An Experimental Study on the Performance of a Newly Developed Pico Hydroelectric Device

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Abstract

As electricity demand increases, different renewable energy sources were continuously explored to cope with the rising demand of an eco-friendly and affordable energy source. The concept of Hydroelectric Generators was considered and the researchers developed a Pico Hydroelectric generating device which is called the Aqualite to provide households with an alternative power supply. It is a device that powers 3 basic essential household appliances with the use of water. The initial design of the prototype was made but the goal of this experimental research is to optimize the performance of the device by determining significant factors affecting its output in Watts and Lux and by testing different combinations of fittings and pipes to get the best design for the device. The researchers have tested 36 combinations and run 30 trials for each and have collected 1,080 values for the Watts output and another 1,080 values for Lux output. These values were analyzed statistically and the researchers have found the best and optimal design for the pico hydroelectric device. This could help the inventors to develop the device and be more functional effectively and efficiently. With this invention and supporting research, the community could have a sustainable alternative source of energy

Keywords
Hydroelectric Generators, Experimental Research, Sustainable source of energy

1. Introduction

With the increasing number of demand for electricity generation, it is directly proportional to the supply. As the demand for this energy rises, the government compensates it with the supply and spend years of research solely for ways of electricity generation.

The 2017 nation's top demand resulted to 13,789 MW. Compared to the year 2016, 2017's total peak demand was 5.17 MW higher than the 13,272 MW of 2016. Then again, the all out power supply, as far as introduced limit, developed by 6.1% from 21,425 MW in 2016 to 22,730 MW in 2017. New capacities which resulted to a total of 835 MW were added to the nation's supply base in 2017 which incorporate coal-fired (630 MW), solar (127 MW), oilbased (77 MW), and hydropower (1 MW) (Department of Energy of the Philippines, 2017) . As far as offered by network, Luzon contributed 392 MW or 47%, Mindanao at 337 MW or 40% and Visayas at 106 MW or 3%. Luzon supplied 392 MW, Visayas at 106 MW and Mindanao at 337 MW which is designated of share by grid. The year likewise observed the end of the regulated demand in Mindanao which developed by 6.5% or 107 MW from 1,653 MW in 2016 to 1,760 MW in 2017 (Greentumble, 2017) Having only 1 MW on hydropower in the Philippines, it is evident that the government does not prioritize this industry. Knowing that the country is surrounded by huge amount of body water, lots of commercial and residential establishment in different provinces can benefit from these resources.

Access to electricity (% of population) in Philippines was reported at 90.98 % in 2016, according to the World Bank collection of development indicators, compiled from officially recognized sources Access to electricity (% of rural population) in Philippines was reported at 86.26 % in 2016. According to Helmenstine (2018), different energy production methods generate both positive and negative impacts to the environment. The continuous use of non-renewable energy has clear implications for our health and wellbeing, both of which are intimately connected with the impacts of non-renewable resources on our environment.

There are ten types of energy, each energy has its own functions and role to do work. Energy has two different types, renewable and non-renewable. Its different forms can come from the air, water, heat, and a lot more. First, the Mechanical Energy, it is the energy that is produced by a movement of a body or the location of an object. It is the sum of Kinetic Energy and Potential energy. Kinetic Energy is the energy of motion of a body while Potential Energy is the energy of of an object's position. Electromagnetic Energy (Radiant Energy) is the energy from light and electromagnetic waves (U.S. Energy Information Administration, 2019). The other types of energy are: Thermal Energy, Nuclear Energy, Chemical Energy, Sonic Energy, Gravitational Energy, and Ionization Energy. The highlighted and defined types of energy are being used for Renewable Energy. Renewable, as the word states, it can be reused. This type greatly uses natural resources that provide less pollution such as light, wind and water.

Non-renewable, resources that once used it cannot be used again. Most of these resources are extracted from the ground, fossil fuels, gases, etc. These resources are more commonly or conventionally used for producing energy, and it provides a greater negative impact to the world once used up.

The trend of energy today tends to lean more on promoting and using renewable energy sources. It advantages mainly focus on to lessen pollution and promote sustainability, energy shortages also do not apply to renewable energy. Less pollution means more growth and sustainability, which can greatly affect us positively through health, businesses, and all other factors. Renewable energy largely depends on resource availability, which would mean less resource less energy to be produced. And its initial investment and cost of maintenance are high. New technologies and innovations are being studied for it to be more efficient and effective in the world's condition today. Comparing renewable from nonrenewable, renewable is more eco-friendly but less efficient for the technology today. Non-renewable is more effective and efficient but tends to have a negative impact. (Stulz, R. et. al. 2011)

Evidently, the use of different non-renewable sources has a variety of harmful impacts on our environment due to the varying ways of how these are extracted. Perhaps the most well-known impact of using non-renewable energy sources is the emission of greenhouse gases, in particular carbon dioxide and methane, which contribute to climate change. Non-renewable energy sources are not just altering our Earth's atmosphere by increasing the amount of greenhouse gas emissions. They also emit a variety of pollutants that affect people's health and the environment. It is not just the air that we breathe which gets polluted. Dangerous pollutants that are emitted into the air can take a part in the water cycle. This is the case of acid rain which forms when sulphur and other chemicals are introduced into the atmosphere from industrial processes. Chemicals suspended in the air then turn the rain mildly acidic. It is also important not to forget environmental impacts that come about as a result of the extraction of nonrenewable resources or the disposal of the waste they generate. There is very clear evidence illustrating the impact of surface mining both in the short and long-term. For instance, huge volumes of excess rock or soil are dumped in other locations such as nearby valleys affecting those ecosystems. For this research, it is essential to know how these energy is consumed, computed and distributed. Also, seeing the technology that mostly uses these energy consumptions is important to view the factors affecting the demand of energy.

Lastly, there is something to be said about unintended consequences or rather unforeseen and accidental effects. Oil spills are extremely damaging to nearby shores and ecosystems. With these economic and environmental issues formed by generating power through non-renewable energy, researches nowadays focuses mainly on how to use renewable energy to somehow lessen the extraction of these non-renewable energy.

Currently, hydroelectricity in the Philippines is still being further developed, with an estimate of 25 hydropower plants in the country. The Department of Energy (DOE) states that the country still lacks power plants to filter the water produced by typhoons yearly. Hydropower can also be placed in most of the countries regions, but due to its costs, cuts were made and compared to other cheaper and more common energy sources (Roque, 2016)

In this experimental research, a product design or prototype was experimented for its reliability and credibility to produce hydroelectric power. This prototype is meant to be the downscaled type of the bigger hydroelectric generating technology present nowadays. It was downscaled because it will target to the smaller market, in the household level, to be specific. The researchers tend to have an optimized design for a universal and portable hydroelectric generator that can serve rural and some urban residences in the Philippines which will be called "**Aqualite**". This research would Identify components or combination of components that can optimize the performance of Aqualite in terms of a) electricity generated and b) the amount of light that can be produced by LED light bulbs. This would help reduce electricity costs of household and commercial establishments. The scope of this research focuses on a new hydroelectric device that regulates power for some 12V and 5V household devices such as: LED Lights, Portable Charger and Mini Fans. The Government can deploy the product in areas affected by natural calamities. It can also be used in government housing in rural and hard to reach areas. It is also beneficial for the Industry because it can use the product for the promotion of renewable energy in the country, offering a new alternative in energy generation.

2. Methods

2.1 Pico hydroelectric device

Aqualite is designed to have three 12-Volt ports and two 5-Volt ports. The three 12-Volt ports are used to light up the LED Bulb, the supply power to the cooling fan and to supply power to the water pump. The two 5-Volt ports are used for charging cellular phones. The initial total power of this prototype, regardless of the pipe fittings is three 12-Volt turbine running in 2.2 Amperes having a 26.4 Watts output each; plus two 5-Volt turbine running in 1 Ampere having 5 Watts output each; having a total output of 89.2 Watts. This study proposes the use of these LED Bulbs; It is said in the previous paragraph that the working input of an LED Bulb is only 12.5 watts; cooling fans are at the same rate and cellular phone charger are in 2-6 watts working input meaning the least value of power that the Aqualite should produce to make this study acceptable and valuable is 12.5 Watts having at least 5.68V. Having this minimum power rates, the researchers can say that the study is acceptable and valuable. This also says that the objectives are possible to be obtained. The initial design of the prototype was formed based on the factors that were mentioned in literature; and rom those factors, materials that are needed were identified. The factor concerning the Pressure, 5 different types of motors were tested and only 1 worked; it was the 6L/min Motor. For the factor concerning the generation of electricity, 3 types of turbines were considered since there are only 2 types of turbines in the market; they were the 5V and 12V Rated turbines.

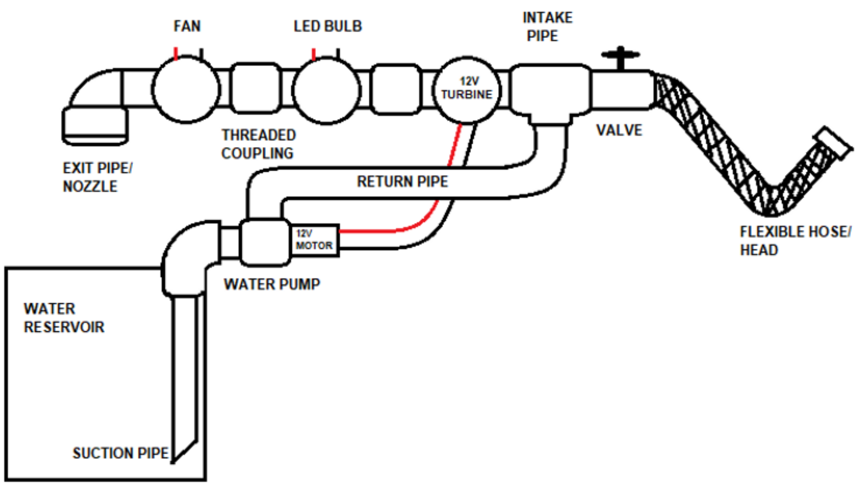

Figure 1. Schematic diagram of Aqualite

2.2 Experiment Proper

The researchers must conduct these following procedures to show that the device is working: (1) Testing the power output in Watt units to generate a 12-Volt DC Light Bulb. Its working input and its Luminance as output; (2) Testing the power output in Watt units to measure a portable cooling device (portable cooling fan). (3) And last is to test the power output in Watt units to measure the rate of a normal 5Volt cellular phone charger. The amount of mAH (milliamp hour, electric power over time) delivered in a phone battery.

The experimental research that is to be conducted would be a Mix & Match process. Among the factors that are given and explained above, different outputs would be obtained based from its variability. The objective of the experiment is to determine the effect of each factor to the final output and to find the highest power produced in Watt units. Each of the factors was tested in a total of 30 trials to ensure the accuracy of the measurement. The researchers used a randomized Block design, since the overall number of the parts of the prototype is nine. There are many parts that can be grouped to create a combination that would affect the output of the prototype.

One of the primary interests of the researchers is to determine the possible maximum power output of the prototype in watts. In order to attain the optimal or best result, the researchers considered four changing variables and three constant variables such as the; number of motors, number of turbines, pressure, length of suction pipe, type of water and the temperature of water.

2.3 Prototype Set-ups

Table 1 shows the four different set-ups made from the initial Faucet input set-up.

Table 1: Prototype Set-ups for Experimental Design

Prototype Set-Up:	**Consists of:**
Initial Set-Up: Faucet Input	3 Turbines, Two 12 Volts, One 5 volts
Set-Up B: Water Bucket 1	1 Motor, 3 Turbines, Two 12 volts, One 5 volts
Set-Up C: Water Bucket 2	1 Motor, 5 Turbines, three 12 volts, two 5 volts
Set-Up D: Water Bucket 3	2 Motor, 3 Turbines, Two 12 volts, One 5 volts
Set-Up E: Water Bucket 4	2 Motor, 5 Turbines, three 12 volts, two 5 volts

Figure 2 shows the extracted view of the Set-up for this experiment. This innovation enables users to charge their 5 and 12 volt gadgets with the use of any water reservoir available. With the use of micro water turbines, it converts the energy of the flowing water into mechanical energy. This mechanical energy is then converted into electricity with the use of the mini hydroelectric generator. There are two outlets designated for 12-volt gadgets and one outlet for 5-volt gadget.

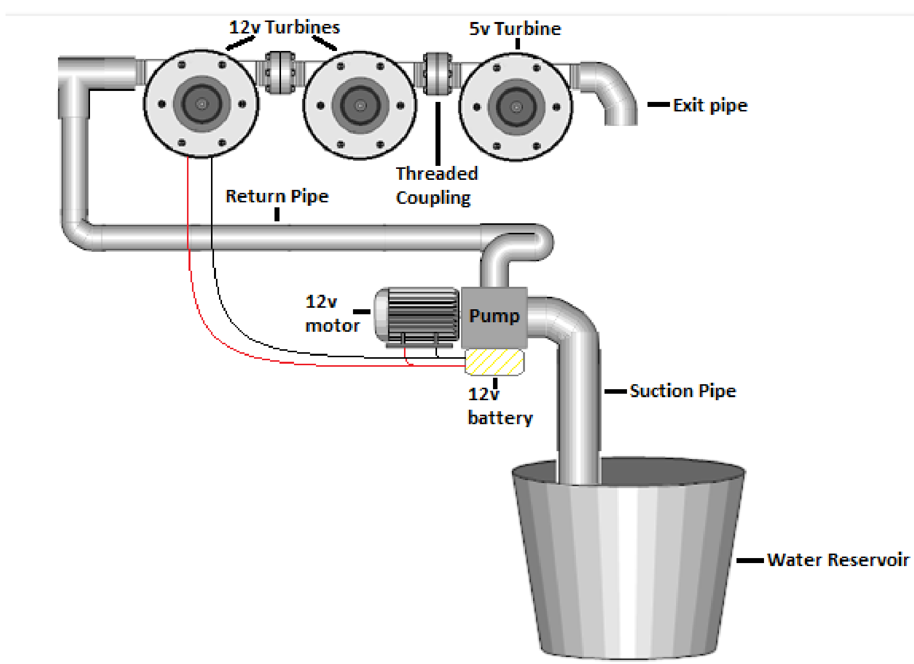

Figure 2. Extracted View of the Main Set Up of the Prototype

3. Results

Table 2 shows the summary of results for the different combinations of motors, turbines, water type and water temperature used in the experiment. These are the different factors that initially affects the output of the device in terms of Watts and Lux.

Table 2: Summary of Results for the different combinations of components

Motor	No. of Turbines	Type of Water	Temperature of Water	MODE; Output in WATTS	MODE; Output in LUX
Single	3	Tap Water	Warm	23.5	98
Single	3	Tap Water	Cold	16	153
Single	3	Tap Water	Hot	0	0
Single	3	Salt Water	Warm	22	98
Single	3	Salt Water	Cold	0	0
Single	3	Salt Water	Hot	0	0
Single	3	Mineral Water	Warm	22	98
Single	3	Mineral Water	Cold	0	0
Single	3	Mineral Water	Hot	0	0
Single	5	Tap Water	Warm	36.5	98
Single	5	Tap Water	Cold	0	0
Single	5	Tap Water	Hot	0	0
Single	5	Salt Water	Warm	36.5	99.5
Single	5	Salt Water	Cold	0	0
Single	5	Salt Water	Hot	0	0
Single	5	Mineral Water	Warm	36.5	99.5
Single	5	Mineral Water	Cold	0	0
Single	5	Mineral Water	Hot	0	0
Double	3	Tap Water	Warm	41	314
Double	3	Tap Water	Cold	37	382
Double	3	Tap Water	Hot	33	307
Double	3	Salt Water	Warm	33	233
Double	3	Salt Water	Cold	33	143
Double	3	Salt Water	Hot	37	149

Double	3	Mineral Water	Warm	37	352
Double	3	Mineral Water	Cold	41	399
Double	3	Mineral Water	Hot	29	31
Double	5	Tap Water	Warm	49.6	314
Double	5	Tap Water	Cold	48.6	314
Double	5	Tap Water	Hot	47.8	314
Double	5	Salt Water	Warm	48.6	314
Double	5	Salt Water	Cold	23.5	98
Double	5	Salt Water	Hot	22	98
Double	5	Mineral Water	Warm	49.6	314
Double	5	Mineral Water	Cold	60	314
Double	5	Mineral Water	Hot	41	314

The collected data was used for different statistical tools, and the following results in correlation was summarized and interpreted. Table 3 shows the relationship and correlation of each variable to one another. In their intersection, there are two results: (1) Pearson Correlation and (2) P-Value. The closer the pearson correlation value to +1 or -1, the stronger the correlation. A negative correlation coefficient means that as one variable increases, the other variable decreases. P-Value less than 0.05 indicates a significant correlation between the variables. Increasing the number of turbines, increases the number of output in Watts but not in LUX. The number of motors coincides with the pressure of water inside the system so the number of motor has a direct proportionality with Watts and in LUX.

Table 3. Summary of correlation analysis

	No. of Motor	**No. of Turbines**	**Suction pipe length**	**pressure**	**Temp of water**	**Output in watts**
No. of Turbines	-0.001 0.976					
Suction pipe length	0.001 0.981	-0.0269 0.000				
pressure	1.000 *	-0.001 0.976	0.001 0.981			
Temp of water	0.318 0.000	0.141 0.000	-0.136 0.000	0.318 0.000		
Output of watts	0.763 0.000	0.148 0.000	-0.384 0.000	0.753 0.000	0.294 0.000	
Luminance/LUX	0.753 0.000	0.148 0.000	-0.384 0.000	0.753 0.000	0.294 0.000	1.000 *

Cell Contents: Pearson Correlation
P-Value

Table 4 is the generated result for ANOVA and Post-hoc test which means if the water temperature changes, it has a significant effect on the output of the generated electricity which is in watts. Using the Tukeys Method, it has a significant difference when the temperature reaches 26 degrees Celsius. Based on the results, having a low temperature of water tends to produce more output than of the high temperature. Outputs in Luminance and/or Watts have significant differences also depending on the number of turbines and number of motors.

Table 4. ANOVA and Post-hoc Results

RESPONSE	**Factor**	**P-value**	**Significant Different**	**Tukey Test**
WATTS	Temperature of Water	0	With significant difference	26.67 degrees Celsius
WATTS	Type of water	0	With significant difference	Mineral water (warm), Salt water (warm), Tap water (warm, cold)
WATTS	Number of Turbines	0	With significant difference	n/a
WATTS	Number of Motors	0	With significant difference	n/a
LUMINANCE	Temperature of Water	0	With significant difference	26.6667 degrees Celsius
LUMINANCE	Type of water	0	With significant difference	Tap water (cold, hot, warm), Mineral water (warm, hot)
LUMINANCE	Number of Turbines	0.938	No significant difference	n/a
LUMINANCE	Number of Motors	0	With significant difference	n/a
WATTS	Temperature of Water	0	With significant difference	26.67 degrees Celsius
WATTS	Type of water	0	With significant difference	Mineral water (warm), Salt water (warm), Tap water (warm, cold)
WATTS	Number of Turbines	0	With significant difference	n/a
WATTS	Number of Motors	0	With significant difference	n/a
LUMINANCE	Temperature of Water	0	With significant difference	26.6667 degrees Celsius
LUMINANCE	Type of water	0	With significant difference	Tap water (cold, hot, warm), Mineral water (warm, hot)
LUMINANCE	Number of Turbines	0.938	No significant difference	n/a
LUMINANCE	Number of Motors	0	With significant difference	n/a

Figure 3 shows the regression formula fthat determines the significant components that will make a significant change on the electrical output (in watts). The electricity generated by the hydroelectric device can be affected by the significant factors with p values less than 0.05 like number of motors, number of turbines, length of suction pipes. However, the types of water even if its hot, cold or warm does not significantly affect the electricity generated(in watts). The R squared is at 82.11 which means that majority of the components identified does have significant effect on the electricity generated.

Regression Analysis: output (watts) versus No. of Motor, ... pe of water

The following terms cannot be estimated and were removed:
pressure, SECTION

Method

Categorical predictor coding (1, 0)

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	13	307504	23654	376.67	0.000
No. of Motor	1	151338	151338	2409.90	0.000
No. of Turbines	1	1107	1107	17.62	0.000
suction pipe length	1	7687	7687	122.41	0.000
temp of water	1	1601	1601	25.49	0.000
type of water	9	38932	4326	68.88	0.000
Error	1067	67006	63		
Lack-of-Fit	86	66225	770	967.83	0.000
Pure Error	981	781	1		
Total	1080	374510			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
7.92454	82.11%	81.89%	*

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1.10	8.25	0.13	0.894	
No. of Motor	26.753	0.545	49.09	0.000	1.28
No. of Turbines	1.144	0.272	4.20	0.000	1.28
suction pipe length	-1.743	0.158	-11.06	0.000	3.59
temp of water	0.0894	0.0177	5.05	0.000	2.73
type of water					
mineral water - cold	-5.50	7.96	-0.69	0.490	107.77
mineral water - hot	-15.09	8.01	-1.88	0.060	109.07
mineral water - warm	-1.42	7.99	-0.18	0.859	108.45
salt water - cold	-15.65	7.97	-1.97	0.050	107.77
salt water - hot	-20.12	8.00	-2.52	0.012	108.63
salt water - warm	0.01	7.98	0.00	0.999	108.19
tap water - cold	-5.10	7.97	-0.64	0.522	107.79
tap water - hot	-12.00	7.98	-1.50	0.133	108.15
tap water - warm	-10.01	8.05	-1.24	0.214	110.06

Regression Equation

type of water			
mineral water- cold	output (watts)	=	1.10 + 26.753 No. of Motor + 1.144 No. of Turbines - 1.743 suction pipe length + 0.0894 temp of water
mineral water - cold	output (watts)	=	-4.40 + 26.753 No. of Motor + 1.144 No. of Turbines - 1.743 suction pipe length + 0.0894 temp of water
mineral water - hot	output (watts)	=	-13.99 + 26.753 No. of Motor + 1.144 No. of Turbines - 1.743 suction pipe length + 0.0894 temp of water
mineral water - warm	output (watts)	=	-0.32 + 26.753 No. of Motor + 1.144 No. of Turbines - 1.743 suction pipe length + 0.0894 temp of water
salt water - cold	output (watts)	=	-14.56 + 26.753 No. of Motor + 1.144 No. of Turbines - 1.743 suction pipe length + 0.0894 temp of water
salt water - hot	output (watts)	=	-19.02 + 26.753 No. of Motor + 1.144 No. of Turbines - 1.743 suction pipe length + 0.0894 temp of water
salt water - warm	output (watts)	=	1.11 + 26.753 No. of Motor + 1.144 No. of Turbines - 1.743 suction pipe length + 0.0894 temp of water
tap water - cold	output (watts)	=	-4.00 + 26.753 No. of Motor + 1.144 No. of Turbines - 1.743 suction pipe length + 0.0894 temp of water
tap water - hot	output (watts)	=	-10.90 + 26.753 No. of Motor + 1.144 No. of Turbines - 1.743 suction pipe length + 0.0894 temp of water
tap water - warm	output (watts)	=	-8.91 + 26.753 No. of Motor + 1.144 No. of Turbines - 1.743 suction pipe length + 0.0894 temp of water

Figure 4. Regression Analysis for Electricity Generated (output in watts)

4. Discussion

4.1. Decision Analysis

The researchers used Decision Analysis to create and identify the best possible combination of the device. That was weighted in 5 different criteria: cost, practicality, performance in LUX, Performance in WATTS, and reliability. The highest weighted score was chosen as the best combination.

In doing the decision analysis, the researchers picked the 6 high performing combinations (based on output in watts and in lux) out of the 36 combinations tested. These combinations were scored based on the 5 criteria with different weights; these criteria was formed based on the factors we have considered in the earlier part of this research. Practicality was formed concerning its portability and the amount of effort the user would do (accessibility of inputs like water type and water temperature); performances both in Lux and Watts were formed, basically because that is the dependent variable the researchers are trying to establish. Reliability was formed concerning the performances; because it could be functional but not consistent. Cost is a criteria because it could make or break the whole product sales ability. Table 5 shows the summary of the experiment needed fot the DA analysis.

Table 5. Decision Matrix Analysis

DECISION MATRIX ANALYSIS						
OPTIONS:	**Motor**	**Turbine**	**Type**	**Temp**	**WATTS**	**LUx**
D1	**2**	**5**	**Mineral Water**	**Cold**	**60**	**314**
D2	**2**	**5**	**Tap Water**	**Warm**	**49.6**	**314**
D3	**2**	**3**	**Tap Water**	**Warm**	**41**	**314**
D4	**2**	**3**	**Mineral Water**	**Cold**	**41**	**399**
D5	**1**	**5**	**Tap Water**	**Warm**	**36.5**	**98**
D6	**1**	**5**	**Salt Water**	**Warm**	**36.5**	**99.5**

Design 2 has the highest weighted score so therefore we can conclude that different combinations have different ourput. . The design has the combination **Double Motor Pump - 5 turbines - Tap Water - Warm.** Having a modal value of 49.6Watts and 314 Lux as an output.

Table 6. Decision Analysis Results

		D1		D2		D3		D4		D5		D6	
Criteria	WEIGHT	SCORE	WEIGHTED SCORE	SCORE	WEIGHTED SCORE	SCORE	WEIGHTED SCORE	SCORE	WEIGHTED SCORE	SCORE	WEIGHTED SCORE	SCORE	WEIGHTED SCORE
COST	0.15	1	0.15	3	0.45	5	0.75	3	0.45	4	0.6	4	0.6
PRACTICA	0.15	2	0.3	5	0.75	4	0.6	2	0.3	3	0.45	3	0.45
PERFORM	0.35	5	1.75	4	1.4	3	1.05	3	1.05	1	0.35	1	0.35
PERFORM	0.25	4	1	4	1	4	1	5	1.25	1	0.25	2	0.5
RELIABILIT	0.1	2	0.2	5	0.5	5	0.5	2	0.2	1	0.1	1	0.1
	TOTAL		**3.4**		**4.1**		**3.9**		**3.25**		**1.75**		**2**
DECISION:	**D2**	DOUBLE MOTOR - 5 TURBINES - TAP WATER - WARM											

5. Conclusion

The researchers have set a long term goal to reduce the electricity cost of households and commercial establishments by using a newly invented pico hydroelectric device. Based on a quantitative and qualitative analysis of 1,080 values of Watts output and 1,080 values of Lux output, it can be concluded that there are significant differences among the combinations of different components/parts in producing electricity supply in watts and in lux. From this analysis, the researchers have determined that water temperature, water type, the number of turbines and number of motors have a significant difference in output both in Watts and in Lux. When temperature rises, water molecules becomes stagnant and helps the stability of its flow inside the pipes giving it a higher output in terms of watts. Also, it was proven that having different types of water into the system has varying values. Increasing the number of turbines increases the number of output in Watts but not in LUX. The number of motors coincides with the pressure of water inside the system so the number of motor has a direct proportionality with Watts and in LUX. So therefore, the researchers conclude that these factors significantly affect the performance of the newly invented micro hydroelectric device, Aqualite. It is a suggestion to the makers and inventors that they should use the best and optimal design that was proven in this research. This result prompted further research of our system.

Reduction of electricity cost for household and commercial establishments can be achieved by using the newly invented pico hydroelectric device with the estimated savings of **Php 14, 547.73 / year** for a conservative use of LED bulbs, electric fan and phone charging. From the different assessments done, the researchers have developed recommendations for future improvements which includes: (1) research for optimizing motors and turbines, (2) to have an ergonomic casing for the device and (3) to have a better output rating, higher than what this research established.

References

Achour, Bachir. (2015). “What is the difference between tap water and drinking water?”. Retrieved from https://www.researchgate.net/post/What_is_difference _between_tap_water_and_drinking_water

Andreas, M. Larsen, D. Drews, M. (2018). Water use in electricity generation for water-energy nexus analyses: The European case. Retrieved from https://www.sciencedirect.com/science/article/pii/S004 8969718339184

Gore, J. et al. (2007). Alaska Hydro-Flow Generator. Retrieved from https://deepblue.lib.umich.edu/bitstream/ handle/2027.42/50510/?sequence=1

Helmenstine, A. M. (2018). Name 10 Types of Energy. Retrived from https://www.thoughtco.com/main-energy-forms-andexamples-609254

Kubala, Jillian. (2018). Purified vs Distilled vs Regular Water: What’s the difference?. Retrieved from https://www.healthline.com/nutrition/purified-vsdistilled-vs-regular-water#section7

Matos, C. et al. (2018) Overview of Large-Scale Underground Energy Storage Technologies for Integration of Renewable Energies and Criteria for Reservoir Identification. Retrieved from https://www.sciencedirect.com/science/article/pii/S2352152X18301919

Roque, V. (2016). Can hydropower work for the Philippines?. Retrieved from https://powerphilippines.com/2016/07/05/277

Stulz, R. et. al. (2011). A Sustainable Energy Vision for the future. Retrieved from https://www.sciencedirect.com/science/article/pii/B978 0123851369100166

Tsai, S. et al. (2016). Models for forecasting growth trends in renewable energy. Retrieved from https://www.sciencedirect.com/science/article/pii/S136 4032116302143

Department of Energy of the Philippines. (2017). 2017 Power demand and supply highlights. Retrieved from https://www.doe.gov.ph/electric-power/2017power-supply-and-demand-highlights-januarydecember-2017

Department of Physics. University of Illinois at Urbana-Champaign. (2007). Retrieved from https://van.physics.illinois.edu/QA/listing.php?id=236& t=what-is-saltwater

Harmful Effects of Non-Renewable Resources on the Environment. (2017). Retrieved from https://greentumble.com/harmful-effects-of-nonrenewable-resources-on-the-environment/

Nova Teachers. (2004). Retrieved from https://www.pbs.org/wgbh/nova/teachers/activiti es/2402_titanic.html [15] Roque, V. (2016). Can hydropower work for the Philippines?. Retrieved from https://powerphilippines.com/2016/07/05/277/

Philippine Access to Electricity. (2016). Retrieved from https://tradingeconomics.com/philippines/access-toelectricity-percent-of-population-wb-data.html

U.S. Energy Information Administration. (2019). Converting Biomass to Energy. Retrieved from https://www.eia.gov/energyexplained/?page=biomass _home

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