical power is higher than the actual generated power.

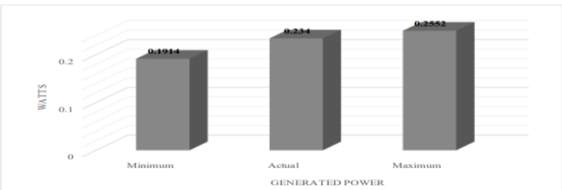


Figure 3.3. Comparison between Actual and Efficient Theoretical Power

The computed minimum efficient theoretical power is 0.1914W while the computed maximum efficient theoretical power is 0.2552W. Comparing the actual, the study aimed to generate electricity no lower than the minimum and almost equal or higher than the maximum to conclude that the design is efficient. The actual generated power, as shown in figure 3.2, is 0.234W. As shown in figure 3.3, the actual is within the range of calculated minimum and maximum efficient power. Thus, the study concludes that the design is 73.35% efficient.

3.7 Similitude

Similitude is a theory designed to allow engineers to establish the necessary parameters for a scaled model of a full-scale prototype using a set of tools known as similitude methods (Casaburo et al., 2019). In this study, the researchers used a reverse engineering method. Reverse engineering is the process of transforming critical features of an existing object to create accurate or upgraded physical models of it (Saiga et al., 2021).

According to the US Department of Energy-Road Lighting Guidelines, LED lights should be rated 70 W with 10-40m luminaires for one-sided streetlights in minor places or remote areas. On the other hand, according to Finepixel, an engineering website specializing in LED lighting systems, led streetlights can have a 30 to 60WH on a 6-meter-high pole and 60-100WH for an 8-meter-high pole. The study used 30WH LED streetlights. The researcher obtained 360W for 12 working hours by calculating the total needed power.

Considering the maximum efficiency factor (80%), the researchers adopted a 40 Ah battery with 480 W battery capacity as the basis for the required power. Thus, the required efficient power is 32 WH. This is expected to be stored in the 40Ah battery.

Applying the formula for theoretical power, with an assumption of 250 mm pipe diameter, the researcher obtained a flow velocity of 3.4641 m/s. Multiplying the obtained flow velocity to the cross-sectional area, the flow rate is estimated to be 0.159996 cms. By definition, flow rate is a fluid's volumetric rate of flow. Applying this principle, the researcher obtained a 1.91995 cu.m, say 2 cu.m estimated volume needed for the containers.

Following the design, the generator should be a 230V rated 3400 rpm DC generator motor. For the diameter of the pulley, applying the ratio of 1:02, the researchers obtained a 3- and 15-inches diameter for the driven and driving pulley, respectively. For the turbine, applying the relationship of rotational speed and diameter of a rotating object, a 19 inches diameter Pelton wheel is recommended to obtain the needed rotational speed.

The other miscellaneous components, such as wires, connectors, and holders, will be based on the arrangement of the simulated pico-hydropower plant during construction. Hence, this study is only for the pico-hydropower plant's general idea design utilizing the modified Heron's siphon principle.

Table 3.4. Prototype Vs Actual

Components	Prototype	Actual
Tank dimension	0.019 cu.m	2 cu.m
Turbine diameter	5 inches	20 inches
Driving pulley diameter	4 inches	15 inches
Driven pulley diameter	0.8 inch	3 inches
Generator motor	12 V	230 V
Battery	3V 1 Ah	12 V 40 Ah
Required power for LED Streetlights (per Hour)	0.00335 WH	30 WH

After the similitude, the components increased their sizes and capacity. Thus, it indicates that the larger the required load, the larger the hydropower plant. The streetlights used in the similitude are 30 WH LED streetlights, which is the average power consumption of the LED streetlights according to the Department of Energy. For tank dimension, from 0.019 cu.m, it became 2 cu.m. The turbine diameter increases by 15 inches. The driving pulley increased its diameter to 15 inches while the driving was 3 inches. The generator motor and battery also increased their capacity.

3.8 Cost Analysis of the Designed Prototype

Cost analysis for the production of the prototype was discussed in this section. All the materials, labor, quantity, and cost written in the detailed cost analysis were the overall cost expenses during the construction of the prototype.

Table 3.5. Material and Labor Cost for the Prototype

Type	Cost (pesos)
Material	6016.00
Labor	2100.00
Total Amount	8116.00

Table 3.5 shows the total material and labor cost for the construction of the prototype. For the materials cost, all the material expenses for the prototype, including the metal stand, the total material cost is 6016.00 php. For the labor cost, including fabrication labor and welding, the total labor cost is 2100.00 php. The total cost for the construction of the prototype is 8116.00 php. Cost analysis for the production of the prototype was discussed in this section. All the materials, labor, quantity, and cost written in the detailed cost analysis were the overall cost expenses during the construction of the prototype.

4. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

The pico-hydropower plant, integrating the principle of a modified Heron's siphon, is a technology innovation that can potentially solve the problem of insufficient electricity for remote area street lighting. The design in Figure 2.4 was used to construct the prototype. The pico-hydropower plant prototype worked and produced electricity of 0.234W or 2.6V and can light a 1.5-V light bulb. Using similitude, the pico-hydropower plant is expected to produce a 32W, considering the 80% efficiency factor, generated electrical power in an increasing approach.

The power plant utilizing the prototype can light a 1.5-V lightbulb with 0.234W generated electrical power. After similitude, the design is expected to produce a 32W. Thus, the design is capable of lighting 30-W LED streetlights.

The viability of the design was based on the working state of the power plant. With a flow rate of 0.006337 cmm and a rotational speed of 490 rpm, the study concluded that the designed pico-hydropower plant is viable in a prototype with 0.234 W and in a 32W generated power (theoretically simulated).

The viability of the design gave a positive chance to solve the lack of electric power for the street lighting in Camias. Modifying the principle of Heron’s siphon allowed the design to work. In the design, the modified section is within the piping of the siphon and the height of the water container. The dimensions of the pipe connections range from 20 mm to 18 mm. This is to accelerate the flow of water inside the system. The height of the water container is modified to control the pressure inside the system.

A 0.234W was obtained as the actual power generated by the designed pico-hydropower plant. Also, the calculated minimum and maximum efficient power are 0.1914W and 0.2552W respectively. By analysis, the actual is higher than the minimum efficient power but lesser than the maximum. This indicates that the design produced efficient electricity within the range average efficient power. Therefore, the study conclude that the designed pico-hydropower plant is efficient. Synthesizing, the design of a pico-hydropower plant is both viable and efficient.

4.2 Recommendation

The recommendation is an important section in the research study since it provides additional suggestions and alternative solutions for the research problem. In this study, the recommendations are clustered into two. First is the recommendation for the improvement of the prototype. The other is the recommendation for the improvement of the study.

Recommendation for the improvement of the prototype is based on the problems seen during the construction of the prototype.

First, pressure is vital for the mechanism of the Heron's siphon. The increase and decrease of pressure can significantly affect the performance of its system. Thus, the researchers also recommend using high-pressure piping for the materials and pressure vessels for the container.

The use of different technologies to produce a higher rotational speed for the mechanical component is also recommended. In the current study, the researcher utilized a pulley and belt system to increase the revolutions per minute. It is advisable to design a different ratio of pulleys or use an alternative device such as a gear and belt system. In addition, the addition of another pulley system is also recommended.

The current study used a 12V motor generator with 2200-3000 rpm for the generator. Based on the results, the motor can light 1.5V LED lights. The researcher recommends using a low-rpm high-voltage generator motor for future studies. This is to increase the generated electrical power at a lower rotational speed. This type of generator motor is relatively expensive and difficult to find due to its limited availability. Alternatively, some machine shops can design and build this type of motor generator.

The prototype built in the study is sealed using a neutral silicone sealant, a type of adhesive. Due to that, the piping system of the prototype is easy to detach from the containers. Thus, it affects the pressure inside the siphon. The study recommends using different connecting methods or materials to confine the pressure inside the siphon. The researchers highly recommend the use of high-pressure tank containers. Also, the use of highly adhesive materials to increase their durability.

Lastly, during the mechanism, the prototype needed to be lifted to increase the flow rate of the water during discharge. The research recommends designing an alternative method to speed up the initial flow of discharge water. Consideration for the change in hydraulic elevation is highly recommended.

The recommendation for the improvement of the study is based on the seen limitations of the study. It can be directly or indirectly related to the study topic.

The current study's design can produce an average actual electrical power of 2.6V. This power can light a 1.5-volt lightbulb. However, the result should be cautiously treated due to the unstable voltage. The use of an automatic voltage regulator (AVR) is highly recommended to precisely maintain the appropriate level of generating voltage. Ayas and Sahin's study from 2021 claimed that actual power losses in power-generating units are a widespread problem that has to be resolved. Future researchers should look at automatic voltage regulator (AVR) devices to reduce these power losses.

The mechanism of Heron's siphon is not in total perpetual motion. Due to external factors such as high temperatures, evaporation, and water losses, the water inside the siphon can reduce as time passes. However, the researcher limits the study to maintaining the amount of water. The study wants to recommend the consideration of water maintenance for future researchers. The use of openings in the middle container is seen as one of the possible alternatives.

Another recommendation is the consideration of cost analysis for the production of the designed pico-hydropower plant. According to Bellen (2017), the hydropower plant's production is relatively expensive. Materials for the hydropower plant are rare on the market. Different machines and fabrications are needed to ensure the materials are appropriate for the design.

The study also recommends road analysis and design. The road design for installing the pico-hydropower plant and street lights should be based on the Philippine Electrical Code and the Department of Energy-Roadway Lighting Guideline.

In this study, the modifications to the Heron's siphon were the dimensions of the pipe connection and the container. The design is viable and efficient since it produces actual electric power above the minimum efficiency level. The researcher recommended the use of different modifications for the heron's siphon. Using a motor inside the siphon to accelerate the water flow can be considered.

The researcher did not focus on the losses during the siphon mechanism. Water loss is a factor that can improve the efficiency of the pico-hydropower plant. The researchers want to recommend considerations for system losses while it is operating. This is to maximize the use of water in the pico-hydro power plant.

For the validity of the viability and efficiency of the design, the researcher only used the prototype's performance for its viability and comparison of actual power to its theoretical power for efficiency. Another recommendation is to perform different testing methods. This will increase the validity of the design. Also, different devices or simulation software can produce more accurate results for various parameters. Such direct testing of the efficiency of the design is also recommended.

Lastly, the researcher recommends widening the area of usage and not limiting the use of the generated power for street lighting. Creating a trial for other uses, such as residential use, is recommended.

5. ACKNOWLEDGEMENT

This study would not have been possible without the guidance and help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study. The researchers would like to extend their deepest gratitude and appreciation to the following individuals.

To their parents for helping and supporting them not only financially but also for inspiring them to finish their work, throughout the research experimentation.

To the Tourism and Engineering Department heads of the Municipality of Porac, Pampanga, and the residents of barangay Camias, Porac, Pampanga, for letting the researcher gather and utilize data that is vital for the research process.

To the teachers, thesis advisers, and thesis coordinators for encouraging and guiding the researchers in their research project.

To the Department of Science and Technology (DOST) Region III Office and DOST-SEI for giving the researchers the encouragement and assistance to continue the study and complete this research project.

To the Civil Engineering Department - College of Engineering and Architecture for giving the researchers the opportunity to study and experience this kind of research project.

And to The Almighty God who helped the researchers discover their talents and abilities as responsible Engineering students of Don Honorio Ventura State University.

6. REFERENCES

[1] Ayas, M. S., & Sahin, E. (2021). FOPID controller with fractional filter for an automatic voltage regulator. Computers & Electrical Engineering, 90, 106895.

[2] Bellen, C. (2017). Factors that influence the success and failure of micro-hydropower (MHP) sites in disaster-prone areas: insights from the Philippines. | Semantic

[3] Scholar. https://www.semanticscholar.org/paper/Factors-that-influence-the-success-and-failure-of-:Bellen/73312965d60f458e75fb78cfe9c484acb7f78e1f

[4] Boparai, S., Hong, K., & Borelli, J. L. (2020). Experimental Approaches. The Wiley Encyclopedia of Personality and Individual Differences, 55–59. https://doi.org/10.1002/9781118970843.ch79

[5] Cadag, J., Petal, M., Luna, E., Gaillard, J., Pambid, L., & Santos, G. (2017). Hidden disasters: Recurrent flooding impacts on educational continuity in the

[6] Philippines. Retrieved September 28, 2022, from https://www.sciencedirect.com/science/article/abs/pii/S2212420917302200?via3Dihub&fbclid=IwAR2U5XW_0NFU2P1UsP5M59s4pH8Wb9ujksTMMMuM0TkHNQJVCXb_5GJcW1s.

[7] Casaburo, A., Franco, F., & De Rosa, S. (2019). A Review of Similitude Methods for Structural Engineering. Applied Mechanics Reviews, 71(3). https://doi.org/10.1115/1.4043787

[8] Dongmei, S., Cairui, Y., & Shaoyang, W. (2019, February 23). Study on Structural Characteristics of Siphon Well Design in a Power Plant. Semantic Scholar. https://www.semanticscholar.org/paper/Study-on-Structural-Characteristics-of-Siphon-Well-Dongmei-Cairui/ed4cbdd37362f9fd236a8a9c67787099fd0b52e6

[9] Durrani, A., Mojahid, O., & Uzair, M. (2019). Micro Hydro Power Plant using Sewage Water of Hayatabad Peshawar | Semantic Scholar. Retrieved November 22, 2022, from https://www.semanticscholar.org/paper/Micro-Hydro-Power-Plant-using-Sewage-Water-of-Durrani-Mujahid. Retrieved December 8, 2022, from https://www.tandfonline.com/doi/full/10.1080/09692290.2018.1511449

[10] ENGLISH09 - Heron's Fountain - Heron's Fountain Harnessing Potential Energy To Provide Electricity! This Fountain That Has No Motor Is A Small Scale Model Of A New | Course Hero. (2020). Course Hero. Retrieved May 16, 2023, from

https://www.coursehero.com/file/55610442/Herons-fountain/

[11] Gioia, D. (2013). Seeking Qualitative Rigor in Inductive Research | Semantic Scholar.

https://www.semanticscholar.org/paper/Seeking-Qualitative-Rigor-in-Inductive-Research-Gioia-Corley/2006480b3c6baecd3ca7d6a7e876839f6a616556

[12] Gonzalez, M. (2005). Map of Pampanga showing the location of Porac [Map]. English

Wikipedia.https://commons.wikimedia.org/wiki/File:Ph_locator_pampanga_porac.png

[13] Google. (n.d.). [Map of Mt. Barundon View Deck, Camias, Porac, Pampanga]. Retrieved

May 16, 2023, from https://goo.gl/maps/Ttes4oXNZ1vE9tNS8

[14] Google map. (n.d.). [Barundon, Camias View Deck, Aetas, Porac, Pampanga]. Retrieved

May 16, 2023, from https://goo.gl/maps/swGqJwYVtDYEw7rj6

[15] How renewable energy consumption lower global co - wiley online library. (n.d.). Retrieved December 15, 2022, from https://onlinelibrary.wiley.com/doi/abs/10.1111/twec.12898

[16] Jebaseeli, E. E. E., Susitra, D., & Sundaram. (2021, March 1). Energy saving in

street lighting system. Semantic Scholar.

https://www.semanticscholar.org/paper/Energy-saving-in-street-lighting-system-Jebaseeli Susitra/65b4052fc7261d0aaed5b7e34ab4a22e73705dae

[17] Kamran, M. (2023). Energy sources and technologies. In Elsevier eBooks (pp. 23–69). Elsevier BV. https://doi.org/10.1016/b978-0-323-99560-3.00010-7

[18] Khan, M. (2014, August 15). Alternative ABC methods and funding justification.

Retrieved September29,2022, from https://www.sciencedirect.com/science/article/pii/B9780124072244000101?fbclid=IwAR26WPm8qqzA1MI2PWFW1SrvFxtYeYIT4iKxU43rUD9Pm9-sHIa0GoKOuQ.

[19] Matlakala, M., Von Kallon, D. V., Mogapi, K. E., Mabelane, I. M., & Makgopa, D. M. (2019). Influence of Impeller Diameter on the Performance of Centrifugal pumps. IOP Conference Series, 655(1), 012009. https://doi.org/10.1088/1757-899x/655/1/012009

[20] Passago, S., Yodying, c, Monatrakul, w, & Santiboon, T. T. (2020). Research and development of renewable energy: Prototype of LED street lighting from solar energy | Abstract. https://www.sysrevpharm.org/abstract/research-and-development-of-renewable-energy-prototype-of-led-street-lighting-from-solar-energy-65610.html

[21] Quaranta, E. (2019). Optimal Rotational Speed of Kaplan and Francis Turbines with Focus on Low-Head Hydropower Applications and Dataset Collection. Journal of Hydraulic Engineering, 145(12). https://doi.org/10.1061/(asce)hy.1943-7900.0001643

[22] Rahman, M. S., Nabil, I. M., & Alam, M. M. (2017,). Global Analysis of a

Renewable Micro Hydro Power Generation Plant. AIP Publishing. Retrieved December 8, 2022, from https://aip.scitation.org/doi/abs/10.1063/1.5018532.

[23] Saiga, K., Ullah, A. S., Kubo, A., & Tashi. (2021). A Sustainable Reverse Engineering Process. Procedia CIRP, 98, 517–522. https://doi.org/10.1016/j.procir.2021.01.144

[24] Schinko1, T., Drouet2, L., Vrontisi3, Z., Hof4, A., Hinkel6, J., Mochizuki1,

(2019, November 19). Https://orcid.org/0000-000310004251,IOPscience. RetrievedSeptember28,2022,from https://iopscience.iop.org/article/10.1088/25157620/ab6368/meta?fbclid=IwAR0Eb3jCfeku_wwx5oxhzO04cbpWutumz0IIpzQkkAkiDstLi5nvq5asG0

[25] Shahzad, K. (2018). An ecological feasibility study for developing sustainable street

lighting system | Semantic Scholar. https://www.semanticscholar.org/paper/An-ecological-feasibility-study-for-developingShahzad%C4%8Cu%C4%8Dek/ac04b74c2519ec0285f063d76d704fcd9540ff21

[26] Sheard, J. (2018). Quantitative data analysis. ScienceDirect. Retrieved December 6,

2022, fromhttps://www.sciencedirect.com/science/article/pii/B9780081022207000182

[27] Singh, V. K., & Singal, S. K. (2017). Renewable and Sustainable Energy Reviews.

Operation of Hydro Power Plants-a Review, 69, 610–619.

https://www.sciencedirect.com/science/article/abs/pii/S1364032116309200

[28] Soiferman, L. K. (2010). Compare and Contrast Inductive and Deductive Research

Approaches. | Semantic Scholar. Retrieved December 5, 2022, from https://www.semanticscholar.org/paper/Compare-and-Contrast-Inductive-and-Deductive-Soiferman/ef7d03e081eb53962a669ed2dc214a2de4ed843a

[29] Sulaiman, N., Ahmad, S. S. S., & Ahmad, S. (2019). Logical Approach: Consistency Rules between Activity Diagram and Class Diagram. International Journal on Advanced Science, Engineering and Information Technology, 9(2), 552. https://doi.org/10.18517/ijaseit.9.2.7581

[30] Sürücü, L., & Malakci, A. (2020). VALIDITY AND RELIABILITY IN

QUANTITATIVE RESEARCH | Semantic Scholar. https://www.semanticscholar.org/paper/VALIDITY-AND-RELIABILITY-IN-QUANTITATIVE-RESEARCH-S%C3%BCr%C3%BCc%C3%BC-Ma%C5%9Flakc%C4%B1/9c9c4751dbc8dc41c556edae1b827f84a70170fa

[31] Thiel, G., Ensslin, S., & Ensslin, L. (2017, April). Street Lighting Management and

Performance Evaluation: Opportunities and Challenges. ResearchGate.

https://www.researchgate.net/publication/317024328_Street_Lighting_Management_and_Performance_Evaluation_Opportunities_and_Challenges

[32] https://www.semanticscholar.org/paper/Optimization-Design-of-a-Rain-Power-Utilization-on-Yu-Wang/d07382f631618a2544a0b8fd40fffe299ec4a110

[33] Vopson, M. M. (2021, October 1). Estimation of the information contained in the visible

matter of the universe. AIP Publishing. Retrieved December 8, 2022, from

https://aip.scitation.org/doi/full/10.1063/5.0064475

[34] Wijayawardhana, L. M. J. R., Weerasinghe, K. D. N., & Navaratne, C. (2021). Tipping bucket device for measuring runoff in small catchments. Hydrological Sciences Journal-journal Des Sciences Hydrologiques, 1–9. https://doi.org/10.1080/02626667.2021.1977307

[35] Williamson, K., Johanson, G., Byrne, A., Given, L., Kenan, M., & Olivia, G. (2018).

The future of information research | Semantic Scholar.

Retrieved December 6, 2022, from https://www.semanticscholar.org/paper/The-future-of-information-research-Williamson-Johanson/4e42fd5794d47c32e5554484cc91aebc6aeb6fde

[36] Yu, J., & Wang, J. (2020, September 16). Optimization Design of a Rain-Power

Utilization System Based on a Siphon and Its Application in a High-Rise Building. Semantic Scholar.

[37] YunyuZhanga (2021, September 9). Assessment of Hydropower Sustainability: Review and modeling. Journal of Cleaner Production. Retrieved December 8, 2022, from https://www.sciencedirect.com/science/article/abs/pii/S0959652621030924

[38] Zakki, A., & Windyandari, A. (n.d.). The application modular floating pontoon to support floods disaster evacuation system in heavily populated residential areas. Retrieved September 28, 2022, from https://ejournal.undip.ac.id/index.php/ijse/article/view/7695?fbclid=IwAR37OxK427vClZZJ3baQybrNGPVbJb1vzoAj8EJQLPFaofO0I78cyBpkPEc

[39] Zhao, C., Dujic, D., Mester, A., Steinke, J., Weiss, M., & Steffanituf, T. (2014).

Power Electronic Traction Transformerâ Medium Voltage Prototype | Semantic Scholar. https://www.semanticscholar.org/paper/Power-Electronic-Traction-Transformer%E2%80%94MediumZhaoDuji%C4%87/ac809713c7c5c24812d93fef3ea6e7649369bfe3

