HARVESTING ELECTRICAL ENERGY FROM LIVING PLANTS

A Thesis

Presented to

The Faculty of the Graduate School

Samar State University

Catbalogan City, Samar

In Partial Fulfillment

of the Requirements for the Degree

Masters in Technician Education (MTE)

Major in Electrical Technology

RAFFY A. VILLARUEL

November 2019

APPROVAL SHEET

This thesis entitled **"HARVESTING ELECTRICAL ENERGY FROM LIVING PLANTS,"** prepared and submitted by **Raffy A. Villaruel** in partial fulfillment of the requirements for the degree **MASTER OF TECHNICIAN EDUCATION**, has been examined and recommended for acceptance and approval for **ORAL EXAMINATION.**

PONCIANO P. MACAPAÑAS, Ph. D.
Adviser

- -

Approved by the Committee on Oral Examination on **November 6, 2019** with a grade of **PASSED**.

FELISA E. GOMBA, Ph. D.
Vice President for Academic Affairs
Chairman

RONALD L. ORALE, Ph. D.
Vice President for Research and Extension Services
MEMBER

EMILIO H. CEBU, Ph. D.
Extension Coordinator, Graduate School
MEMBER

- -

Accepted and approved in partial fulfilment of the requirements for the degree Bachelor of Science in Industrial Technology, major in Electrical Technology, School Year **2019 - 2020**.

November 6, 2019
Date of Oral Examination

ESTEBAN A. MALINDOG, JR. Ph. D.
Dean, Graduate School

ACKNOWLEDGMENT

The researcher wishes to express his heartfelt thanks and appreciation to the persons who magnanimously contributed to the successful completion of this research undertaking.

To **Dr. Felisa E. Gomba,** Vice President for the Academic Affairs, Samar State University Catbalogan City, for her proficient support extended to the researcher which made this research possible.

To **Dr. Ponciano P. Macapañas**, Adviser, Dean of College of Industrial Technology, Samar State University, Catbalogan City for his ready guidance , suggestions and encouragement whenever the writer encountered problems during the writing of the paper ;

To **Dr. Ronald L Orale**, Vice President for Research and Planning Services, Samar State University, Catbalogan City, and **Dr. Emelio H. Cebu**, faculty member of Samar State University, Catbalogan City, for sharing their knowledge which guided him in the conduct of this study.

To **Nathalie Ann A. Acosta**, Secretary to the Dean, Graduate School, Samar State University, Catbalogan City also one of the panel members of the researcher's oral defence for her suggestions during the deliberation.

To my loving father **Rafael S. Villaruel** and mother **Erlinda Q. Antor** for their untiring motivation and strong concern to carry on when things seemed unbearable and for their moral and financial support.

To my beloved, supportive and understanding wife **Jeanelyn Judloman Villaruel** and to my daughter **Rajean J. Villaruel** who serve as my inspiration and strength in this thesis paper.

Above all, to the **Almighty God** for giving the writer the patience, inspiration strength blessings and guidance; to **HIM** the researcher owes everything.

The Researcher

DEDICATION

To God,

for giving good health and wisdom from the start

until my last struggle…

To my Family,

for their deepest love and support

To my Mentors,

for sharing their expertise…

To my family,

for their inspiration…

To all of you, the researcher humbly dedicate this

academic masterpiece.

-Raffy

ABSTRACT

Electricity is one of the most vital and indispensable resource needed by the present society. But as urbanization and industrialization continue to grow, the demand for it increases by both people and industry. Hence, there is a need to look for alternative source of electric energy such as living plants. A study was conducted to develop an enhanced electric energy production technologies from living plants using the exploratory research design. The study utilized banana, cactus, taro root crop, papaya and water lily as living plants energy sources. The bio-electro chemical and electrophysiological compounds of these plants were determined, including the methods used in harvesting electrical energy. The findings showed that cactus, banana, papaya, taro root crop and water lily have bio-electrochemical and electrophysiological components especially from their water contents. Moreover, the 203.2mm copper wire harvested the most electrical energy using the enhanced electrical energy production technology. The results also revealed that cactus and water lily produced higher electrical energy when harvested by the enhanced electrical production technology as compared to other living plants used in the study as energy sources. The findings also revealed highly significant differences in the harvested electrical energy between cactus, banana, papaya, taro root crop and water lily in terms of both wattage and voltage using the enhanced electric energy production technology. The study concluded that cactus and water lily are potential sources of electrical energy due to their high water content. Furthermore, the enhanced electrical energy production technology is an effective mechanism to harvest electrical energy from living plants particularly cactus

and water lily. It is highly recommended that other living plants with higher water component be tried out and considered as sources of electrical energy using the enhanced electrical energy production technology.

TABLE OF CONTENTS

Chapter 1

THE PROBLEM AND ITS SETTING

Introduction

Electricity is indispensable on a micro- and macro-scale. On the one hand, it is vital to modern life as it powers lights and appliance at home. On the other hand, electricity generation is essential to economic development. It powers many industry processes and is, in fact, used to power trains and to charge electric vehicles. Subsequently, electricity use is rising rapidly as major economies develop in various parts of the world. As a consequence, this need for electricity drives a growing demand for electricity generation.

At present, there are various sources of electricity generation in operation around the globe. For one, there are fossil fuel power plants that burn carbon fuels such as coal, oil or gas to generate steam that drives large turbines that produce electricity. Although these power plants can generate electricity reliably over long periods of time, they nevertheless emit carbon dioxide into the atmosphere which causes climate change. Then, there are also large hydro power plants which generate electricity by storing water in vast reservoirs behind massive dams that, in turn, flows through turbines to generate electricity. This seems to be a viable electric generation. Yet, with dry periods, water reservoirs may be drained, thus, causing a possibility of reduced electric generation, and with rainy periods, flooding of reservoirs can have a serious impact on the ecology (World Nuclear Association, 2018).

It is thus clear from the aforesaid discussions that every form of electricity generation has its strengths and weaknesses. On top of which, most countries have to pay a high price for their domestic and industrial consumption. In the Philippines, for instance, the year 2016 was characterized by a significant increase in electricity consumption from 82,413,213 megawatt hour in 2015 to 90,797,891 megawatt hour in 2016 which was roughly a 10 percent increase compared to the 6.7 percent in 2015. Said increase is primarily driven by the growth of residential consumption at 12.7 percent from 22,747,049 megawatt hour in 2015 to 25,631,254 megawatt hour in 2016 due to high requirements for cooling system which, in turn, was due to the strong El Nino (Department of Energy, 2016).

Moreover, with such an enormous electricity need, knowing what sources of electricity generation does the country has becomes an important consideration. Based on the data on gross power generation by plant type, the largest electric generation source was coal estimated at 33,952,671 megawatt hour accounting for 49.6 percent generation share, followed by natural gas at 20,547,239 megawatt hour or 30 percent of generation share. Renewable energy source accounted for 17 percent of the generation share at roughly 11,627,735 megawatt hour. Of the renewable sources, hydroelectric power plants accounted for the largest share at 8.4 percent with roughly 5,723,985 megawatt hour compared to geothermal with only 5.7 percent share at roughly 3,909,704 megawatt hour (Department of Energy, 2017).

Although in the Philippine setting, renewable electric generation does not account for the small share, globally it does generate a relatively small share of electricity. Now, with the current demands of growing industries vis-à-vis the need to protect the environment, future electricity generation will need a range of options, especially those that are cost-efficient and environment-friendly. Consequently, there has been efforts to develop alternative forms of energy. Yet, the development of alternative forms of energy has been limited. In fact, the most prolific renewable energy source is wood fuel which poses health risks as well as creating black carbon emissions. Despite the importance of developing new energy sources, there are still barriers to the adoption of renewable energy. Among these barriers include high upfront and technology costs, non-competitiveness, non-viable markets, inaccessible financial packages, and social acceptability (Delos Santos, 2018).

So far, the country is leading in the efforts to develop renewable sources of energy in Southeast Asia. However, most of the renewable energy sources was focused on solar energy, with limited development using bioelectricity or electric generation from living plants.

However, Dayou (2013), a Malaysian researcher demonstrated the potential of harvesting electrical energy from living plants. By enhancing the current technology in harvesting electrical power from other known renewable sources, he was able to harvest electricity from living plants by embedding electrodes into the plant to allow the flow of ions and hence generate electricity. He conducted multiple random tests using different types of electrodes and plants as an attempt to determine the characteristics of the harvesting system. It was found that voltages are produced to a greater or lesser extents by all test where combination of copper-zinc and cactus produces the highest voltage. The enhancement harvesting system has the ability to light up Light Emitting Diode (LED), digital clock and calculator which grants it a potential to be used for low power electrical consumption.

An innovation on the electric energy production technology from living plants was patented by Plant-e in 2007. Plant-e develops products in which living plants generate electricity. The patented technology enables us to produce electricity from living plants at practically every site where plants can grow. The technology is based on natural processes and is safe for both the plant and its environment. The technology is referred to as the Plant Power Concept which is based on the cooperation of plants and microorganisms to produce inside electricity. The advantage of the Plant Power Concept is that renewable, clean electricity can be produced while the facility can be well integrated in the landscape. The Plant Powers' energy source is available everywhere plants grow and can therefore reduce depending on external energy resources (Gowtham and Shunmug, 2013).

This has prompted the researcher to conceptualize an electric energy source from living plants in consonance with the need to reduce the consumption of commercially-available generation source and the need to protect the environment. Hence, this research aimed to develop an enhanced electric energy production technology from living plants using banana (*Musa balbisiana*), cactus (*Pachycereus pringlei),* taro root crop (talyan) (*Colocasia esculenta),* papaya *(Carica papaya),* and water lily *(Nymphaeaceae*) as energy sources.

Statement of the Problem

This study aimed to develop an enhanced electric energy production technologies from living plants, to wit: banana (*Musa balbisiana*), cactus (*Pachycereus pringlei),* taro root crop (talyan) (*Colocasia esculenta),* papaya *(Carica papaya),* and water lily *(Nymphaeaceae*).

Specifically, this study sought to answers the following questions:

1. What are the chemical and physical-structure components of the following living plants:

1.1 Banana (*Musa balbisiana*);

1.2 Cactus (*Pachycereus pringlei);*

1.3 Taro Root Crop (Talyan) (*Colocasia esculenta);*

1.4 Papaya *(Carica papaya);* and

1.5 Water Lily *(Nymphaeaceae*)?

2. What are the methods used in harvesting electrical energy along the following elements:

2.1 Type of electrodes used; and

2.2 Type of living plants as energy sources?

3. Is there a significant difference in the harvested electrical energy among the living plants in terms of:

3.1 wattage; and

3.2 voltage and power capacity?

4. What enhancement technological process may be developed to increase electrical energy output using these five plants?

Hypothesis

On the basis of the aforementioned specific problems, the null hypothesis was tested:

1. There is no significant difference in the harvested electrical energy among the living plants in terms of:

1.1 wattage; and

1.2 voltage and power capacity.

Theoretical Framework

Living plants have the potential to serve as electric energy sources when appropriate electric energy production technology is developed. On this premise, the study is being conducted with the theoretical underpinnings based on the

Ricardian Theory of Comparative Advantage, Real Options Theory of Electric Generation, and Electrophysiological Property (AP) of Living Plants.

The Ricardian Theory of Comparative Advantage holds that under free trade, an agent will produce more of and consume less of a good for which they have a comparative advantage (Dixit & Victor, 1980, cited in "Comparative Advantage", 2018). Moreover, comparative advantage is the economic reality describing the work gains from trade for individuals, firms or nations which arise from differences in their factor endowments or technological progress (Maneschi, 1998, cited in "Comparative Advantage", 2018). In a smaller scale, an electrical energy source has a comparative advantage over others in producing a particular energy comparable in wattage, and voltage and power capacity if they can produce that good at a lower relative opportunity cost.

Likewise, this study was based on the Real Options Theory of Electric Generation. In essence, the said theory is focused on assessing the value of flexibility within projects under uncertainty. This flexibility, in turn, represents the capabilities of managers to adjust projects in response to uncertainties, and can enhance the projects' worth. The said theory can further increase the value of flexible projects such as renewable energy projects (REP) by managing uncertainties associated with the projects and their environments. Increasing the value of REP can be achieved by enhancing their financial appeal and improving their design. Therefore, RO Theory can be used to enhance the competitiveness of REP by applying real options to exploit the flexibility associated with their specific designs, uncertainties and environments (Hastie, 1974; Myers, 1977, cited in Cesena, 2012).

Accordingly, enhancing electric generation technology from living plants conforms to this theory inasmuch as it is more flexible than other renewable energy projects. The electric generation technology from living plants has the same value – that is, the generation of power, yet, its project cost is not as much as other REPs. In this case, the electric generation technology from living plants is more convenient as it offers additional options to make it more appealing even if the value of the options cannot be quantified.

Finally, the study is formed around the electrophysiological property of living plants. Rapid plant responses to environmental changes are associated to electrical excitability and signalling, using the same electrochemical pathways to drive physiological responses, characterized in plants by continuous growth. Electrical pulses can be monitored in plants as signals, which are transmitted through excitable phloematic cell membranes, enabling the propagation of electrical pulses in the form of a depolarization wave or action potential (AP) (Dziubinska et al., 2001; Fromm & Spanswick, 2007, cited in Gurovich, 2018).

Conceptual Framework

Figure 1 presents the schematic paradigm of the study on harvesting electrical energy from living plants. As shown in the diagram, the study made use of the input-process-output (IPO) model of research that were represented by three boxes.

The first box was the input of the study. It contained the five living plants used as electrical energy sources which included the following; banana (*Musa Balbisiana*), Cactus (*Pachycereus Pringlei*), Taro Root Crop (*Talyan*) (*Colocasia Esculemta*), Papaya (*Carica Papaya*) and Water Lily (*Nymphaeaccae*).

The second box was the process of the study. It was focused on the development of the electrode harvester and its testing for functionality.

The electrical energy harvested from the different living plants served as the output of the study. The arrows connecting the three (3) boxes indicated the sequential flow of the steps in conducting the research activities.

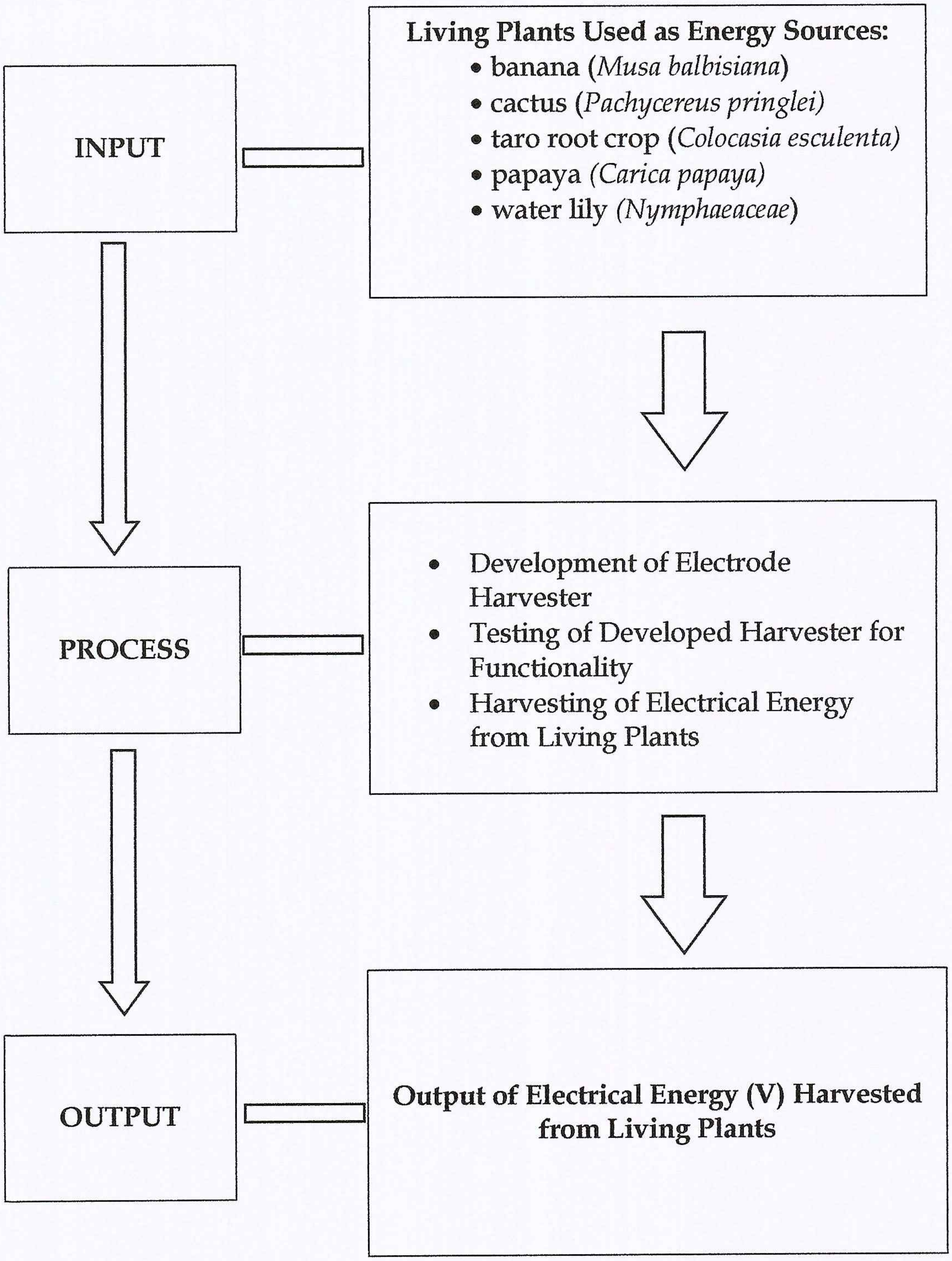


Figure 1. The Conceptual Paradigm of the Study

Significance of the Study

The study would be of significance to the students, teachers, local government units (LGUs), community, key officials of the Department of Science and Technology (DOST), National Electrification and Administration/Department of Energy (NEA / DE), and future researchers.

DOST Key Officials. The key officials of the Department of Science and Technology (DOST) would be given opportunities to probe into the functional utility of the proposed enhanced electric energy production technology from living plants on a larger scale through technical assistance to the researcher. Likewise, they would be able to re-assess existing electric energy production technology for comparative analysis in terms of wattage and voltage and power capacity; and in terms of potential utilization and extent of acceptability in terms of efficiency and cost-benefit analysis.

NEA / DE. The environment friendly organizations would be prompted to find funding sources for researchers who focus on developing electric energy production technology from environment-friendly sources like living plants. With their funding sources, more and more electric energy production technology from renewable sources like plants would be developed and utilized.

LGU Officials. The study would be of particular importance to the local government officials especially those assigned to the City Planning and Development Office (CPDO) to harness local electric energy production potential from sources that can give efficiency and can optimize cost-benefit concerns in order to reduce the community's reliance from commercial providers of electricity.

Future Researchers. The future researchers would be provided with inputs to conduct similar researches involving other living plants and, hopefully, on a larger scale than households.

Scope and Delimitation

Using a developmental research design, this study aimed to develop an enhanced electric energy production technologies from living plants, to wit: banana (*Musa balbisiana*), cactus (*Pachycereus pringlei*), taro root crop (talyan) (*Colocasia esculenta*), papaya (*Carica papaya*), and water lily (*Nymphaeaceae*). The said plants were preselected because of their availability in the locality, inexpensiveness, and capacity for invasive placement of electrodes to the component parts. The researcher focused on harvesting electric energy using varied types of electrodes and along different types of living plants as energy sources, and based on the plants' bio-electrochemical and electrophysiological components.

Finally, the study was conducted from July 2018-March 2019 of Academic Year 2018-2019 in Calbayog City, Samar.

Definition of Terms

The following terms were defined conceptually and operationally to provide readers with clearer understanding of this study.

Banana. The term pertains to a tree-like perennial herb (Robinson & Galan, 2010). In this research, however, the wild species of banana also known as Pacol (*Musa balbisiana*) plant was used as one of the living plants to be harvested with electric energy.

Biophysiological Components. These are plant structures that performs basic functions like photosynthesis (Nobel, 2005). As used in this study, this refers to the structure components of living plant that contribute in generating electricity using the enhanced electric energy production technology cell (Rozendal and Rabaey, 2008). In this study, this refers to the microbial fuel cells (MFCs) and microbial electrolysis cells (MECs).

Bioelectrochemical Components. These are organic plant components that are broken down by electrically active bacteria in an electrochemical

Cactus. The cactus plant is a member of the Cactaceae family comprising about 127 genera; derived from the Latin word, kaktos, which means spiny plant whose identity is not certain; occurs in a wide range of shapes and sizes; lives in habitats subject to at least some drought; and almost all are succulents, thickened fleshy parts adapted to store water (Anderson, 2001). As used in this study, the term referred to the cactus plant locally available in the Province of Samar which was used as one of the living plants to be harvested with electric energy.

Electric Energy Generation Technology. The term conceptually refers to electricity generation technology which harnesses a naturally existing energy flux and converts that flux to electricity; follows a paradigm different from conventional energy sources (Ahlstrom, 2005). As applied to this research, this referred to the electric energy generation technology from living plants, particularly, banana, cactus, taro root crop (talyan), papaya, and water lily.

Electrodes. The term is defined as an electrical conductor used to make contact with a non-metallic part of a circuit (Weinberg, 2003). In this study, this was taken in the same context as it is defined in the foregoing statement but referred specifically to the best pair that produces the highest power output.

Electrophysiological Component. Structures of living plants whose function pertains broadly to the flow of ions (current ions) in biological tissues (Noble, 2005). In this study, this refers to plant tissues that facilitate the flow of ions when generating electricity from plants.

Optimization of Harvesting System. As defined, the term pertains to the best combination of electrodes and energy source found from the electric energy production technology from living plants; considered along the following aspects: a) number of electrodes used, and b) use of an appropriate conditioning circuit (Choo & Dayou, 2018). In this research, the term meant the most effective use of the enhanced electric energy production technology based from the best combination of the types of electrodes and living plants used as energy source.

Papaya. It is commonly referred to as papaw or pawpaw; a succulent fruit of a large plant of the family Caricaceae that is considered a tree; scientifically known as Carica papaya (www.britannica.com). This term was used in this study as it is conceptually defined but was selected as one the five living plants to be used as electric energy source.

Taro Root Crop. It refers to the physiognomically unbranched sympodium from the Alocasia family; specifically known as Alocasia elongata or talyan (Thai Forest Bulletin, 2008). In this study, the term referred to Talyan which is specific to Eastern Visayas and was one of the five plants selected as an electric energy source.

Voltage. It is conceptually defined as the pressure from an electrical circuit's power source that pushes charged electrons (current) through a conducting loop, enabling them to do work such as illuminating light; voltage is equal to pressure and is measured in volts (V) ("What is Voltage?", 2018). The term was used in this study as one of the criteria through which the difference between the harvested electrical energy sources from the five living plants was measured.

Water Lily. The term refers to the family of flowering plants which live as rhizomatous aquatic herbs in temperate and tropical climates around the world; rooted in soil in bodies of water, with leaves and flowers floating on or emergent from the surface (Angiosperm Phylogeny Group, 2009). The term was used in this study as it was defined conceptually but was one of the five plants selected as an electric energy source.

Wattage. Conceptually, the term represents the amount of work done or electricity consumed per unit time; the unit of measurement for electrical power

(Boulianne, 2018). The term was used in this study as one of the criteria through which the difference between the harvested electrical energy sources from the five living plants was measured.

Chapter 2

REVIEW OF RELATED LITERATURE AND STUDIES

This chapter presents and discusses ample literature and studies about the bio-electrochemical and electrophysiological components of five living plants, the optimization and potential application of electric energy sourced from the living plants, and other similar topics which were reviewed by the researchers as they shed light to the problem being investigated. Similarly, this chapter includes major findings of previous researches on the development of electric energy production technology from renewable energy sources like plants.

Related Literature

This part enumerates and discusses relevant literature reviewed by the researchers as they found relevance to the development of enhanced electric energy production technology from living plants.

Energy is a central concern facing the world today. The emphasis is on the most economic and environment-friendly energy sources. In particular, clean, efficient, affordable and reliable energy services are indispensable for global prosperity. Hence, developing countries like the Philippines are in need to expand access to reliable and modern energy services if they are to reduce poverty and improve the health of their citizens while at the same time increasing productivity, enhancing competitiveness and promoting economic growth (UN Advisory Group on Energy and Climate Change, 2010).

Meanwhile, plants power life on Earth. They are the original food source supplying energy to almost all living organisms and the basis of the fossil fuels that feed the power demands of the modern world. But, burning the remnants of long-dead forests is changing the world in dangerous ways. Plants contain water-filled tubes called xylem elements that carry water from their roots to their leaves. The water flow also carries and distributes dissolved nutrients and other things such as chemical signals. The Finnish researchers, whose work is published in PNAS, developed a chemical that was fed into a rose cutting to form a solid material that could carry and store electricity. The result was a complex electronic network permeating the leaves and petals, surrounding their cells and replicating their pattern (Thompson, 2009).

Scientists have known for some time that plants can conduct electricity. In fact, researchers at the Massachusetts Institute of Technology found that plants can pack up to 200 millivolts of electrical power. A millivolt is one-thousandth of a volt. The researchers discovered that big leaf maple trees generated a steady voltage of up to a few hundred millivolts. Powering a circuit, however, required a much higher voltage. To extract electricity from trees and convert it into useful energy, researchers built a boost converter capable of picking up as little as a 20 millivolt output and storing it to produce a greater output. By hooking it up to a tree using electrodes, the custom-built device was able to generate an output voltage of 1.1 volts, enough to run low-power sensors (Living Science, 2009).

Taking cue from the aforementioned electric energy harvest from living plants, this study aimed to develop enhanced electric energy production technology from banana, cactus, taro root crop (Talyan), papaya and water lily plants. For one, the potential of banana is being assessed as an alternative energy source for North Queensland. In fact, the Australian Banana Growers' Association, Inc. has assessed the potential of bananas as methane source for energy production. It was found out that bananas can be converted to methane for electricity generation. Yet, there is no certainty that bananas are a cost-effective energy source, and whether there is sufficient volume for residential use (The University of Queensland News, 2004). In India, for instance, a 17-year-old youth innovated a bio cell that generated up to 12 volts of electricity, enough to light two LED bulbs from one banana stem. The concept is simple – the bio energy in the banana stem is converted into electrical energy by using electrodes. The bio cell works as long as there is natural acid in the banana stem (Beats, 2018).

Similarly, scientists in France have transformed the chemical energy generated by photosynthesis into electrical energy by developing a novel biofuel cell using cactus through photosynthesis which is the process by which plants convert solar energy into chemical energy. In the presence of visible light, carbon dioxide (CO_2) and water (H_20) are transformed into glucose and O_2 during a complex series of chemical reactions. Researchers developed a biofuel cell that functions using the products of photosynthesis (glucose and O_2) and is made up of two enzyme-modified electrodes. The cell was then inserted in a cactus. Once the electrodes, highly sensitive to O_2 and glucose, had been implanted in the cactus leaf, the scientists succeeded in monitoring the real-time course of photosynthesis in vivo. They were able to observe an increase in electrical current when a desk lamp was switched on, and a reduction when it was switched off. During these experiments, the scientists were also able to make the first ever observation of the real-time course of glucose levels during photosynthesis (CNRS, 2010).

Furthermore, the researchers showed that a biofuel cell inserted in a cactus leaf could generate power of 9 µW per cm^2. Because this yield was proportional to light intensity, stronger illumination accelerated the production of glucose and O_2 (photosynthesis), so more fuel was available to operate the cell. In the future, this system could ultimately form the basis for a new strategy for the environmentally-friendly and renewable transformation of solar energy into electrical energy.

Meanwhile, papaya, known as Carica papaya L. is typical of tropical and sub-tropical regions which require temperature of between 21 and 33^0 C and does not tolerate cold weather which is usually less than 15^0 C (Crane, 2005; Fuggate, et al, 2010; Rivera-Pastrana, et al., 2010; Yadava, Burris & McCrary, 1990, cited in Oliveira & Vitoria, 2011). On the other hand, prolonged dry periods reduce crop output (Almeida, et al., 2003, cited in Oliveira & Vitoria, 2011). Papaya crops require year-round labor, which has made it an excellent choice from a socio-economic perspective in countries that produce it.

However, the quality of the papayas grown can be compromised by conditions and practices adopted during commercialization (Nunes et al., 2010, cited in Oliveira & Vitoria, 2011). It is an elongated berry of various sizes with a smooth thin skin and a greenish-yellow color (Calegario, Puschmann, Finger, & Costa, 1997; Fagundes & Yamanishi, 2001; Fuggate et al., 2010, cited in Oliveira & Vitoria, 2011). Its flesh is thick with a color ranging from yellow to red and offers a pleasant, sweet, mellow flavor (Devitt, Sawbridge, Holton, Mitchelson, & Dietzgen, 2006; Fuggate et al., 2010, cited in Oliveira & Vitoria, 2011).

Practically every part of the papaya plant is of economic value and its use ranges from nutritional to medicinal. The fruit are popularly used as desert or processed into jam, puree or wine, while the green fruits are cooked as vegetable (Matsuura et al., 2004; Ahmed et al., 2002; OECD, 2005, cited in Nwofia, Ojimelukwe & Eji, 2012). The seeds are medicinally important in the treatment of sickle cell diseases (Imaga et al. 2009, cited in Nwofia, et al., 2012), poisoning related disorder (Okeniyi et al., 2007, cited in Nwofia, et al., 2012). The leaf tea or extract has a reputation as a tumor destroying agent (Walter 2008, cited in Nwofia, et al., 2012). The fresh green tea is an antiseptic whilst the brown, dried pawpaw leaves are best as a tonic and blood purifies (Atta, 1999, cited in Nwofia, et al., 2012). The tea also promotes digestive and aid in treatment of ailment such as chronic indigestion, overweight and obesity, arteriosclerosis, high blood and weakening of the heart (Mantok, 2005, in Nwofia, et al., 2012).

Another living plant which may be a potential source of electric energy are water lilies known scientifically as Nymphaea lotus which is an aquatic flora that are most abundant in water bodies. For an ordinary observer, the presence of water lilies is that of an aesthetic and serene aquatic environment. The white water lily type is predominant and grows freely in most environments. The plant has wide-round leaves that float flat on the water surface which are greenish in colour, and is thus able to carry out photosynthesis. The white water lilies produce bulbs that develop from the matured flowers (Stephen, et al., 2010).

Moreover, water lilies manifest different biochemical composition such as carbohydrate, protein, lipid and fiber and also some essential element such as sodium, potassium, magnesium, phosphorus, and zinc in addition to anti-oxidant Vitamins (A, C and E). It also shows that there are anti-nutritional factors in the bulb which are low and may be applied to other uses in chemical and pharmaceutical industries.

The plant, known in other countries as water hyacinth, has been transformed into a biogas. A study carried out by Almoustapha, et al., 2008 (in Kunutsa & Mufundirwa, 2013) revealed that it is possible to produce biogas from a mixture of water hyacinth and fresh rumen residue. Biogas outflow is related to seasonal variations in temperature. For the same retention time, the total volume of biogas obtained during the warm season is 1.8 times greater than that obtained during the cool season. Several other researches confirmed the possibility of producing biogas from water hyacinth. According to Nijaguna (2002, in Kunutsa & Mufundirwa, 2013), aquatic plants generate high-quality biogas but their salinity of 35-50 parts per 1000 is a serious problem. Water hyacinth produces 20.3 liters of biogas per kg of dry matter. Similarly, Jagadeesh (2012, in Kunutsa & Mufundirwa, 2013) noted that a hectare of water hyacinth can produce enough biogas each day to generate between 90 and 180 cubic meters of methane, equivalent to 3.44 to 6.88GJ of energy production.

Therefore, water hyacinth invasions in lakes can be harnessed for environmental benefit and renewable energy production. Water hyacinth has a very high cellulose content making them a potential renewable energy source. While controlling water hyacinth populations has proven to be beyond the capabilities of local government, using these plants for energy production provides an alternative approach to dealing with this invasive species. Water hyacinth can be used to produce biogas, an energy source that already has been embraced world over. An investigation into the possibility of bio-converting water hyacinth to yield biogas adds value and solves the problem of water hyacinth management as well as gives a solution to the energy and power shortages since people would no longer rely on the expensive LPG nor grid electricity. Biogas will lead to reduced use of fuel wood and diesel generators hence an innovative technology to the reduction of greenhouse gas emissions.

The aforementioned discussions on some living plants which possess potential of being sourced as an electric energy highlighted the increasing use of renewable energy as it provides an excellent opportunity for mitigation of greenhouse gas emission and reducing global warming through substituting conventional energy sources (Panswar, Kaushik & Kothari, 2011; Arent & Gelman, 2011; Swift-Hook, 2013, cited in Choo & Dayou, 2018). Accordingly, the aggressive utilization of renewable energy is an effort to safeguard the future and the Earth (Hinrichs & Kleinbach, 2006, cited in Choo & Dayou, 2018). Switching to renewable energy sources for electricity generation provides beneficiary management strategies from the economic, as well as environment point of view (Varun, Parakash & Baht, 2009, cited in Choo & Dayou, 2018).

Among the options are the weak energy sources. Previous studies has found a method that generate bioelectricity by direct extraction of photosynthetic electrons with inserting a Nano electrode from living algal cell (Wong, cited in Choo & Dayou, 2018). Similarly, it was shown the possibility of harvesting electricity from a living-plant using Glucose Oxidase (GOx) and bilirubin oxidase (BOD) modified electrodes during photosynthesis process (Flexer & Mano, 2010, cited in Choo & Dayou, 2018).

Given such options to extract electricity from living plants, Choo and Dayou (2018) conducted random tests by embedding pairs of electrodes into the plants where electrical energy is harvested by completing the connection with conditioning circuit. Towards the end, the best combination that produces the highest voltage was tested on Light Emitting Diode (LED), digital clock and also a digital calculator to investigate its potentiality on low electrical power appliances.

Since there are many types of electrodes available, the best pair that produces the highest power output has to be determined prior to any further optimization attempts. Choo and Dayou (2018) identified four different material of electrodes have been selected because they are locally abundant and easily available. They consisted of copper, ferum, zinc and aluminium. The positive and negative terminal of the electrode was determined according to its electrochemical potential, *E*. Therefore, the electrode with higher and lower electrode potential, $E°$ was selected as anode and cathode, respectively. Simultaneous oxidation and reduction process occur at anode and cathode allow the flow of negative ions to the anode and positive ions move towards cathode (Timberlake, 2009, cited in Choo & Dayou, 2018). On the other hand, only plants with good potential were considered, taking into consideration easy embedding and stem moisture content. In fact, the plants which were selected included pulai tree (*Alstonia Sp*), banana tree (*Musa acuminate*) and aloe vera (*Aloe Barbadensis*). Finally, the potential application of the harvested energy was tested on low electrical consumption appliance including LED lights, digital clocks and scientific calculators.

In a similar vein, designer Ermi van Oers created a lamp called Living Light that can harness energy from a living plant. The long-term goal is to power cities with green energy harnessed by plants. The science behind this project stems from the photosynthetic process which allows plants to grow and thrive. Plants essentially generate protons and electrons which can create electricity. When the plant breaks down bacteria to develop the energy, the microbial fuel cell captures the electors in an anode compartment which transfers the electrons through a wire. Essentially, it is a form of solar energy on a very natural level. The plant, encased in a glass tube, lights up when someone touches it. Living Light was built to be an entirely self-sufficient closed loop power source that does not need electric sockets. As an off-grid light source, the lamp has the potential to help millions of people around the world who do not have reliable or environmentally safe sources of energy. The designer hopes to tap into the massive potential of this technology and not only light streetlights and parks but also eventually turn forests and rice fields into power plants which can offer natural energy. It is hoped to see a future where cities can swap traditional electric grids with microbial energy systems (Kaplan, 2017).

The aforementioned literature provided ample precedent to lay out the groundwork and deepen the theoretical support for the conduct of the present research.

Related Studies

The succeeding discussions present the reviewed previously conducted researches whose findings provided valuable inputs in laying out the foundation of the problem currently being investigated in the present research.

One of the noteworthy researches cited here is that of Helder, Chen, Vander Harst & Strik (2013) which developed a new biomass energy technology in 2008 called the plant-microbial fuel cell (P-MFC). In this system, electricity was generated with living plants thus producing bioelectricity through a green roofing. The study revealed that the environmental performance of the P-MFC is currently worse than that of conventional electricity production technologies due to the limited power output of the P-MFC and the materials presently used in the P-MFC. Granular activated carbon (anode material), gold wires (current collectors), and Teflon-coated copper wires (connecting anode and cathode) have the largest impact on environmental performance. Use of these materials needs to be reduced or avoided and alternatives need to be sought. Increasing power output and deriving co-products from the P-MFC will increase environmental performance of the P-MFC. At this stage it is too early to compare the P-MFC with other (renewable) energy technologies since the P-MFC is still under development.

Although the previous research was on developing a P-MFC as an electric energy production technology from plants, it nevertheless paralleled the present research which developed electric energy production technology from five living plants through insertion of certain types of electrodes into the plants' parts.

Another research which is relevant to the present study is that of Goto et al. (2015) which investigated the effects of grapheme oxide (GO) on electricity generation in soil microbial fuel cells (SMFCs) and plant microbial fuel cell (PMFCs). GO at concentrations ranging from 0 to 1.9 g ·kg−1 was added to soil and reduced for 10 days under anaerobic incubation. All SMFCs (GO-SMFCs) utilizing the soils incubated with GO produced electricity at a greater rate and in higher quantities than the SMFCs which did not contain GO. In fed-batch operations, the overall average electricity generation in GO-SMFCs containing 1.0 g·kg−1 of GO was 40 ± 19 mW·m−2, which was significantly higher than the value of 6.6 ± 8.9 mW·m−2 generated from GO-free SMFCs ($p < 0.05$). The increase in catalytic current at the oxidative potential was observed by cyclic voltammetry (CV) for GO-SMFC, with the CV curve suggesting the enhancement of electron transfer from oxidation of organic substances in the soil by the reduced form of GO. The GO-containing PMFC also displayed a greater generation of electricity compared to the PMFC with no added GO, with GO-PMFC producing 49 mW·m−2 of electricity after 27 days of operation. Collectively, this study demonstrates that GO added to soil can be microbial reduced in soil, and facilitates electron transfer to the anode in both SMFCs and PMFCs.

The present study and the previous study of Goto et al. paralleled the present research in terms of their purpose to generate electricity from alternative sources to veer away from the commercially-available sources. Nevertheless, they diverged in the sense that the previous research focused on investigating the effects of grapheme oxide (GO) on electricity generation in soil microbial fuel cells (SMFCs) and plant microbial fuel cell (PMFCs) while the present research was on an enhancement of electric energy production technology from living plants. In this case, the present research was more concerned with the development of a technology which would extract energy from living plants while the previous research dealt more with determining the impact of an element on electricity generation.

Flexer and Mano (2010) proposed a new method for the direct and continuous measurement of O_2 and glucose generated during photosynthesis. Said system is based on amperometric enzyme biosensors comprising immobilized redox enzymes (glucose oxidase (GOx) and bilirubin oxidase (BOD) and redox hydrogels "wiring" the enzyme reaction centers to electrodes. It was found out that these electrodes, implanted into a living plant, responded in real time to visible light as an external stimulus triggering photosynthesis. They proved to be highly selective and fast enough and may be a valuable tool in understanding photosynthesis kinetics. Furthermore, the product demonstrated that the electrodes could harvest glucose and O_2 produced during photosynthesis to produce energy, transforming sunlight into electricity in a simple, green, renewable and sustainable way.

The previous study of Flexer and Mano was worthy of note in the present research because they were both concerned with proposing new methods and/or products which could facilitate easier, most efficient and cost-effective innovations in society. Yet, they differed because Flexer and Mano focused on developing new method to generate glucose during photosynthesis whereas the present research dealt with the production of energy from living plants using enhanced electric energy production technology.

Wetser, et al. (2016) aimed to start-up an oxygen reducing bio-cathode in situ in a tubular PMFC applied in a Phragmites australis peat soil and a Spartina anglica salt marsh. PMFCs with a biocathode were successfully started in the peat soil. Oxygen reduction is clearly catalysed, likely by microorganisms in the cathodes, as the over-potential decreased resulting in an increased current density and cathode potential. The maximum daily average power generation of the best peat soil PMFC was 22 mW m2. PMFCs with a biocathode in the salt marsh only started with pure oxygen diffusion reaching a maximum daily average power generation of 82 mW m2. Both wetland PMFCs were successfully started with natural occurring microorganism in the anode and cathode. Calculations show that the power density can be increased by improving the PMFC design limiting crossover of oxygen and substrate.

The study of Wetser, et al. and the present research both aimed at discovering efficient and effective methods. However, the previous research zeroed in on starting up an oxygen reducing biocathode in situ in a tubular PMFC applied in a Phragmites australis peat soil and a Spartina anglica salt marsh. By contrast, the present research dealt with an enhanced electric energy production technology out of living plants.

Mosqud et al. (2017) designed water plants microbial fuel cells (MFCs) for bioelectricity generation. Organic soil and marine sediment were used for fresh water and sea water plants, respectively. It was observed that sea plants were more efficient for bioelectricity generation than the fresh water plants. The peak voltage reached at 520 mV when *Phragmites australis* was used. The MFCs without plants always showed significantly lower (80% lower) voltage in both soils. Seasonal variation was not prominent; however, daily solar radiation had noteworthy influences on voltage generation for both plants.

The study of Mosqud et al. was similar to the present research inasmuch as they both dealt with bioelectricity generation. Nevertheless, they differed because the previous study was more on the design of a water plants microbial fuel cells whereas the present research was more on the enhancement of an already existing technology on electric energy production from living plants. Hence, the present research was an attempt to improve on an existing bioelectricity generation technology in contrast to the previous research which was more of discovering a new method to generate electric energy source.

Another similar research upon which the present study finds relevant is that of Chee, et al., (2016) which developed a data acquisition (DAQ) system for instantaneous monitoring of electrical potential in plants using aloe vera as a plant sample. The static response characterization, capability index (P/T), and Pearson's coefficient of correlation procedures were applied to assess the reliability of the obtained data. This developed system offers the capability of *in situ* monitoring and detecting gradual changes in the electrical potential of plants up to a correlational strength of greater than 0.7. Interpretation of the electrical signal mechanisms in the *Aloe vera* plant and the optimization of the electricity can be achieved through the application of this monitoring system. This system, therefore, can serve as a tool to measure and analyse the electrical signals in plants at different conditions.

The said research used aloe vera as the lone living plant sample to generate electric energy through the process of photosynthesis which contrasted the present research which included five living plant samples, namely, banana, cactus, taro root crop (Talyan), papaya and water lily.

In a research entitled, "Banana Biomass as Potential Renewable Energy Resource: A Malaysian Case Study", Tok, et al. (2010) investigated the energy potential generated by banana plant biomass in Malaysia. A maximum power of 80.52MW can be obtained from direct combustion and 869.13MW from anaerobic digestion, giving rise to an estimate of 949.65 MW.

The said study therefore provided valuable inputs into the potential use of banana plant as an electric energy source. Yet, Tok, et al. converted banana plant into biomass to generate electricity whereas the present research directly inserted electrodes into the banana stem to see the potentiality of said living plant to generate electricity.

Kardile (2017), in a research entitled, "Unveiling the New Source of Green Energy – A Plant", developed an electric energy source from living plants by embedding pairs of electrodes into them to allow flow of ions and hence generate electricity. Living-plants take CO2 and H2O and capture the light energy. This energy is stored in plats as sugars produced. Some part of this stored energy, transferred to the roots of the plants. This transferred energy is in form of electrons as a by-product. Multiple tests using different type of electrodes and plants suggested that voltages are produced to greater or lesser extents where combination of copper (Cu)-zinc (Zn) and Bauhinia Racemosa L. produces the highest voltage output. The obtained result confirmed that the natural process is responsible for production of clean, renewable, sustainable, efficient plant produced electricity as a future renewable bio-energy source.

The study of Kardile was similar to the present research because they both focused on discovering alternative energy sources which are environment-friendly. Yet, they differed in other aspects such as in the process of research and in the types of plants

Choo, Dayou and Surugau (2014) investigated the presence of trace metals from the electrodes using Flame Atomic Absorption Spectroscopy (FAAS) to gain insight into the origin of the energy production. To further justify the stated hypothesis, comparison of trace metals concentration in electrodes immersed in Aloe Vera between opened and closed circuit is also investigated. The obtained result confirmed that the electrochemistry process is responsible for the mechanism of the energy production from living plant.

All the above-mentioned researches provided valuable insights to further strengthen the conduct of the present investigation on enhancement of electric energy production from living plants. The mentioned researches in this section differed from the present investigation in terms of focus and variables studied yet, they were relevant as they shed light to the problem being investigated in the present research.

Chapter 3

METHODOLOGY

This chapter presents the research design, instrumentation, data gathering procedure, and statistical treatment of data.

Research Design

The study utilized the exploratory research design in harvesting electricity from living plants using the enhanced electric energy production technology. The living plants used as energy sources were banana (*Musa balbisiana*), cactus (*Pachycereus pringlei)*, taro root crop (talyan) (*Colocasia esculenta)*, papaya *(Carica papaya)*, and water lily *(Nymphaeaceae*). The exploratory method of research is conducted for a problem that has not been studied more clearly, intended to established priorities, develop operational definitions and improve the final research design (Shields, 2003). Exploratory research does not aim to provide conclusive evidence, but helps to have a better understanding of the problem. Hence, exploratory research is the initial research which forms the basis of a conclusive and comprehensive research.

Instrumentation

This study made use of a prototype electrode harvested to determine the electricity which can be generated from the five living plants used as sources of electric energy. Said electrode harvester was developed by the researcher as an enhanced electric energy production technology using local available materials in the community like pure zinc as a negative conductor and copper nails used as a positive conductor.

Validation of Instruments

To test the validity and reliability of the developed electrode harvester, multiple pre-testing was conducted on the five living plants. This was made by embedding the electrodes into the plants to allow the few of ions and generate electricity. The pre-trial showed that the combination of the positive-negative electrodes and the plants produces electricity which powered and turned on cellular phones and digital calculators. This was an indication that the developed electrodes has the ability to harvest electrical energy from living plants. Hence, the research instrument is a valid source of data for the study on harvesting electricity from living plants.

Data Gathering Procedure

This study of harvesting electricity from living plants involved two phases, namely; the pre-testing phase and the exploratory phase.

a. **Pre-testing phase**. The pre-testing phase occurred before the start of the experiment. The pre-testing phase involved the determination of the weakness and/or inadequacy of the existing electric energy production technology. This phase likewise involved the trial-and-error testing of the different types of electrodes which provided the best output of electric energy as matched with the five living plant sources. In addition, this phase involved the ocular inspection of places where the five living plants, to wit: banana (*Musa balbisiana*), cactus (*Pachycereus pringlei)*, taro root crop (talyan) (*Colocasia esculenta)*, papaya *(Carica papaya)*, and water lily *(Nymphaeaceae*) could be harvested. During this phase, the researcher developed the prototype of the enhanced electric energy production technology from living plants, avoiding all moderating factors which might have influence on the experimentation, through trail-and-error method. This phase was also part of the validation process for the developed prototype electrodes on the enhanced electric energy production technology.

b. **Exploratory phase.** In this section, detail procedures of several experimental steps are described. The exploration phase is divided into three parts: selection of electrodes and energy sources, optimization of the harvesting electrode, and investigation on potential applications.

b. 1. Investigation of type of electrodes and energy sources.

Since there are many types of electrodes available, the best pair that produces the highest power output has to be determined prior to any further optimization attempts. In this study, two different electrodes have been selected because they are locally abundant and easily available in the market. They consisted of copper nails (positive conductor) and pure zinc (negative conductor).

Due to the vast variety of plants available locally, only plants with good potential were considered. Aspects of consideration include easy-embedding and stem moisture content. This study selected five different kinds of living plants which were banana, cactus, taro root crop, papaya and water lily. They were selected because they are abundant in the locality as well as their trunk or leaf structure that allow easy embedding by electrodes.

b. 2. Optimization of the harvesting electrode

In the optimization attempts, two aspects were considered in this study, the first being the number of electrodes used and the second was the use of an appropriate conditioning circuit.

It is said that the number of electrodes is analogous to the number of increasing the number of electrodes embedded into the plants, the harvested electrical energy should increase proportionally. Hence, additional pair of electrodes was increase up to five pairs.

The second optimization attempt in this study was use of an electronic circuit to provide conditioning to the harvested power from living plants. This conditioning circuit is aimed to allow electricity to boost until sufficient electricity is used as a "boost converter". To visualize the performance of the energy harvesting system, cellular phone was used as an indicator in terms of its power utilization because it consumes a very small amount of electric power.

b. 3. Investigation on the potential application

As evaluation of this organic energy, potential application on low electrical consumption electronic devices such as cellular phones was investigate. To further investigate these applications, larger testing periods was carried out by allowing the operation mode connected for several minutes to one hour.

Observations was made from time to time to inspect conditions of the harvesting system.

Statistical Treatment of Data

The following statistical tools were used in the analysis of data:

1. The Analysis of Variance (ANOVA) was utilized to determine the electrical energy harvested from different living plants using varied time of testing and length of copper wire.
2. The pairwise mean comparison of treats Least Significant Difference (LSD) Test was employed to find out the significant difference in the harvested electrical energy among living plants.

Ethical Standards

In compliance to the university's policy and guidelines in the conduct of a research, approval was formally sought by the researcher from his adviser to start his study. Likewise, he asked for the consent of the owners of some of the plants he used as energy sources to utilize their plants in the study. They were assured that the plants will not be damage and the study would not harm environment.

Chapter 4

PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

This chapter presents the data collected, their analysis and interpretation. This chapter specifically includes the bio-electrochemical and electrophysiological components of the living plants energy sources, the methods used in harvesting electrical energy, the test of hypothesis, and the implications of the study.

Bio-Electrochemical and Electrophysiological Components of the Living Plants

Table 1 presents the bio-electrochemical and electrophysiological components of the living plants used in the study as electric energy sources, namely; cactus, banana, papaya, taro and water lily. These data were obtained from various sources based on their analysis of the chemical and physiological properties of these plants.

As reflected in the table, the five living plants used as electric energy resources contained varied bio-electrochemical components that convert the energy stored in chemical bonds in living plants into electrical energy through catalytic reactions that occur in these plants. Furthermore, water is the most common electrophysiological component of the living plants. Water is the predominant electrical property of living plants cells and tissues.

Table 1

Bio-electrochemical and Electrophysiological Components of Living Plants

Plants	Bioelectrochemical Components	Electrophysiological Components
Cactus	Fiber, protein and minerals (Ennouri et al,)	Water
Banana	Fat and waxes, pectin hemicellulos, cellulose, lignin, ash (Subagyo & Chafidz, 2018)	Water
Papaya	Papain, and chymopapain (Teixeira de Silva & Nhut, 2007)	Water
Taro	Carbohydrates, protein, fat, crude fiber, ash, vitamins and minerals (Hill, 2015)	Water
Water Lily	Lipid, fiber, protein, ash, carbohydrates, phytochemicals, minerals, vitamins, holocellulos, lignin and tannin (Ezeonu et al, 2017)	Water

The discussions in this part focus on the bio-electrochemical and electrophysiological components of the living plants used as energy sources for this study, namely: Banana (*Musa balbisiana*), Cactus (*Pachycereus pringlei*), Taro

Root Crop (Talyan) (*Colocasia esculenta)*, Papaya *(Carica papaya)* and Water Lily *(Nymphaeaceae*).

<u>Cactus</u>. Cactus (*Pachycereus pringlei)* was one of the living plants utilized for this study as an energy source for the enhanced electric production technology.

Cactus (*Pachycereus pringlei)*, also known as Mexican giant cardoon or elephant cactus, is a species of cactus native to North-western Mexico in the states of Baja California, Baja California Sur, and Sonora. It is commonly known as cardoon, a name derived from Spanish word cardo which means thistle. This plant grows to 20 meters or 60 feet high with a columnar trunk up to 1.5 meter or 4 ½ feet wide. The trunk branches have 11 to 17 ribs covered with many areoles of 20 to 30 grey spines. White flowers bloom from March to June, and then form tan bristly fruits (Ocean Oasis Field Guide, 2019).

The chemical energy generated by cactus plant through photosynthesis has been transformed into electrical energy by developing a novel biofuel cell using cactus through photosynthesis which is the process by which plants convert solar energy into chemical energy. In the presence of visible light, carbon dioxide (CO_2) and water (H_20) are transformed into glucose and O_2 during a complex series of chemical reactions. Researchers developed a biofuel cell that functions using the products of photosynthesis (glucose and O_2) and is made up of two enzyme-modified electrodes. The cell was then inserted in a cactus. Once the electrodes, highly sensitive to O_2 and glucose, had been implanted in the cactus leaf, the scientists succeeded in monitoring the real-time course of photosynthesis in vivo.

They were able to observe an increase in electrical current when a desk lamp was switched on, and a reduction when it was switched off. During these experiments, the scientists were also able to make the first ever observation of the real-time course of glucose levels during photosynthesis (CNRS, 2010).

Furthermore, the researchers showed that a biofuel cell inserted in a cactus leaf could generate power of 9 μW per cm^2. Because this yield was proportional to light intensity, stronger illumination accelerated the production of glucose and O_2 (photosynthesis), so more fuel was available to operate the cell. In the future, this system could ultimately form the basis for a new strategy for the environmentally-friendly and renewable transformation of solar energy into electrical energy.

Banana. The present research used Banana (*Musa balbisiana*) as one of the living plants as an energy source for the enhanced electric production technology. This plant is one of the most important species involved in the origin of cultivated bananas distributed from India to Papua, New Guinea. This species is believed to possess only limited variability. However, recent researches provide that this specie contain a good level of intra-specific variability. Banana (*Musa balbisiana*) is of the wild species (Purabi, et al., 2018).

Moreover, Banana (*Musa balbisiana*) contain flavonoids, polyphenols, tannins, monoterpenoid and sesquiterpenoids, quinones, and saponins. It is also reported as a source of high Potassium, Chloride, Calcium and Carbonate. The seed contains ferulic acid, C16, C18 fatty acid and polyphenols. The root extract contains a calyx arena class of compound which may be responsible for the antioxidant properties, which, in turn, may be partially responsible for its antidiabetogenic and antilipidemic properties. Moreover, an analysis of metal content conducted by Mudiar, et al. (2014) explained that vanadium accumulated in the Musa varieties and at higher rate in M. balbisiena. The Musa balbisiana leaves have rich amount of pentosans and soluble starch along with proteins and chlorophyll.

The peels of Musa balbisiana furnished 100 percent conversion of waste cooking oil into biodiesel. Low cost, renewable heterogeneous catalyst from banana can be developed for fatty acid methyl esters (FAME) production providing a new route for sustainability of fuels. The cause for the excellent conversion is attributed to the strong base sites generated after calcination of the Banana peel. The catalytic activity is largely attributed to the presence of high percentage of potassium in calcined burnt peel ash (CBPA) which facilitated the formation of active species.

Papaya. Another source of living plant for the enhanced electric technology production is Papaya *(Carica papaya)*.

Papaya, known as Carica papaya L. is typical of tropical and sub-tropical regions which require temperature of between 21 and 33^0 C and does not tolerate cold weather which is usually less than 15^0 C (Crane, 2005; Fuggate, et al, 2010; Rivera-Pastrana, et al., 2010; Yadava, Burris & McCrary, 1990, cited in Oliveira & Vitoria, 2011). On the other hand, prolonged dry periods reduce crop output

(Almeida, et al., 2003, cited in Oliveira & Vitoria, 2011). Papaya crops require year-round labor, which has made it an excellent choice from a socio-economic perspective in countries that produce it.

However, the quality of the papayas grown can be compromised by conditions and practices adopted during commercialization (Nunes et al., 2010, cited in Oliveira & Vitoria, 2011). It is an elongated berry of various sizes with a smooth thin skin and a greenish-yellow color (Calegario, Puschmann, Finger, & Costa, 1997; Fagundes & Yamanishi, 2001; Fuggate et al., 2010, cited in Oliveira & Vitoria, 2011). Its flesh is thick with a color ranging from yellow to red and offers a pleasant, sweet, mellow flavor (Devitt, Sawbridge, Holton, Mitchelson, & Dietzgen, 2006; Fuggate et al., 2010, cited in Oliveira & Vitoria, 2011).

Practically every part of the papaya plant is of economic value and its use ranges from nutritional to medicinal. The fruit are popularly used as desert or processed into jam, puree or wine, while the green fruits are cooked as vegetable (Matsuura et al., 2004; Ahmed et al., 2002; OECD, 2005, cited in Nwofia, Ojimelukwe & Eji, 2012). The seeds are medicinally important in the treatment of sickle cell diseases (Imaga et al. 2009, cited in Nwofia, et al., 2012), poisoning related disorder (Okeniyi et al., 2007, cited in Nwofia, et al., 2012). The leaf tea or extract has a reputation as a tumor destroying agent (Walter 2008, cited in Nwofia, et al., 2012). The fresh green tea is an antiseptic whilst the brown, dried pawpaw leaves are best as a tonic and blood purifies (Atta, 1999, cited in Nwofia, et al., 2012). The tea also promotes digestive and aid in treatment of ailment such as chronic indigestion, overweight and obesity, arteriosclerosis, high blood and weakening of the heart (Mantok, 2005, in Nwofia, et al., 2012).

Taro Root Crop. Another of the five living plants used in this study as energy source for the enhanced electric energy production technology is the Taro Root Crop (Talyan) (*Colocasia esculenta).*

Colocasia esculenta is a fast-growing herbaceous plant that originates from a large corm and can grow to 4 feet or 1.5 meter in height. It has been intentionally introduced in many tropical and subtropical regions to be used as a food crop and animal fodder and has subsequently escaped from cultivated areas into natural areas where it becomes invasive. However, in Australia, it is regarded as an environmental weed in Queensland, New South Wales and south-western Western Australia. It is also viewed as an invasive species or aggressive weed in parts of the Caribbean and Americas. *C. esculenta* has several adaptations that aid its survival as a weed. It has the ability to reproduce both sexually by seeds and vegetatively by corms, tubers, and root suckers, and it is adapted to grow in a great variety of substrates and habitats ranging from full sun to deep shaded areas (CABI, 2019).

The *Colocasia esculenta* has the following characteristics: a) proved invasive outside its native range; b) has a broad native range; c) abundant in its native range; d) highly adaptable to different environments; e) is a habitat generalist; f) tolerates, or benefits from, cultivation, browsing pressure, mutilation, fire, and among others; g) tolerant of shade; h) capable of securing and ingesting a wide range of food; i) highly mobile locally; j) benefits from human association (i.e. it is a human commensal); k) long life; l) fast growing; m) has high reproductive potential; and n) reproduces asexually.

Water Lily. The fifth plant used as energy source for the enhanced electric production technology is Water Lily *(Nymphaeaceae)*.

Water lilies known scientifically as Nymphaea lotus which is an aquatic flora that are most abundant in water bodies can potentially be a source of electric energy. The white water lily type is predominant and grows freely in most environments. The plant has wide-round leaves that float flat on the water surface which are greenish in colour, and is thus able to carry out photosynthesis. The white water lilies produce bulbs that develop from the matured flowers (Stephen, et al., 2010).

Moreover, water lilies manifest different biochemical composition such as carbohydrate, protein, lipid and fiber and also some essential element such as sodium, potassium, magnesium, phosphorus, and zinc in addition to anti-oxidant Vitamins (A, C and E). It also shows that there are anti-nutritional factors in the bulb which are low and may be applied to other uses in chemical and pharmaceutical industries. The plant, known in other countries as water hyacinth, has been transformed into a biogas. A study carried out by Almoustapha, et al., 2008 (in Kunutsa & Mufundirwa, 2013) revealed that it is possible to produce biogas from a mixture of water hyacinth and fresh rumen residue. Biogas outflow is related to seasonal variations in temperature. For the same retention time, the total volume of biogas obtained during the warm season is 1.8 times greater than that obtained during the cool season. Several other researches confirmed the possibility of producing biogas from water hyacinth. According to Nijaguna (2002, in Kunutsa & Mufundirwa, 2013), aquatic plants generate high-quality biogas but their salinity of 35-50 parts per 1000 is a serious problem. Water hyacinth produces 20.3 liters of biogas per kg of dry matter. Similarly, Jagadeesh (2012, in Kunutsa & Mufundirwa, 2013) noted that a hectare of water hyacinth can produce enough biogas each day to generate between 90 and 180 cubic meters of methane, equivalent to 3.44 to 6.88GJ of energy production.

Therefore, water hyacinth invasions in lakes can be harnessed for environmental benefit and renewable energy production. Water hyacinth has a very high cellulose content making them a potential renewable energy source. While controlling water hyacinth populations has proven to be beyond the capabilities of local government, using these plants for energy production provides an alternative approach to dealing with this invasive species. Water hyacinth can be used to produce biogas, an energy source that already has been embraced world over. An investigation into the possibility of bio-converting water hyacinth to yield biogas adds value and solves the problem of water hyacinth management as well as gives a solution to the energy and power shortages since people would no longer rely on the expensive LPG nor grid electricity. Biogas will lead to reduced use of fuel wood and diesel generators hence an innovative technology to the reduction of greenhouse gas emissions.

In developing the electrode harvester, pure zinc and copper nails were used as negative and positive conductors, respectfully. These were grinded and placed into the terminal block for groupings with a 5 zinc and 5 copper conductors per group with a parallel connections. A wire terminal was soldered and connected into the groups of electrodes.

Testing of the developed electrode harvester was conducted on each plant by connecting the five electrodes to specific plant part. For banana, the electrodes were embedded to the stalks of the trunk, the thick leaves of cactus, the stalk of the leaves of taro root crop plant, the young fruit stem of papaya, and the stem of cactus leaves. The cactus plant was, however, taken out of the water to avoid possible electrocution before the electrodes were attached to the plant. The collected electrical energy from each plant was stored in a lithium battery and connected to a 1.2 volts LED bulb.

During the actual harvesting of electrical energy from living plants, different lengths of copper wire were used and at varying minutes of test time. The harvested electrical energy were recorded for statistical analysis.

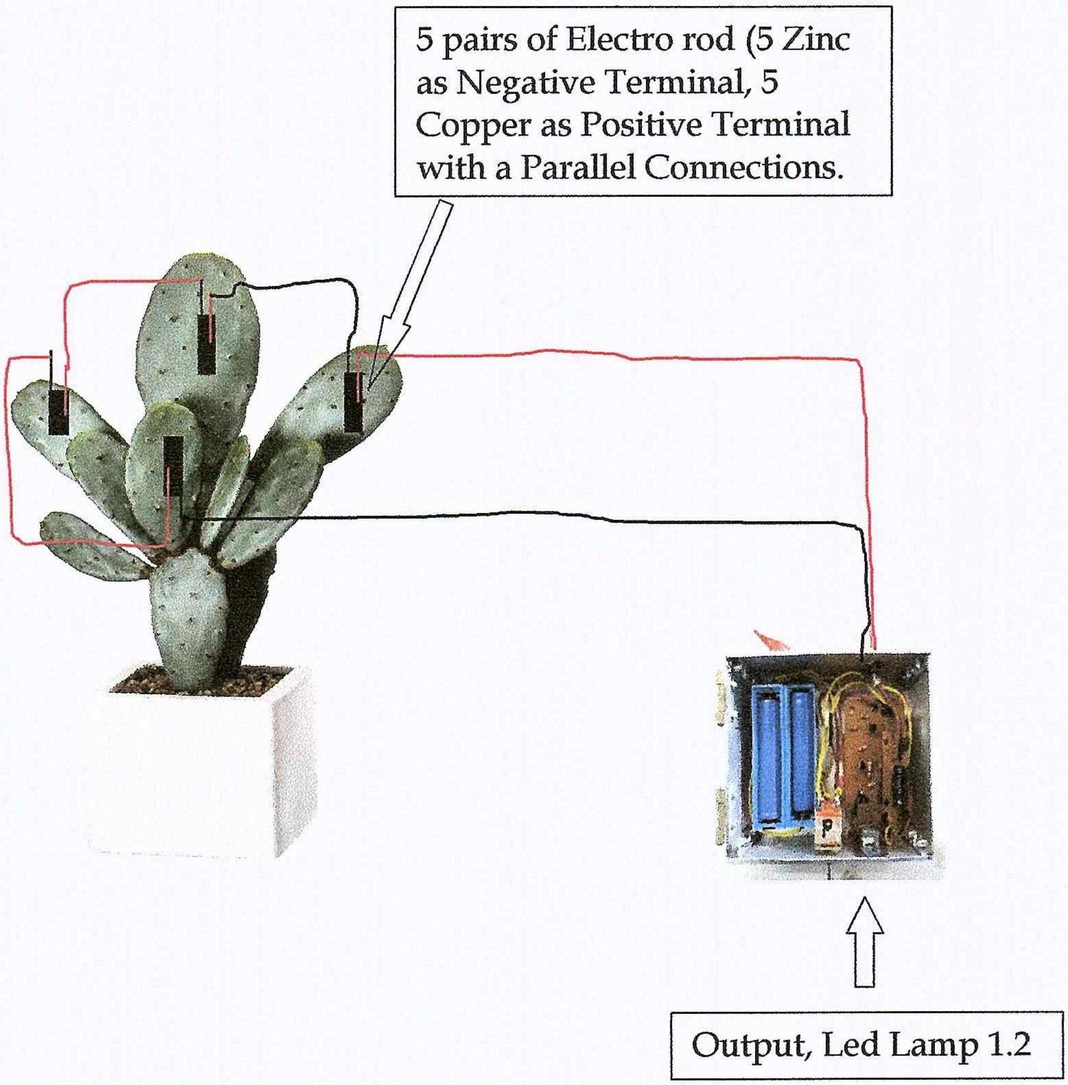


Figure 2. **The Methods in Harvesting Electrical Energy from Plants**

Harvested Electric Energy

The methods used in harvesting electrical energy in the five sampled living plants in this study along types of electrodes used and type of living plants as energy sources are herein presented in this section

The electrical energy from the living plants was harvested using copper wire of different lengths and varied time of harvesting electricity. The electrode harvester was embedded into the trunk/leaf of living plants and cellular phone was utilized as an electronic device to indicate the harvested electrical power from these plants. Different time of testing periods were observations were recorded from time to time to measure which length of copper wire and time of testing can harvest the stronger electricity from these living plants. The succeeding tabular presentations and discussions focus on the electrical energy harvested from the various living plants used in this study using a 203.2 millimeters copper wire.

Table 2 shows the electrical energy harvested from a cactus plant using a 203.2 millimeters copper wire.

Table 2

Harvested Electrical Energy from Cactus Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	1.18	1.68E-08	203.2	0.353	0.009670708	0.01347
10	1.18	1.68E-08	203.2	0.353	0.009670708	0.01347
15	1.18	1.68E-08	203.2	0.353	0.009670708	0.01347
20	1.18	1.68E-08	203.2	0.353	0.009670708	0.01347
25	1.17	1.68E-08	203.2	0.353	0.009670708	0.01324
30	1.18	1.68E-08	203.2	0.353	0.009670708	0.01347
35	1.19	1.68E-08	203.2	0.353	0.009670708	0.01369
40	1.18	1.68E-08	203.2	0.353	0.009670708	0.01347
45	1.18	1.68E-08	203.2	0.353	0.009670708	0.01347
50	1.18	1.68E-08	203.2	0.353	0.009670708	0.01347
55	1.18	1.68E-08	203.2	0.353	0.009670708	0.01347
50	1.18	1.68E-08	203.2	0.353	0.009670708	0.01347
Total	**14.160**	**0.00020**	**2438.4**	**4.236**	**0.116048**	**0.162**
Mean	**1.1800**	**1.68E-05**	**203.2**	**0.353**	**0.009671**	**0.0134**
SD	**0.0043**	**0**	**3E-14**	**5.8E-17**	**0**	**9.6E-05**

The table shows that at various times of testing at five minutes until 60 minutes or one hour, the voltage of electrical energy harvested from cactus plant remained relatively the same at 1.18 volts, except at 25 minutes when there was 1.17 volts. Accordingly, the table also shows that at these times of testing, there was relatively the same wattage drawn at 0.01347. The total electrical energy harvested from cactus was 14.1600. Its mean was 1.1800 with a standard deviation of 0.0043. This implies the presence of electrical energy harvested from the cactus plant using copper wire of 203.2 millimeters. However, the result likewise implied a very week wattage of electrical energy which is way below that required to light a lamp which is approximately 60 watts.

Table 3 shows the electrical energy harvested from a banana using a 203.2 millimeters copper wire.

Table 3

Harvested Electrical Energy from Banana Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	1.05	1.68E-08	203.2	0.000000353	0.009670708	0.01066
10	1.03	1.68E-08	203.2	0.000000353	0.009670708	0.01026
15	1.03	1.68E-08	203.2	0.000000353	0.009670708	0.01026
20	1.02	1.68E-08	203.2	0.000000353	0.009670708	0.01006
25	1.01	1.68E-08	203.2	0.000000353	0.009670708	0.00987
30	1.01	1.68E-08	203.2	0.000000353	0.009670708	0.00987
35	1.01	1.68E-08	203.2	0.000000353	0.009670708	0.00987
40	1.01	1.68E-08	203.2	0.000000353	0.009670708	0.00987
45	1.00	1.68E-08	203.2	0.000000353	0.009670708	0.00967
50	1.00	1.68E-08	203.2	0.000000353	0.009670708	0.00967
55	0.99	1.68E-08	203.2	0.000000353	0.009670708	0.00948
60	0.99	1.68E-08	203.2	0.000000353	0.009670708	0.00948
Total	**12.150**	**0.0002**	**2438.400**	**4.2360**	**0.1160**	**0.1190**
Mean	**1.0125**	**1.68E-08**	**203.200**	**0.3530**	**0.0097**	**0.0099**
SD	**0.0176455**	**0**	**2.969E-14**	**5.79795E-17**	**0**	**0.0003**

The table provides that at various times of testing varied voltage of electrical energy was drawn. At five minutes, there was 1.05 volts and a corresponding 0.01066 watts of electrical energy harvested. However, the table shows a decreasing voltage vis-à-vis wattage of electric energy harvested as the time of harvest is prolonged. At 60 minutes, there was a meagre 0.99 volts and 0.00948 watts, indicating a very weak electrical production. The total harvested electrical energy from banana plant was 12.1500 and the mean was 1.0125 with a standard deviation of 0.0043.

Table 4 shows the electrical energy harvested from a papaya using a 203.2 millimeters-copper wire.

Table 4

Harvested Electrical Energy from Papaya Plant

TIME (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4	R equivalent	
05	1.03	1.68E-08	203.2	0.000000353	0.009670708	0.01026
10	1.02	1.68E-08	203.2	0.000000353	0.009670708	0.01006
15	1.02	1.68E-08	203.2	0.000000353	0.009670708	0.01006
20	1.02	1.68E-08	203.2	0.000000353	0.009670708	0.01006
25	1.02	1.68E-08	203.2	0.000000353	0.009670708	0.01006
30	1.01	1.68E-08	203.2	0.000000353	0.009670708	0.00987
35	1.01	1.68E-08	203.2	0.000000353	0.009670708	0.00987
40	1.01	1.68E-08	203.2	0.000000353	0.009670708	0.00987
45	0.98	1.68E-08	203.2	0.000000353	0.009670708	0.00929
50	0.98	1.68E-08	203.2	0.000000353	0.009670708	0.00929
55	0.98	1.68E-08	203.2	0.000000353	0.009670708	0.00929
60	0.96	1.68E-08	203.2	0.000000353	0.009670708	0.00891
Total	**12.0400**	**0.0002**	**2438.40**	**4.236**	**0.1160**	**0.11690**
Mean	**1.0033**	**0.0000**	**203.20**	**0.353**	**0.0097**	**0.00974**
SD	**0.0223**	**0**	**2.969E-14**	**5.79795E-17**	**0**	**0.00043**

It is also evident in the table that at various times of testing, the electric energy harvested from papaya plant using a 203.2 millimeters copper wire diminished in terms of voltage and wattage. As it is revealed, there was 1.03 volts at five minutes, with a corresponding 0.01026 watts; at 10 minutes, there was 1.02 volts and 0.01006 watts; and at 45 minutes, there was 0.98 volts and 0.00929. Hence, the results show that there was not much electric energy harvested from papaya plant when used with a 203.2 millimeters copper wire. The total harvested electrical energy from papaya plant was 12.0400. Its mean was 1.0033 with a standard deviation of 0.0223.

Table 5 shows the electrical energy harvested from a taro root plant using a 203.2 millimeters copper wire.

Table 5

Harvested Electrical Energy from Taro Root Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V²R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	1.03	1.68E-08	203.2	0.000000353	0.009670708	0.01026
10	1.02	1.68E-08	203.2	0.000000353	0.009670708	0.01006
15	1.02	1.68E-08	203.2	0.000000353	0.009670708	0.01006
20	1.01	1.68E-08	203.2	0.000000353	0.009670708	0.00987
25	0.99	1.68E-08	203.2	0.000000353	0.009670708	0.00948
30	0.98	1.68E-08	203.2	0.000000353	0.009670708	0.00929
35	0.98	1.68E-08	203.2	0.000000353	0.009670708	0.00929
40	0.98	1.68E-08	203.2	0.000000353	0.009670708	0.00929
45	0.98	1.68E-08	203.2	0.000000353	0.009670708	0.00929
50	0.98	1.68E-08	203.2	0.000000353	0.009670708	0.00929
55	0.97	1.68E-08	203.2	0.000000353	0.009670708	0.00910
60	0.97	1.68E-08	203.2	0.000000353	0.009670708	0.00910
Total	**11.9100**	**0.0002**	**2438.40**	**4.2360**	**0.1160**	**0.1144**
Mean	**0.9925**	**0.0000**	**203.20**	**0.3530**	**0.0097**	**0.0095**
SD	**0.0214**	**0**	**2.969E-14**	**5.79795E-17**	**0**	**0.00041**

From the table, it is evident that there was a decreasing amount of electrical energy harvested from a taro root plant as the time of testing is increased. However, the electrical energy harvested is higher at five minutes with 1.03 volts and 0.01026. By contrast, the electrical energy harvested is lower at 60 minutes with 0.97 volts and 0.00910 watts. The harvested electrical energy from taro root plant got the total of 11.9100. The mean was 0.9925 with a standard deviation of 0.0214.

Table 6 shows the electrical energy harvested from water lily plant using a 203.2 millimeters copper wire.

Table 6

Harvested Electrical Energy from Water Lily Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	1.14	1.68E-08	203.2	0.000000353	0.009670708	0.01257
10	1.14	1.68E-08	203.2	0.000000353	0.009670708	0.01257
15	1.14	1.68E-08	203.2	0.000000353	0.009670708	0.01257
20	1.13	1.68E-08	203.2	0.000000353	0.009670708	0.01235
25	1.13	1.68E-08	203.2	0.000000353	0.009670708	0.01235
30	1.12	1.68E-08	203.2	0.000000353	0.009670708	0.01213
35	1.12	1.68E-08	203.2	0.000000353	0.009670708	0.01213
40	1.12	1.68E-08	203.2	0.000000353	0.009670708	0.01213
45	1.10	1.68E-08	203.2	0.000000353	0.009670708	0.01170
50	1.10	1.68E-08	203.2	0.000000353	0.009670708	0.01170
55	1.09	1.68E-08	203.2	0.000000353	0.009670708	0.01149
60	1.09	1.68E-08	203.2	0.000000353	0.009670708	0.01149
Total	**13.4200**	**0.0002**	**2438.4000**	**4.2360**	**0.1160**	**0.1452**
Mean	**1.1183**	**0.0000**	**203.2000**	**0.3530**	**0.0097**	**0.0121**
SD	**0.0190**	**0**	**2.969E-14**	**5.79795E-17**	**0**	**0.0004**

Although the amount of electrical energy produced from water lily decreased as the time of testing was increased, it nonetheless registered the presence of an electrical energy. At five minutes, there was 1.14 volts and a corresponding 0.01257 watts; at 10 minutes, there was a similar voltage of 1.14, and a similar wattage of 0.01257, indicated as the highest electrical energy produced. However, after 20 minutes, the voltage and wattage of electrical energy decreased to 1.13 and 0.01235, respectively. By 60 minutes, the voltage was 1.09 and the wattage was 0.01149. The total harvested electrical energy from water lily was 13.4200. The mean was 1.1183 with a standard deviation of 0.0190.

The succeeding tabular presentations and discussions focus on the electrical energy harvested from the various living plants used in this study using a 406.4 millimeters copper wire.

Table 7 shows the electrical energy harvested from cactus plant using a 406.4 millimeters copper wire.

Table 7

Harvested Electrical Energy from Cactus Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	1.17	1.68E-08	0.4064	0.000000353	0.019341416	0.02648
10	1.16	1.68E-08	0.4064	0.000000353	0.019341416	0.02603
15	1.16	1.68E-08	0.4064	0.000000353	0.019341416	0.02603
20	1.16	1.68E-08	0.4064	0.000000353	0.019341416	0.02603
25	1.17	1.68E-08	0.4064	0.000000353	0.019341416	0.02648
30	1.17	1.68E-08	0.4064	0.000000353	0.019341416	0.02648
35	1.17	1.68E-08	0.4064	0.000000353	0.019341416	0.02648
40	1.18	1.68E-08	0.4064	0.000000353	0.019341416	0.02693
45	1.18	1.68E-08	0.4064	0.000000353	0.019341416	0.02693
50	1.18	1.68E-08	0.4064	0.000000353	0.019341416	0.02693
55	1.19	1.68E-08	0.4064	0.000000353	0.019341416	0.02739
60	1.19	1.68E-08	0.4064	0.000000353	0.019341416	0.02739
Total	**14.080**	**0.0002**	**4876.80**	**4.2360**	**0.2321**	**0.31958**
Mean	**1.1733**	**0.0000**	**406.40**	**0.3530**	**0.0193**	**0.02664**
SD	**0.0107**	**0**	**5.937E-14**	**5.79795E-17**	**0**	**0.00049**

The table shows an increasing pattern of electrical energy harvested from cactus plant using a 406.4 millimeters copper wire at various times of testing. At five minutes, for instance, there was a 1.17 volts and 0.02648 watts; at 10 minutes, there was 1.16 volts and 0.02603; at 25 minutes, there was 1.17 volts and 0.02648; and at 60 minutes, there was 1.19 volts and 0.02739 watts. These data indicate that there was a relatively higher voltage and wattage of electrical energy harvested from cactus plant using a 406.4 millimeters copper wire. The total harvested electrical energy from cactus plant was 14.0800 and the man was 1.1733 with a standard deviation of 0.0107.

Table 8 shows the electrical energy harvested from banana plant using a 406.4 millimeters copper wire.

As regards to the banana plant as an energy source, the table shows a decreasing pattern in terms of voltage and wattage when tested at various times. At five minutes, for instance, the electrical energy harvested was higher at 1.02 volts and 0.02012 watts; and at 10 minutes, there was 1.01 volts and 0.01973 watts. Meanwhile, at 30 minutes, there was 0.99 volts and 0.01896 watts. The total electrical energy harvested from banana plant was 11.9100. Its mean was 0.9925 with a standard deviation of 0.0196.

Table 8

Harvested Electrical Energy from Banana Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	1.02	1.68E-08	406.4	0.000000353	0.019341416	0.02012
10	1.01	1.68E-08	406.4	0.000000353	0.019341416	0.01973
15	1.02	1.68E-08	406.4	0.000000353	0.019341416	0.02012
20	1.01	1.68E-08	406.4	0.000000353	0.019341416	0.01973
25	1.00	1.68E-08	406.4	0.000000353	0.019341416	0.01934
30	0.99	1.68E-08	406.4	0.000000353	0.019341416	0.01896
35	0.99	1.68E-08	406.4	0.000000353	0.019341416	0.01896
40	0.98	1.68E-08	406.4	0.000000353	0.019341416	0.01858
45	0.98	1.68E-08	406.4	0.000000353	0.019341416	0.01858
50	0.98	1.68E-08	406.4	0.000000353	0.019341416	0.01858
55	0.97	1.68E-08	406.4	0.000000353	0.019341416	0.01820
60	0.96	1.68E-08	406.4	0.000000353	0.019341416	0.01783
Total	**11.910**	**0.0002**	**4876.80**	**4.236**	**0.2321**	**0.2287**
Mean	**0.9925**	**1.68E-08**	**406.40**	**0.353**	**0.01934**	**0.01906083**
SD	**0.0196**	**0**	**5.937E-14**	**5.79795E-17**	**0**	**0.0007**

Table 9 shows the electrical energy harvested from papaya plant using a 406.4 millimeters copper wire.

As regards to the papaya plant, the table shows that the amount of electrical energy harvested was highest at five minute-testing time at 1.03 volts and 0.02052 watts. However, at 15 minutes, there was a decrease in voltage and wattage at 1.02 volts and 0.02012 watts, respectively. Finally, there was a drop to 0.98 volts and 0.01858 watts at 60 minutes time of testing. This indicated a decreasing trend of electrical energy harvested from a papaya plant as the time of testing was increased. The total harvested electrical energy was 12.1400. The mean was 1.0117 with a standard deviation of 0.0175.

Table 9

Harvested Electrical Energy from Papaya Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	1.03	1.68E-08	406.4	0.000000353	0.019341416	0.02052
10	1.03	1.68E-08	406.4	0.000000353	0.019341416	0.02052
15	1.02	1.68E-08	406.4	0.000000353	0.019341416	0.02012
20	1.02	1.68E-08	406.4	0.000000353	0.019341416	0.02012
25	1.03	1.68E-08	406.4	0.000000353	0.019341416	0.02052
30	1.02	1.68E-08	406.4	0.000000353	0.019341416	0.02012
35	1.02	1.68E-08	406.4	0.000000353	0.019341416	0.02012
40	1.01	1.68E-08	406.4	0.000000353	0.019341416	0.01973
45	1.00	1.68E-08	406.4	0.000000353	0.019341416	0.01934
50	0.99	1.68E-08	406.4	0.000000353	0.019341416	0.01896
55	0.99	1.68E-08	406.4	0.000000353	0.019341416	0.01896
60	0.98	1.68E-08	406.4	0.000000353	0.019341416	0.01858
Total	**12.140**	**0.0002**	**4876.800**	**4.236**	**0.232**	**0.2376**
Mean	**1.012**	**1.68E-08**	**406.40**	**0.353**	**0.0193**	**0.0198**
SD	**0.018**	**0**	**5.937E-14**	**5.79795E-17**	**0**	**0.0007**

Table 10 shows the electrical energy harvested from taro root plant using a 406.4 millimeters copper wire.

The table shows that there was a noticeable decrease in the amount of electrical energy harvested from the taro root plant as per the voltage and wattage that resulted using a 406.4 millimeters copper wire when the time was varied. At five minutes, there was 1.04 volts and 0.02092 watts. At 10 minutes, there was 1.03 volts and 0.02052 watts until about 15 minutes. Yet, at 60 minutes, there was 1.01

volts and 0.01973 watts. The results denoted a weaker electrical energy harvested from taro root plant using a 406.4 millimeters copper wire. The total harvested electrical energy was 12.3000. The mean was 1.0250 with a standard deviation of 0.0117.

Table 10

Harvested Electrical Energy from Taro Root Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	1.04	1.68E-08	406.4	0.000000353	0.019341416	0.02092
10	1.03	1.68E-08	406.4	0.000000353	0.019341416	0.02052
15	1.03	1.68E-08	406.4	0.000000353	0.019341416	0.02052
20	1.04	1.68E-08	406.4	0.000000353	0.019341416	0.02092
25	1.04	1.68E-08	406.4	0.000000353	0.019341416	0.02092
30	1.02	1.68E-08	406.4	0.000000353	0.019341416	0.02012
35	1.03	1.68E-08	406.4	0.000000353	0.019341416	0.02052
40	1.02	1.68E-08	406.4	0.000000353	0.019341416	0.02012
45	1.01	1.68E-08	406.4	0.000000353	0.019341416	0.01973
50	1.01	1.68E-08	406.4	0.000000353	0.019341416	0.01973
55	1.02	1.68E-08	406.4	0.000000353	0.019341416	0.02012
60	1.01	1.68E-08	406.4	0.000000353	0.019341416	0.01973
Total	**12.3000**	**0.0002**	**4876.80**	**4.2360**	**0.2321**	**0.2439**
Mean	**1.0250**	**1.68E-08**	**406.40**	**0.3530**	**0.0193**	**0.0203**
SD	**0.0117**	**0**	**5.937E-14**	**5.79795E-17**	**0**	**0.0005**

Table 11 shows the electrical energy harvested from water lily plant using a 406.4 millimeters copper wire.

The table provides that there was a 1.15 volts and 0.03837 watts of electrical energy harvested from water lily plant using a 406.4 millimeters copper wire at five minutes testing time; and the same was obtained at 10 minutes.

Table 11

Harvested Electrical Energy from Water Lily Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd2/4 (mm2)	R equivalent	
05	1.15	1.68E-08	406.4	0.000000353	0.029012125	0.03837
10	1.15	1.68E-08	406.4	0.000000353	0.029012125	0.03837
15	1.16	1.68E-08	406.4	0.000000353	0.029012125	0.03904
20	1.16	1.68E-08	406.4	0.000000353	0.029012125	0.03904
25	1.16	1.68E-08	406.4	0.000000353	0.029012125	0.03904
30	1.17	1.68E-08	406.4	0.000000353	0.029012125	0.03971
35	1.17	1.68E-08	406.4	0.000000353	0.029012125	0.03971
40	1.16	1.68E-08	406.4	0.000000353	0.029012125	0.03904
45	1.17	1.68E-08	406.4	0.000000353	0.029012125	0.03971
50	1.18	1.68E-08	406.4	0.000000353	0.029012125	0.04040
55	1.18	1.68E-08	406.4	0.000000353	0.029012125	0.04040
60	1.18	1.68E-08	406.4	0.000000353	0.029012125	0.04040
Total	**13.9900**	**0.0002**	**4876.8000**	**4.2360**	**0.2321**	**0.4732**
Mean	**1.1658**	**1.68E-08**	**406.4**	**0.353**	**0.029012125**	**0.0394**
SD	**0.0108**	**0**	**5.937E-14**	**5.79795E-17**	**0**	**0.00073**

As regards to the water lily plant, there was an increasing trend in the electrical energy harvested as the time of testing was increase. As a matter of fact, it was highest at 60 minutes as there was 1.18 volts and 0.04040 watts. The findings indicated that the water lily plant harvested the most energy using the enhanced electrical production technology using a 406.4 millimeters copper wire. The harvested total electrical energy was 13.9900. Its mean was 1.1658 with a standard deviation of 0.0108.

The succeeding tabular presentations and discussions focus on the electrical energy harvested from the various living plants used in this study using a 609.6 millimeters copper wire.

Table 12 shows the electrical energy harvested from cactus plant using a 609.6 millimeters copper wire.

Using a 609.6 millimeters copper wire, the table shows an increasing trend of harvested electrical energy from cactus plant at various testing times. At five minutes, there was 1.12 volts and 0.03639 watts; at 10 minutes, there was 1.13 volts and 0.03705 watts. At 60 minutes, there was a 1.20 volts and 0.04178 watts. The total harvested electrical energy was 13.8600. The mean was 1.1550 with a standard deviation of 0.0254

This indicated a higher amount of electrical energy produced from cactus plant at various time of testing using a 609.6 millimeters copper wire.

Table 12

Harvested Electrical Energy from Cactus Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd2/4 (mm2)	R equivalent	
05	1.12	1.68E-08	609.6	0.000000353	0.029012125	0.03639
10	1.13	1.68E-08	609.6	0.000000353	0.029012125	0.03705
15	1.13	1.68E-08	609.6	0.000000353	0.029012125	0.03705
20	1.14	1.68E-08	609.6	0.000000353	0.029012125	0.03770
25	1.14	1.68E-08	609.6	0.000000353	0.029012125	0.03770
30	1.15	1.68E-08	609.6	0.000000353	0.029012125	0.03837
35	1.15	1.68E-08	609.6	0.000000353	0.029012125	0.03837
40	1.16	1.68E-08	609.6	0.000000353	0.029012125	0.03904
45	1.17	1.68E-08	609.6	0.000000353	0.029012125	0.03971
50	1.18	1.68E-08	609.6	0.000000353	0.029012125	0.04040
55	1.19	1.68E-08	609.6	0.000000353	0.029012125	0.04108
60	1.20	1.68E-08	609.6	0.000000353	0.029012125	0.04178
Total	**13.860**	**0.0002**	**7315.20**	**4.2360**	**0.34810**	**0.4646**
Mean	**1.1550**	**1.68E-08**	**609.60**	**0.3530**	**0.0290**	**0.0387**
SD	**0.0254**	**0**	**1.187E-13**	**5.79795E-17**	**0**	**0.0017**

Table 13 shows the electrical energy harvested from banana plant using a 609.6 millimeters copper wire.

With a 609.6 millimeters copper wire, the table shows a decreasing amount of electrical energy harvested from banana plant based on the voltage and wattage harvested. At five minutes, for instance, there was 1.09 volts and 0.03447 watts; at 10 minutes, there was 1.08 volts and 0.03260 watts. At 60 minutes, there was 1.02 volts and 0.03018 watts. The findings revealed a lower and weaker electrical energy harvested from banana plant using the enhanced electrical production technology with a 609.6 millimeters copper wire. The harvested electrical energy got the total of 12.5500. The mean was 1.0458 with a standard deviation of 0.0227.

Table 13

Harvested Electrical Energy from Banana Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	1.09	1.68E-08	609.6	0.000000353	0.029012125	0.03447
10	1.08	1.68E-08	609.6	0.000000353	0.029012125	0.03384
15	1.06	1.68E-08	609.6	0.000000353	0.029012125	0.03260
20	1.06	1.68E-08	609.6	0.000000353	0.029012125	0.03260
25	1.05	1.68E-08	609.6	0.000000353	0.029012125	0.03199
30	1.04	1.68E-08	609.6	0.000000353	0.029012125	0.03138
35	1.04	1.68E-08	609.6	0.000000353	0.029012125	0.03138
40	1.03	1.68E-08	609.6	0.000000353	0.029012125	0.03078
45	1.03	1.68E-08	609.6	0.000000353	0.029012125	0.03078
50	1.03	1.68E-08	609.6	0.000000353	0.029012125	0.03078
55	1.02	1.68E-08	609.6	0.000000353	0.029012125	0.03018
60	1.02	1.68E-08	609.6	0.000000353	0.029012125	0.03018
Total	**12.5500**	**0.0002**	**7315.20**	**4.2360**	**0.34810**	**0.3810**
Mean	**1.0458**	**1.68E-08**	**609.6**	**0.353**	**0.029012125**	**0.03175**
SD	**0.0227**	**0**	**1.187E-13**	**5.79795E-17**	**0**	**0.0014**

Table 14 shows the electrical energy harvested from papaya plant using a 609.6 millimeters copper wire.

The table reveals a low and decreasing electrical energy harvested from papaya plant using a 609.6 millimeters copper wire when done at varying times of testing. At five minutes, there was 0.97 volts and 0.02730 watts. At 15 minutes, there was a 0.95 volts and 0.02618 watts; at 30 minutes, there was a 0.94 volts and 0.02564 watts; and at 60 minutes, there was a 0.88 volts and 0.02247 watts. The findings indicated a weak electrical energy harvested from papaya plant using a 609.6 millimeters copper wire. The total harvested electrical energy was 11.1200. Its mean was 0.9267 with a standard deviation of 0.0311

Table 14

Harvested Electrical Energy from Papaya Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	0.97	1.68E-08	609.6	0.000000353	0.029012125	0.02730
10	0.97	1.68E-08	609.6	0.000000353	0.029012125	0.02730
15	0.95	1.68E-08	609.6	0.000000353	0.029012125	0.02618
20	0.94	1.68E-08	609.6	0.000000353	0.029012125	0.02564
25	0.94	1.68E-08	609.6	0.000000353	0.029012125	0.02564
30	0.94	1.68E-08	609.6	0.000000353	0.029012125	0.02564
35	0.93	1.68E-08	609.6	0.000000353	0.029012125	0.02509
40	0.92	1.68E-08	609.6	0.000000353	0.029012125	0.02456
45	0.90	1.68E-08	609.6	0.000000353	0.029012125	0.02350
50	0.90	1.68E-08	609.6	0.000000353	0.029012125	0.02350
55	0.88	1.68E-08	609.6	0.000000353	0.029012125	0.02247
60	0.88	1.68E-08	609.6	0.000000353	0.029012125	0.02247
Total	**11.1200**	**0.0002**	**7315.20**	**4.2360**	**0.34810**	**0.2993**
Mean	**0.9267**	**1.68E-08**	**609.6**	**0.353**	**0.029012125**	**0.025**
SD	**0.0311**	**0**	**1.187E-13**	**5.79795E-17**	**0**	**0.0017**

Table 15 shows the electrical energy harvested from taro root plant using a 609.6 millimeters copper wire.

As it is provided in the table, there was a 0.98 volts of electrical energy harvested from taro root crop and a 0.02786 watts when done using a 609.6 millimeters copper wire at five minutes time of testing. As the time of testing progressed until 15 minutes, the electrical energy harvested started to decrease to 0.97 volts and 0.02730 watts; at 20 minutes, there was 0.93 volts and 0.02509 watts; and at 45 minutes, there was 0.94 volts and 0.02564 watts. Lastly, at 60 minutes, there was a 0.91 volts and 0.02402 watts.

Table 15

Harvested Electrical Energy from Taro Root Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd2/4 (mm2)	R equivalent	
05	0.98	1.68E-08	609.6	0.000000353	0.029012125	0.02786
10	0.98	1.68E-08	609.6	0.000000353	0.029012125	0.02786
15	0.97	1.68E-08	609.6	0.000000353	0.029012125	0.02730
20	0.93	1.68E-08	609.6	0.000000353	0.029012125	0.02509
25	0.91	1.68E-08	609.6	0.000000353	0.029012125	0.02402
30	0.90	1.68E-08	609.6	0.000000353	0.029012125	0.02350
35	0.90	1.68E-08	609.6	0.000000353	0.029012125	0.02350
40	0.95	1.68E-08	609.6	0.000000353	0.029012125	0.02618
45	0.94	1.68E-08	609.6	0.000000353	0.029012125	0.02564
50	0.94	1.68E-08	609.6	0.000000353	0.029012125	0.02564
55	0.91	1.68E-08	609.6	0.000000353	0.029012125	0.02402
60	0.91	1.68E-08	609.6	0.000000353	0.029012125	0.02402
Total	**11.2200**	**0.0002**	**7315.20**	**4.2360**	**0.34810**	**0.3046**
Mean	**0.9350**	**1.68E-08**	**609.6**	**0.353**	**0.029012125**	**0.0254**
SD	**0.0300**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0016**

The trend indicated a decreasing amount of electrical energy harvested from taro root crop using a 609.6 millimeters copper wire when done at different times. The total harvested electrical energy was 11.2200. The mean was 0.9350 with a standard deviation of 0.0300.

Table 16 shows the electrical energy harvested from water lily plant using a 609.6 millimeters copper wire.

The table shows that there was a 1.11 volts and 0.03575 watts of electrical energy harvested from water lily using a 609.6 millimeters copper wire at five minutes. This was followed by 1.12 volts and 0.03639 watts electrical energy harvested at 10 minutes. The table likewise shows a decreasing trend in the electrical energy harvested in terms of voltage and wattage as the time of testing increased. At 60 minutes, for instance, there was 1.05 volts and 0.03199 watts of electrical energy. The harvested total electrical energy was 12.9300. The mean was 1.0775 with a standard deviation of 0.0249.

The succeeding tabular presentations and discussions focus on the electrical energy harvested from the various living plants used in this study using an 812.8 millimeters copper wire.

Table 16

Harvested Electrical Energy from Water Lily Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd2/4 (mm2)	R equivalent	
05	1.11	1.68E-08	609.6	0.000000353	0.029012125	0.03575
10	1.12	1.68E-08	609.6	0.000000353	0.029012125	0.03639
15	1.10	1.68E-08	609.6	0.000000353	0.029012125	0.03510
20	1.10	1.68E-08	609.6	0.000000353	0.029012125	0.03510
25	1.08	1.68E-08	609.6	0.000000353	0.029012125	0.03384
30	1.07	1.68E-08	609.6	0.000000353	0.029012125	0.03322
35	1.08	1.68E-08	609.6	0.000000353	0.029012125	0.03384
40	1.06	1.68E-08	609.6	0.000000353	0.029012125	0.03260
45	1.05	1.68E-08	609.6	0.000000353	0.029012125	0.03199
50	1.05	1.68E-08	609.6	0.000000353	0.029012125	0.03199
55	1.06	1.68E-08	609.6	0.000000353	0.029012125	0.03260
60	1.05	1.68E-08	609.6	0.000000353	0.029012125	0.03199
Total	**12.9300**	**0.0002**	**7315.20**	**4.2360**	**0.3481**	**0.4044**
Mean	**1.0775**	**1.68E-08**	**609.6**	**0.353**	**0.0290**	**0.034**
SD	**0.0249**	**0**	**1.187E-13**	**5.79795E-17**	**0**	**0.0016**

Table 17 shows the electrical energy harvested from cactus plant using an 812.8 millimeters copper wire.

The table presents that there is 1.02 volts electrical energy harvested from cactus plant using an 812.8 millimeters copper wire at five minutes test time and there was a corresponding 0.04026 watts. This was followed by 1.01 volts and 0.03947 watts of electrical energy harvested from an 812.8 millimeters copper wire at 10 minutes. As the time of testing progressed, the amount of electrical energy harvested decreased. In fact, at 60 minutes, there was a 0.92 volts and 0.03275 watts of electrical energy harvested from cactus plant. The harvested electrical energy obtained the total of 11.4900. The mean was 0.9575 with a standard deviation of 0.0393.

Table 17

Electrical Energy from Cactus Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	1.02	1.68E-08	812.8	3.53E-07	0.038692351	0.04026
10	1.01	1.68E-08	812.8	3.53E-07	0.038692351	0.03947
15	1.00	1.68E-08	812.8	3.53E-07	0.038692351	0.03869
20	0.97	1.68E-08	812.8	3.53E-07	0.038692351	0.03641
25	0.97	1.68E-08	812.8	3.53E-07	0.038692351	0.03641
30	0.97	1.68E-08	812.8	3.53E-07	0.038692351	0.03641
35	0.96	1.68E-08	812.8	3.53E-07	0.038692351	0.03566
40	0.92	1.68E-08	812.8	3.53E-07	0.038692351	0.03275
45	0.93	1.68E-08	812.8	3.53E-07	0.038692351	0.03347
50	0.91	1.68E-08	812.8	3.53E-07	0.038692351	0.03204
55	0.91	1.68E-08	812.8	3.53E-07	0.038692351	0.03204
60	0.92	1.68E-08	812.8	3.53E-07	0.038692351	0.03275
Total	**11.490**	**0.0002**	**9753.60**	**4.2360**	**0.46430**	**0.4264**
Mean	**0.9575**	**1.68E-08**	**812.8**	**0.353**	**0.038692351**	**0.03553**
SD	**0.0393**	**0**	**1.187E-13**	**5.79795E-17**	**7.24744E-18**	**0.00293**

Table 18 shows the electrical energy harvested from banana plant using an 812.8 millimeters copper wire.

As it is presented in the table, there was 0.58 volts and 0.01302 watts of electrical energy harvested from banana plant using an 812.8 millimeters copper wire. This was followed by 0.54 volts or 0.01128 watts electrical energy harvested from the enhanced electrical energy production technology using an 812.8 millimeters copper wire at 10 minutes test time; 0.53 volts and 0.01087 volts at 15 minutes test time; and 0.47 volts and 0.00855 watts electric energy at 60 minutes test time. The findings indicated not only a decreasing amount of electric energy but also a weak electric energy harvested. The electrical energy harvested had the total of 6.0100. Its mean was 0.5008 with a standard deviation of 0.0348.

Table 18

Harvested Electrical Energy from Banana Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V²R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	0.58	1.68E-08	812.8	3.53E-07	0.038692351	0.01302
10	0.54	1.68E-08	812.8	3.53E-07	0.038692351	0.01128
15	0.53	1.68E-08	812.8	3.53E-07	0.038692351	0.01087
20	0.52	1.68E-08	812.8	3.53E-07	0.038692351	0.01046
25	0.49	1.68E-08	812.8	3.53E-07	0.038692351	0.00929
30	0.49	1.68E-08	812.8	3.53E-07	0.038692351	0.00929
35	0.49	1.68E-08	812.8	3.53E-07	0.038692351	0.00929
40	0.49	1.68E-08	812.8	3.53E-07	0.038692351	0.00929
45	0.47	1.68E-08	812.8	3.53E-07	0.038692351	0.00855
50	0.47	1.68E-08	812.8	3.53E-07	0.038692351	0.00855
55	0.47	1.68E-08	812.8	3.53E-07	0.038692351	0.00855
60	0.47	1.68E-08	812.8	3.53E-07	0.038692351	0.00855
Total	**6.0100**	**0.0002**	**9753.6**	**4.236**	**0.4643**	**0.117**
Mean	**0.5008**	**1.68E-08**	**812.8**	**0.353**	**0.0387**	**0.0097**
SD	**0.0348**	**0**	**1.187E-13**	**5.79795E-17**	**7.24744E-18**	**0.00139**

Table 19 shows the electrical energy harvested from papaya plant using an 812.8 millimeters copper wire.

As it is revealed in the table, there is 0.62 volts of electrical energy harvested from papaya plant using an 812.8 millimeters copper wire; and a 0.01487 watts of electrical energy at five minutes test time. This is followed by 0.59 volts and 0.01347 watts at 15 minutes; and 0.50 volts and 0.00967 watts at 60 minutes. The data showed a decreasing electrical energy harvested from papaya plant using an 812.8 millimeters copper wire. The total harvested electrical energy was 6.6600. The mean was 0.5550 with a standard deviation of 0.0410.

Table 19

Harvested Electrical Energy from Papaya Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	0.62	1.68E-08	812.8	3.53E-07	0.038692351	0.01487
10	0.62	1.68E-08	812.8	3.53E-07	0.038692351	0.01487
15	0.59	1.68E-08	812.8	3.53E-07	0.038692351	0.01347
20	0.57	1.68E-08	812.8	3.53E-07	0.038692351	0.01257
25	0.57	1.68E-08	812.8	3.53E-07	0.038692351	0.01257
30	0.56	1.68E-08	812.8	3.53E-07	0.038692351	0.01213
35	0.54	1.68E-08	812.8	3.53E-07	0.038692351	0.01128
40	0.54	1.68E-08	812.8	3.53E-07	0.038692351	0.01128
45	0.53	1.68E-08	812.8	3.53E-07	0.038692351	0.01087
50	0.52	1.68E-08	812.8	3.53E-07	0.038692351	0.01046
55	0.50	1.68E-08	812.8	3.53E-07	0.038692351	0.00967
60	0.50	1.68E-08	812.8	3.53E-07	0.038692351	0.00967
Total	**6.6600**	**0.0002**	**9753.60**	**4.2360**	**0.46430**	**0.1437**
Mean	**0.5550**	**1.68E-08**	**812.80**	**0.3530**	**0.0387**	**0.0120**
SD	**0.0410**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0018**

Table 20 shows the electrical energy harvested from taro root plant using an 812.8 millimeters copper wire.

The table reveals a decreasing amount of electric energy harvested from taro root plant using an 812.8 millimeters copper wire at varying test time. At five minutes, for instance, the electrical energy harvested is higher at 0.82 volts and 0.02602 watts, whereas at 60 minutes, there was 0.61 volts and 0.01440 watts harvested electrical energy. The total harvested electrical energy was 8.1200. Its mean was 0.6767 with a standard deviation of 0.0623.

Table 20

Harvested Electrical Energy from Taro Root Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				$P_{losses}= V^2R$ Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd²/4 (mm2)	R equivalent	
05	0.82	1.68E-08	812.8	3.53E-07	0.038692351	0.02602
10	0.72	1.68E-08	812.8	3.53E-07	0.038692351	0.02006
15	0.74	1.68E-08	812.8	3.53E-07	0.038692351	0.02119
20	0.71	1.68E-08	812.8	3.53E-07	0.038692351	0.01950
25	0.68	1.68E-08	812.8	3.53E-07	0.038692351	0.01789
30	0.67	1.68E-08	812.8	3.53E-07	0.038692351	0.01737
35	0.66	1.68E-08	812.8	3.53E-07	0.038692351	0.01685
40	0.64	1.68E-08	812.8	3.53E-07	0.038692351	0.01585
45	0.64	1.68E-08	812.8	3.53E-07	0.038692351	0.01585
50	0.62	1.68E-08	812.8	3.53E-07	0.038692351	0.01487
55	0.61	1.68E-08	812.8	3.53E-07	0.038692351	0.01440
60	0.61	1.68E-08	812.8	3.53E-07	0.038692351	0.01440
Total	**8.1200**	**0.0002**	**9753.60**	**4.2360**	**0.46430**	**0.2143**
Mean	**0.6767**	**1.68E-08**	**812.8**	**0.353**	**0.0387**	**0.018**
SD	**0.0623**	**0**	**1.187E-13**	**5.79795E-17**	**7.24744E-18**	**0.0034**

Table 21 shows the electrical energy harvested from water lily plant using an 812.8 millimeters copper wire.

As it is indicated in the table, there is a relatively higher electrical energy harvested from water lily plants using an 812.8 millimeters copper wire. Yet, the amount of electrical energy harvested was decreasing as the test time was varied from five minutes to 60 minutes.

At five minutes, there was a 1.04 volts and 0.04185 watts of electrical energy. This was followed by 1.02 volts and 0.04026 watts at 15 minutes; 1.01 volts and

0.03947 watts at 20 minutes; and at 30 minutes, there was 0.98 volts and 0.03716 watts.

Table 21

Harvested Electrical Energy from Water Lily Plant

Time (mins)	Voltage (V)	Resistance R =ρL/A (Ω)				P_{losses}= V^2R Watts (W)
		ρ (Ω.m)	Length (mm)	A=πd2/4 (mm2)	R equivalent	
05	1.04	1.68E-08	812.8	3.53E-07	0.038692351	0.04185
10	1.04	1.68E-08	812.8	3.53E-07	0.038692351	0.04185
15	1.02	1.68E-08	812.8	3.53E-07	0.038692351	0.04026
20	1.01	1.68E-08	812.8	3.53E-07	0.038692351	0.03947
25	0.98	1.68E-08	812.8	3.53E-07	0.038692351	0.03716
30	0.98	1.68E-08	812.8	3.53E-07	0.038692351	0.03716
35	0.96	1.68E-08	812.8	3.53E-07	0.038692351	0.03566
40	0.96	1.68E-08	812.8	3.53E-07	0.038692351	0.03566
45	0.94	1.68E-08	812.8	3.53E-07	0.038692351	0.03419
50	0.93	1.68E-08	812.8	3.53E-07	0.038692351	0.03347
55	0.93	1.68E-08	812.8	3.53E-07	0.038692351	0.03347
60	0.91	1.68E-08	812.8	3.53E-07	0.038692351	0.03204
Total	**11.7000**	**0.0002**	**9753.6000**	**4.2360**	**0.46430**	**0.4422**
Mean	**0.9750**	**1.68E-08**	**812.8000**	**0.3530**	**0.0387**	**0.0369**
SD	**0.0444**	**0**	**1.187E-13**	**5.79795E-17**	**7.24744E-18**	**0.00337**

Lastly, there was a 0.91 volts and 0.03204 watts electrical energy harvested using an 812.8 millimeters copper wire at 60 minutes test time. The total harvested electrical energy was 11.7000. The mean was 0.9750 with a standard deviation of 0.04444.

<u>**Comparison of the Harvested Electrical Energy among the Living Plants**</u>

The tabular and graphical presentations and discussions in this part focus on the differences in the harvested electrical energy among the living plants, namely: cactus, banana, papaya, taro root, and water lily as to their wattage and voltage and power capacities.

The table 22 presents the electrical energy output (V) harvested from cactus using different lengths of copper wire at varying test times.

As shown in the table, the total electrical energy output harvested from cactus at 5 minutes to 1 hour test time using 203.2 mm of copper wire was 3.0900. The mean energy output was 0.2575 with a standard deviation of 0.0260. When using 406.4 mm of copper wire, the total electrical energy output was 3.0300 and the mean was 0.2525 with a standard deviation of 0.0234.

Table 22

Output of Electrical Energy (V) Harvested from Cactus with Different Lengths of Copper Wire.

Time (mins)	Length of Copper Wire (mm)			
	203.2	406.4	609.6	812.8
05	0.21	0.21	0.21	0.17
10	0.22	0.22	0.22	0.18
15	0.23	0.23	0.23	0.18
20	0.25	0.24	0.23	0.18
25	0.25	0.25	0.24	0.19
30	0.26	0.25	0.25	0.19
35	0.27	0.26	0.25	0.19
40	0.27	0.27	0.26	0.19
45	0.28	0.27	0.26	0.19
50	0.28	0.27	0.27	0.19
55	0.28	0.28	0.27	0.19
60	0.29	0.28	0.27	0.19
Total	**3.0900**	**3.0300**	**2.9600**	**2.0600**
Mean	**0.2575**	**0.2525**	**0.2467**	**0.1933**
SD	**0.0260**	**0.0234**	**0.0206**	**0.0067**

Meanwhile, the total electrical energy output when using 609.6 mm of copper wire was 2.9600 and its mean was 0.2467 with a standard deviation of 0.0206. For 812.8 mm of copper wire, the total electrical energy output was 2.0600. Its mean was 0.1719 with a standard deviation of 0.0162.

The result clearly showed that the longer is the time test, the greater is the harvested electrical energy from cactus regardless of the length of the copper wire used. However, the shorter is the length of copper wire used, the greater is the harvested electrical energy from cactus.

Table 23 indicates the output of electrical energy (V) harvested from banana with different lengths of copper wire at varying number of minutes of test time.

The table shows that the total electrical energy harvested from banana using 203.2 mm of copper wire at varying test time was 2.6200 and the output mean was 0.2183 with a standard deviation of 0.0072. However, the total electrical energy output of 2.4500 was noted in both 406.4 mm and 609.6 mm lengths of copper wire with same output mean of 0.2042. But their standard deviation were 0.100 and 0.0079, respectively. For 812.8 mm of copper wire, the total harvested electrical energy was 2.1600. Its mean output was 0.1800 with a standard deviation of 0.0000.

The table shows that the total electrical energy harvested from banana using 203.2 mm of copper wire at varying test time was 2.6200 and the output mean was 0.2183 with a standard deviation of 0.0072.

Table 23

Differences in the Electrical Energy Harvested from Living Plants Using 812.8 mm Copper Wire

Time (mins)	Plants									
	Cactus		Banana		Papaya		Taro		Water Lily	
	In (V)	Out (V)	In (V)	Out (V)	In (V)	Out (V)	In (V)	Out (V)	In (V)	Out (V)
05	1.02	0.17	0.58	0.18	0.62	0.17	0.82	0.18	1.04	0.18
10	1.01	0.18	0.54	0.18	0.62	0.18	0.72	0.18	1.04	0.18
15	1.00	0.18	0.53	0.18	0.59	0.18	0.74	0.18	1.02	0.18
20	0.97	0.18	0.52	0.18	0.57	0.18	0.71	0.18	1.01	0.18
25	0.97	0.19	0.49	0.18	0.57	0.17	0.68	0.18	0.98	0.18
30	0.97	0.19	0.49	0.18	0.56	0.18	0.67	0.18	0.98	0.18
35	0.96	0.19	0.49	0.18	0.54	0.18	0.66	0.18	0.96	0.18
40	0.92	0.19	0.49	0.18	0.54	0.18	0.64	0.18	0.96	0.19
45	0.93	0.19	0.47	0.18	0.53	0.18	0.64	0.18	0.94	0.19
50	0.91	0.19	0.47	0.18	0.52	0.17	0.62	0.18	0.93	0.19
55	0.91	0.19	0.47	0.18	0.50	0.18	0.61	0.18	0.93	0.19
60	0.92	0.19	0.47	0.18	0.50	0.18	0.61	0.18	0.91	0.20
Total	**11.49**	**2.23**	**6.01**	**2.16**	**6.66**	**2.13**	**8.12**	**2.16**	**11.70**	**2.22**
Mean	**0.96**	**0.19**	**0.50**	**0.18**	**0.56**	**0.18**	**0.68**	**0.18**	**0.98**	**0.19**
SD	**0.04**	**0.007**	**0.03**	**0.00**	**0.04**	**0.005**	**0.062**	**0.00**	**0.04**	**0.007**

The table shows that the cactus and water lily harvested higher electrical energy using the enhanced electrical energy production technology using an 812.8 millimetres copper wire. However, there was a decreasing amount of harvested energy at varying testing times. For cactus, the table shows that there was 1.02 volts inputs and 0.17 volts outputs at five minutes; followed by 1.01 volts inputs and 0.18 volts outputs at 10 minutes testing time; and 1.00 volts inputs and 0.18 volts outputs at 15 minutes testing time. On the other hand, for water lily, there was a 1.04 volts inputs and 0.18 volts outputs at five minutes testing time; followed by 1.02 volts and 0.18 volts outputs at 15 minutes testing time. The graphical presentations of the above-mentioned data are shown in Figures 8 and 9.

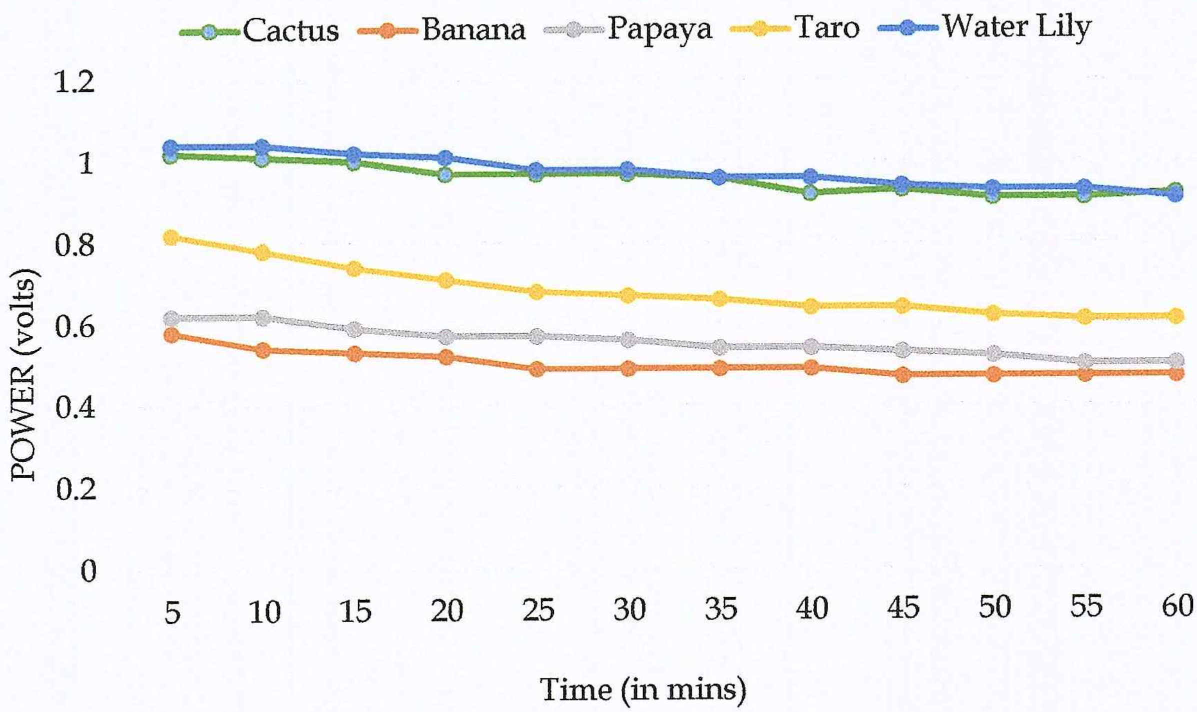


Figure 3. Electrical Energy Harvested from Cactus, Banana, and Papaya using the Enhanced Electrical Production Technology using 812.8 millimeters Copper Wire

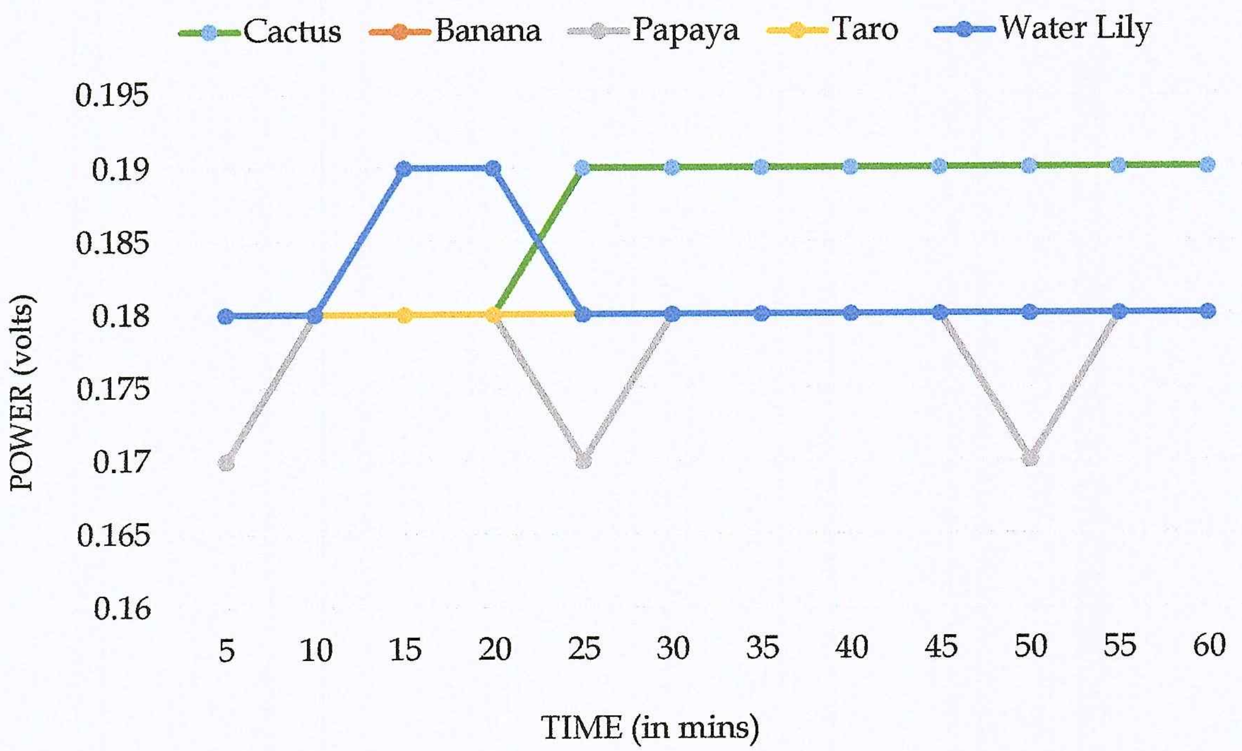


Figure 4. Electrical Energy Harvested from Cactus, Banana, Papaya, Taro Root and Water Lily using the Enhanced Electrical Production Technology using 812.8 millimeters Copper Wire

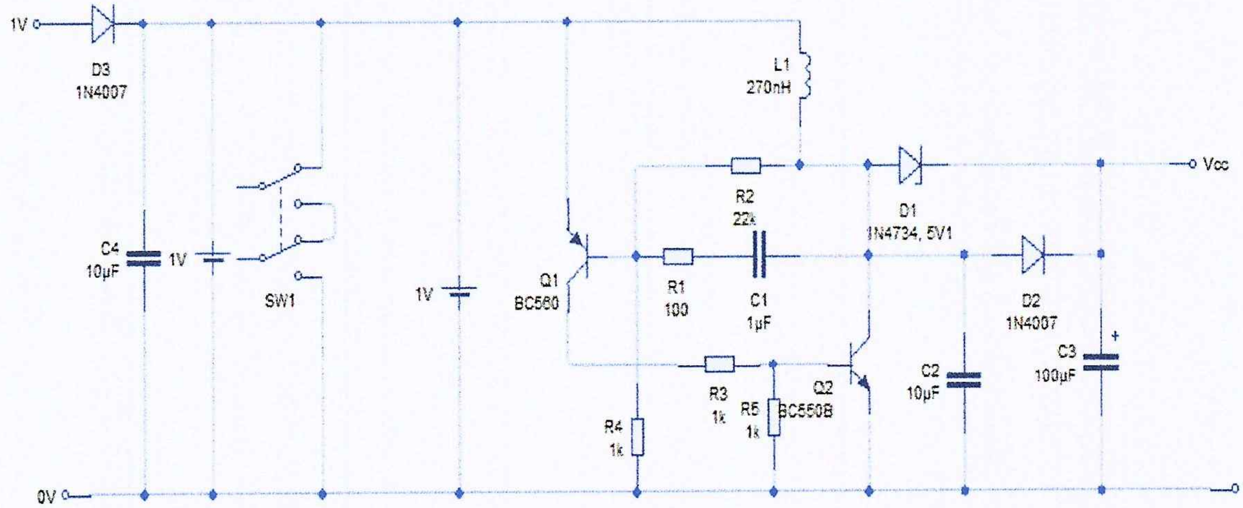


Figure 5. Diagram of the Enhanced Electric Energy Production Harvester from Living Plants

This circuit converts the 1.2V or 1.5V input voltage up to the 5V. While it can apply the current of 10 mA. To begin with, apply the current to the circuit. The current flow through coil (L1). Because transistor (Q1) does not get the bias current. Then, Transistor (Q2) starts working with the current from 1.2V. It flows the emitter to base of (Q2) through resistor (R5) to full circuit. The (Q2) provides current out of the collector to be biased current to T1. The T1 is conducting boost converter but the working of T1 makes the voltage across. Now the L1 connects to the ground like a normal collector-emitter is lower. When the results of this work as a switch. Then, (Q2) has quality conducting. (R3) and capacitor (C2) make this system is high performance. Also, (Q1) is good working. The coil (L1) pass the high current until the maximum in linear form. After that, the polarity of the voltage across (L1) changes. The advantage of this circuit. The voltage drop across it is low. While the transistor switch on the voltage across between collector-emitter is only 0.2V. But it can supply the high current. Transistor (Q2) need to make the base voltage lower than the emitter by around 0.65V. This is being doen by putting a pull down resistor R5 while emitter is connected to 1.2V. This is the base current to T1 to turn it on also. With (Q1) starts to conduct, it provides additional base current path to (Q2) from 0V through (R3) and (C2) to make its collector further conduct. T1 continues to conduct until it could no longer support the current rise of L1 due to its HFE so it will suddenly turn off. This process is repeated over and over which is called an oscillation and thus the circuit is an oscillator.

Test of Significant Difference in the Harvested Electrical Energy among Living Plants

The difference in the harvested electrical energy among the five selected living plants using among the five selected living plants using the enhanced electric energy production technology was measured in terms of wattage and voltage. Table 26 shows the ANOVA of the significant difference in the harvested electrical energy from living plants in terms of wattage.

Table 24

Significant Difference in the Harvested Electrical Energy from Living Plants in Terms of Wattage

Treatment	Wattage							
	203.2 mm	**	406.4 mm	**	609.6 mm	**	812.8 mm	**
Cactus	0.0134	a	0.0263	a	0.0379	a	0.0364	b
Banana	0.0099	c	0.0193	c	0.032	c	0.0097	e
Papaya	0.0100	c	0.0203	b	0.0256	d	0.0124	d
Taro	0.0095	d	0.0207	b	0.0242	e	0.0183	c
Water Lily	0.0123	b	0.0262	a	0.0341	b	0.0379	a

** = Highly significant at 1%
Means with the same letter are not significantly different.

As shown in the table 27, there is no significant difference in the wattage of the harvested electrical energy between banana and papaya when using 203.2 mm of connecting wire from the electric energy production technology to the living plants as indicated by theirs means of 0.0099 and 0.0100, respectfully. However, highly significant differences were noted in the different living plants. The highly significant differences were evidenced by their means of 0.0134 for cactus, 0.0095 for taro, 0.0123 for water lily, and the previously mentioned weighted means of papaya and banana.

For the connecting wire of 406.4 mm, no significant difference in the harvested electrical energy was noted between cactus (0.0263) and water lily (0.0262), and between papaya (0.203) and taro (0.0207). But a highly significant difference existed between banana (0.0193) and the other living plants used as sources of electrical energy. Likewise, highly significant difference were found between water lily and papaya / taro.

Therefore, the null hypothesis in the significant difference in the harvested electrical energy among living plants is rejected in terms of wattage. This implies that living plants vary in the wattage of electrical energy that can be harvested from them using the electric energy production technology.

The next table presents the ANOVA of the significant difference in the harvested electrical energy from living plants in terms of voltage. The same lengths of connecting wires were used in the measurement of the voltage of harvested electrical energy from these plants.

Table 25

Significant Difference in the Harvested Electrical Energy from Living Plants in terms of Voltage

Treatment	Voltage							
	203.2 mm	**	406.4 mm	**	609.6 mm	**	812.8 mm	**
Cactus	1.18	a	1.17	a	1.14	a	0.9700	b
Banana	1.01	c	1.00	c	1.05	c	0.5000	e
Papaya	1.02	c	1.02	b	0.94	d	0.5667	d
Taro	0.99	d	1.03	b	0.91	e	0.6867	c
Water Lily	1.13	b	1.16	a	1.08	b	0.9900	a

** = Highly significant at 1%
Means with the same letter are not significantly different

From the foregoing table, no significant difference was found between banana and papaya in the harvested electrical with 203.2 mm of connecting wire as shown by their respective means of 1.01 and 1.02 in terms of voltage. On the contrary, highly significant difference were noted in the voltage of the harvested electrical energy between and among the different plants. This was indicated by their means of 1.18 for cactus, 0.99 for taro, 1.13 for water lily and the already mentioned weighted means of banana and papaya.

Similarly when using the connecting wire of 496.4 mm, no significant differences were observed between cactus (1.17) and water lily (1.16) and between papaya (1.02) and taro (1.16) in the voltage of the harvested electrical energy from them. On the other hand, highly significant differences were found in the voltage of the harvested electrical energy from banana (1.00) when compared to the other living plants used as electrical energy sources. Likewise, highly significant differences were noted between papaya and the other plants (cactus, banana and water lily), and between taro and the other living plants.

Meanwhile, highly significant differences were found in the voltage of the harvested electrical energy among the five living plants when using both 609.6 mm and 813.0 mm of connecting wires from the electric energy production technology to these plants. These highly significant differences were shown by the variations in their respective weighted means.

Hence, the null hypothesis on the significant difference in the harvested electrical energy among living plants is rejected in terms of voltage. This implies that living plants can provide different voltage of harvested electrical energy when using the electric energy production technology.

From the foregoing table, no significant difference was found in the harvested electrical with 203.2 mm of connecting wire as shown from the data above.

Hence, the null hypothesis on the significant difference in the harvested electrical energy among living plants is rejected in terms of voltage. This implies that living plants can provide different voltage of harvested electrical energy when using the electric energy production technology.

Implications of the Study

Based on the specific findings of the study, the following implications are drawn:

1. Cactus and water lily derived the most electrical energy using the enhanced electrical production technology at varying testing times and length of copper wires used. Thus, of the five living plants used for this study, only these two plants can be potential sources of electrical energy.

2. The water property of cactus and water lily made them potential sources of electrical energy using the enhanced electrical production technology. Thus, the water property of the other living plants, namely: banana, papaya, and taro root crops, are not sufficient enough to produce electrical energy which can be harvested or extracted by said enhanced technology.

3. The electrical energy harvested by the enhanced electrical production technology worked well with shorter length of wire and at shorter testing time. Hence, further enhancement strategies can be used to harvest more electrical energy from living plants even with longer length of wire and longer testing time.

Chapter 5

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary of the major findings of the study, the conclusions and recommendations derived therefrom.

Summary of Findings

Based on the specific problems of the study, the following are the salient findings:

1. The living plants used in this study, cactus, banana, papaya, taro root and water lily, have bio-electrochemical and electrophysiological components, most important is the water component of the plants.

2. According to the types of electrodes used, the 203.2 millimeters copper wire harvested electrical energy with the use of the enhanced electrical production technology.

3. According to the types of living plants, cactus and water lily produced electrical energy when harvested by the enhanced electrical production technology.

4. The electrical technology produced from the living plants are higher in cactus and water lily.

There are highly significant differences in the wattage and voltage of the harvested electrical energy from cactus, banana, papaya, taro and water lily.

Conclusions

From the salient findings of this study, the conclusions were drawn as follow:

1. Cactus and water lily are potential sources of electrical energy as found their water component out in the study.

2. The electrical energy harvested from living plants is dependent on their water content. The higher their water content, the more electrical energy can be harvested from them.

Recommendations

Considering the conclusions made in this study, the recommendations are herein provided as follow:

1. Other living plants with similar characteristics as cactus and water lily must be considered as sources of electrical energy using the enhanced electrical harvest.

2. Similar researches may be conducted in the future to validate the results of the present research.

3. Another similar study may be conducted using other kinds of watery plants as electrical energy sources, utilizing the enhanced electric energy production technology.

BIBLIOGRAPHY

Boulianne, C. (24 April 2017). *How is Wattage Calculated?* Retrieved https://sciencing.com/wattage-calculated-5130879.html.

CABI. *Invasive Species Compendium: Colocasia esculenta (Taro)*. Retrieved July 12, 2019, https://www.cabi.org/isc/datasheet/17221.

Cesena, E.A.M. (2012). Real Options *Theory Applied to Renewable Energy Generation Projects Planning.* Unpublished Dissertation, University of Manchester. Retrieved https://www.escholar.manchester.ac.uk.

Chee, F. et al. (2016). Data Acquisition System for In Sity Monitoring of Chemoelectrical Potential in Living Plant Fuel Cells. *Journal of Biophysics,* Volume 2016, Article ID 6108056, pp 1-7. http://dx.doi.org/10.1155/2016/6108056.

Choo, Y.Y. & Dayou, J. A Method to Harvest Electrical Energy from Living Plants. *Journal of Science and Technology.*

Choo, Y.Y., Dayou, J. & Surugau, N. (2014). Origin of Weak Electrical Energy Production from Living Plants. I*nternational Journal of Renewable Energy Research,* Vol 4, No 1.

Converting Bananas to Electricity. (23 August 2000). *The University of Queensland News.* Retrieved https://www.uq.edu.au, May 17, 2018.

Dayou, Jedol (2013), a method to Harvest Electrical Energy from Living Plants. University of Malaysia, Sabah. Accessed on October 30, 2019 at https://www.researchgate.net.2471…PDF

Department of Energy. (2016). 2016 Philippine Power Situation Report. Retrieved https://www.doe.gov.ph, May 19, 2018.

Delos Santos, A. (2018). *Renewable Energy in the Philippines.* Department of Energy. Retrieved http://www.irena.org, May 19, 2018.

Ennouri, M. et al. (2014), Chemical Composition and Antibacterial Activity of Cactus Pear, Retrieved at https://www.ncbi.nen.nih.gov.pub…

Ezeonu, Stephen C. et al. (2017). Chemical Composition of Water Lily Bulbs, Retrieved at https://researchgate.net.3189…pdf

Flexer, V. & Mano, N. (26 January 2010). From Dynamic Measurements of Photosynthesis in a Living Plant to sunlight Transformation into Electricity. Anal Chem, 82(4), pp 1444-1449. DOI: 10.1021/ac902537h. Retrieved https://pubs.acs.org/doi/full/10.1021/ac902537h, May 19, 2018.

Helder, M., Chen, W.S., Vander Harst, E.J.M., & Strik, D.P.B.T.B. (17 January 2013). Electricity Production with Living Plants on a Green Roof: Environmental Performance of the Plant-Microbial Fuel Cell. Biofpr, Volume 7, Issue 1, pp 52-64. Retrieved https://onlinelibrary.wiley.com/doi/pdf/10.1002/bbb.1373.

Helder, M. (November 2012). *Design Criteria for the Plant-Microbial Fuel Cell: Electricity Generation with Living Plants - from Lab to Application.* Dissertation, Wageningen University, Wageningen, The Netherlands.

Hill, Albent F. (2015). The Nomenclature of the Taro and its Varieties, Botanical Museum Leaflets, Harvard University, 7(7), p. 113.

Gilbert, D., et al. (2006). Sap Flow and Daily Electric Potential Variations in a Tree Trunk. *Plant Science,* 171, pp 672-584. Retrieved https://pdfs.semanticscholar.org.

Goto, Y., et al. (April 2015). Enhancement of Electricity Production by Graphene Oxide Soil Microbial Fuel Cells and Plant Microbial Fuel Cells. *Frontiers in Bioengineering and Biotechnology,* Volume 3, Article 42. doi: 10.3389/fbioe.2015.00042. Retrieved https://www.ncbi.nlm.nih.gov.

Gowtham, R. and Shunmug Bundar, K. U. (2013). generating Current from Plants: Plant -e Technology, Panimalar Institute of Technology Chennai, Accessed on October 30, 2019 at www.irindia.in.pdf

Guruvich, L.A. *Electrophysiology of Woody Plants.* Retrieved http://cdnintechopen.com.

Kaplan, D. (2017). *This Lamp Lights Up with Power from Living Plants. Green Matters.* Retrieved http://www.greenmatters.com.

Kardile, A. V. (2017). Unveiling the New Source of Green Energy - A Plant, *IJEDR,* Volume 5, Issue 2.

Kunutsa, T. & Mufundirwa, A. (May 2013). Biogas Production from Water Hyacinth Case of Lake Chivero - Zimbabwe: A Review. *International Journal of Recent Technology and Engineering,* Volume 2, Issue 2.

Live Science. (15 September 2009) Electricity Harvested from Trees. Live Science. Retrieved https://www.livescience.com.

Moqsud, M. Azizul, Gazali, Tun Ahmad, Omine, Kiyoshi, & Nakata, Yukio. (2017). Green Electricity by Water Plants in Organic Soil and Marine Sediment through Microbial Fuel Cell. *Energy Sources, Part a: Recovery, Utilization, and Environmental Effects,* Volume 39, Issue 2, Retrieved https://www.tandfonline.com/doi/abs/10.1080/15567036.2016.1159263?src=recsys&journalCode=ueso20.

Mudiar, R.H., et al. (2014). Comparative Analysis of Physicochemical Parameters and Bioaccumulation between Musa Species. J bio EnvScie, 5(4), pp 31-34. In Purabi, D. et al. A Review on Musa. *International Journal of Pharmaceutical Science Invention,* Volume 7, Issue 7, Series 1, pp 14-17.

Nwofia, G.E., Ojimelukwe, P., & Eji, C. (March 2012). Chemical Composition of Leaves, Fruit Pulp and Seeds in some Carica papaya (L) morphotypes. *Int. J. med. Arom Plants,* Vol 2, No 1, pp 200-206. Retrieved at https://www.researchgate.net.

Nobel, Park S. (2005). *Plant Physiology,* 3rd Edition, (New York: Elsevier Academic press)

Ocean Oasis Field Guide. *Pachycereus pringlei: Elephant Cactus, Cardon, Cardon pelon.* Retrieved July 12, 2019, https://www.sdnhm.org/oceanoasis/fieldguide/pach-pri.html.

Oliveira, J.G. & Vitoria, A.P. (2011). Papaya: Nutritional and Pharmacological Characterization, and Quality Loss Due to Physiological Disorders: An Overview. *Food Research International,* 44, pp 1306-1313. Retrieved www.elsevier.com

Purabi, D., et al. (July 2018). A Review on Musa. International Journal of Pharmaceutical Science Invention, Volume 7, Issue 7, Series 1, pp 14-17. (Online). Retrieved July 12, 2019, http://www.ijpsi.org/Papers/Vol7(7)/C0707011417.pdf.

Richey, R.C., Klein, J.D. & Nelson, W.A. (18 February 2015). Development Research: Studies of Instructional Design and Development. Retrieved https://www.researchgate.net/publication/263963734_Development_research/download.

Rozendal, R. A. and Rabaey.K. (2008), Trends in Biotechnology, 2nd Edition, (Armsterdam: Elsevier Publishing, Inc.).

Shields, Patrocoa (2013). A Playbook for Research Methods: Integrating Conceptual Frameworks and Project Management, (Stillwater, Ok: New Ferums Press).

Spin-Off: Electricity from Living Plants. (May 29, 2017). Retrieved https://www.wur.nl May 29, 2017.

Stephen, E.C., Adenisi, A.K., Chinedu, I. & Samuel, A.A. (2017). Chemical Composition of Water Lily (Nymphaea lotus) Bulbs. *American Journal of Food Science and Nutrition,* 4(2), pp 7-12. Retrieved http://www.aascit.org/journal/ajfsn.

Subagyo, A. and Chafidz, A. (2018). Banana Pseudo Sten Fiber: Preparation, Characteristics and Applications, Retrieved at https://www.intechopen.com>banana

Teixeira de Silva, J. and Nhut P. T. (2007). Papaya: Biology and Biotechnology, Retrieved at https://www.researchgate.net>2835…pdf

Thompson, S. (28 February 2017). *Scientists Create Electric Circuits inside Plants.* The Conversation. Retrieved http://theconversation.com

Tock, J.Y., et al. (2010). Banana Biomass as Potential Renewable Energy Resource: *A Malaysian case Study. Renewable and Sustainable Energy Reviews,* 14, pp 798-805. Retrieved www.elsevier.com/locate/rser.

United Nations Advisory Group on Energy and Climate Change. (28 April 2010). Energy for a Sustainable Future: Reports and Recommendations. UN Advisory Group on Energy and Climate Change, New York. Retrieved http://www.un.org/millenniumgolas/pdf/AGECCsummaryreport[1].pdf.

"What is Voltage?" (2019). Retrieved https://www.fluke.com/en-ph/learn/best-practices/measurement-basics/electricity/what-is-voltage.

Westser, K., Dieleman, K., Buisman, C. & Strik, D. (31 May 2016). Electricity from Wetlands: Tubular Plant Microbial Fuels with Silicone Gad-Diffusion Biacathodes. *Applied Energy,* 185, pp 642-649. https://doi.org/10.1016/j.apenergy.2016.10.122

World Nuclear Association. Electricity Generation - What are the Options? Retrieved http://www.world-nuclear.org.

A P P E N D I C E S

APPENDIX A

Pictures of the Materials Needed in Making Electrodes Used in the Study

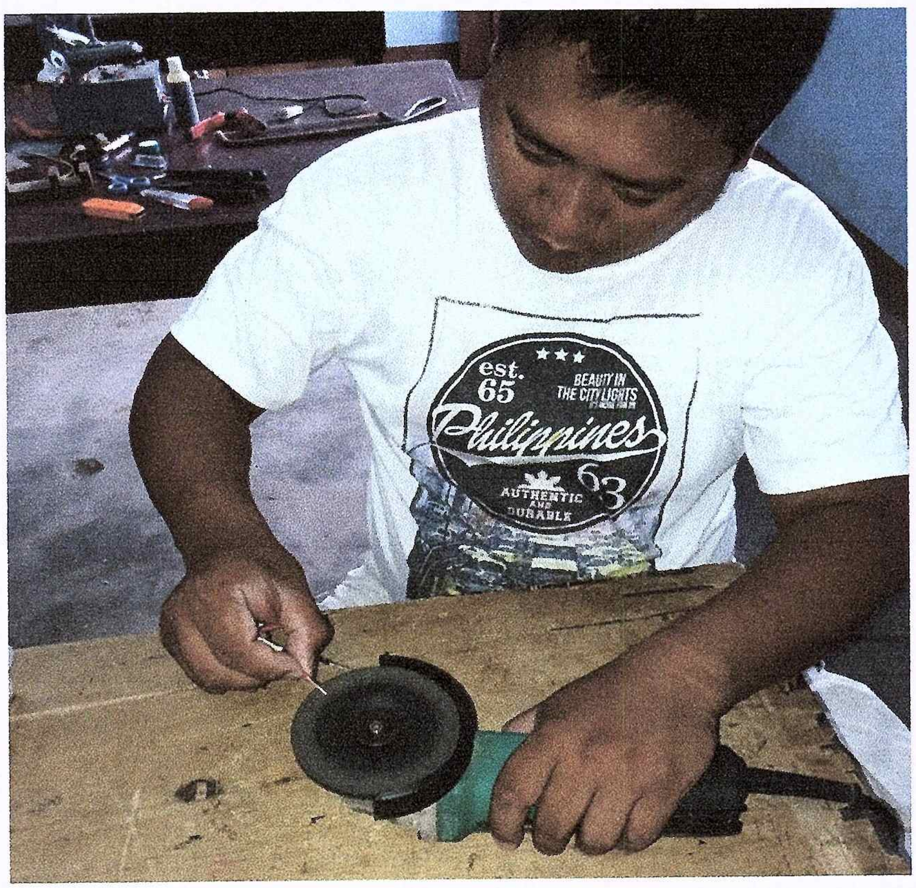
Pure zinc used as a negative conductor

Copper nails used as positive conductor

APPENDIX B

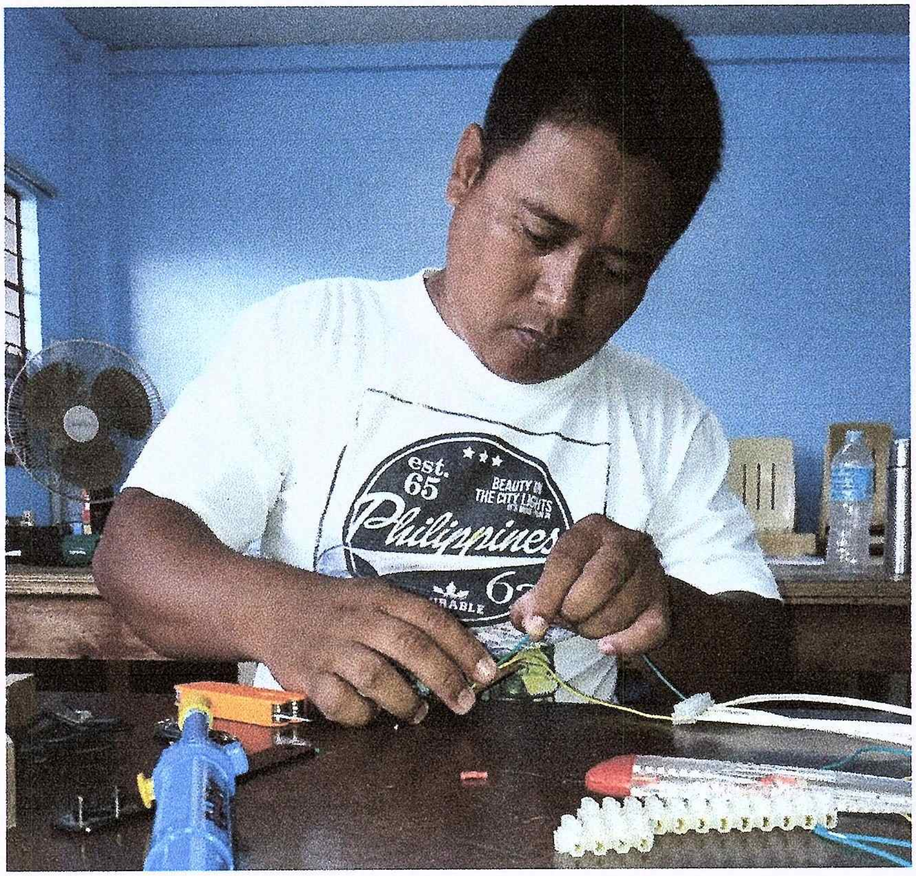
Steps in Making the Electrodes

Step 1:



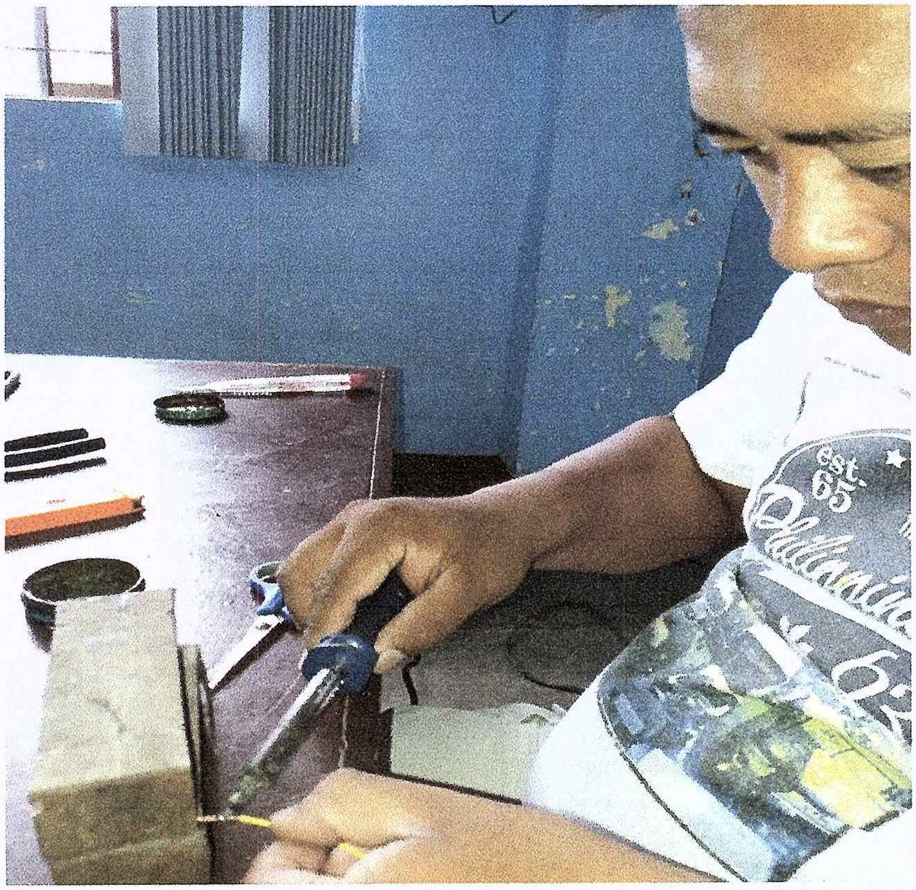
Copper nails and zinc were grinded to form a small of match sticks.

Step 2:

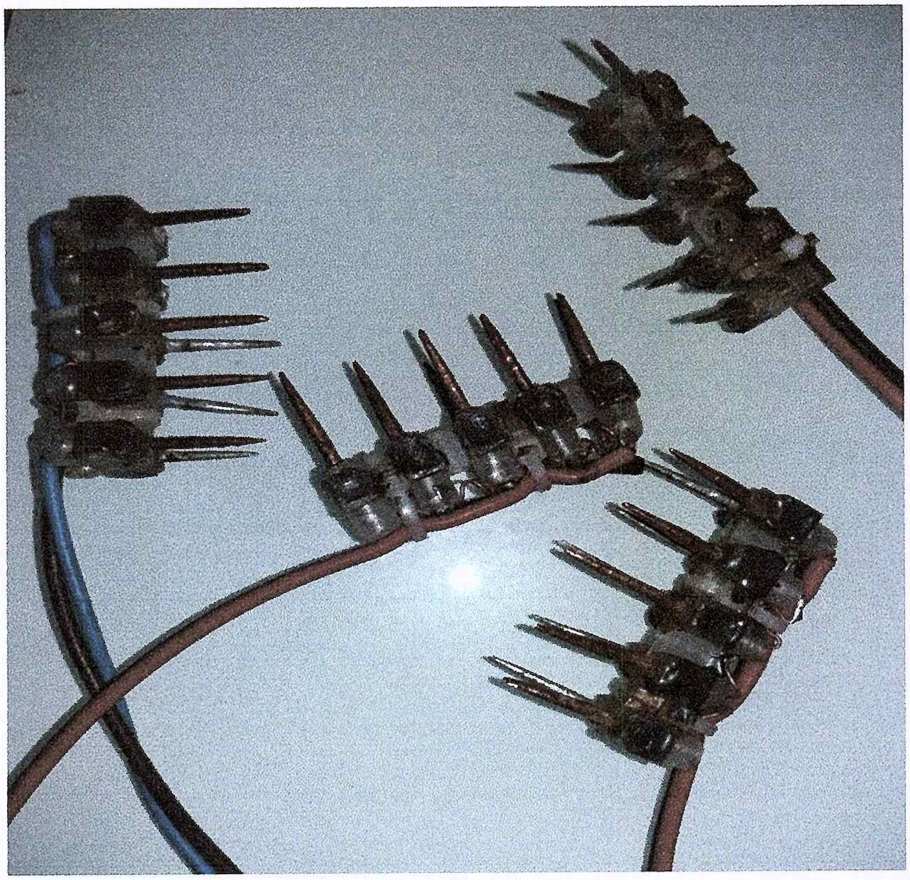


The grinded copper nails and zinc were put into the terminal block for the groupings with five (5) zinc and five (5) copper conductors per group with parallel connections.

Step 3:



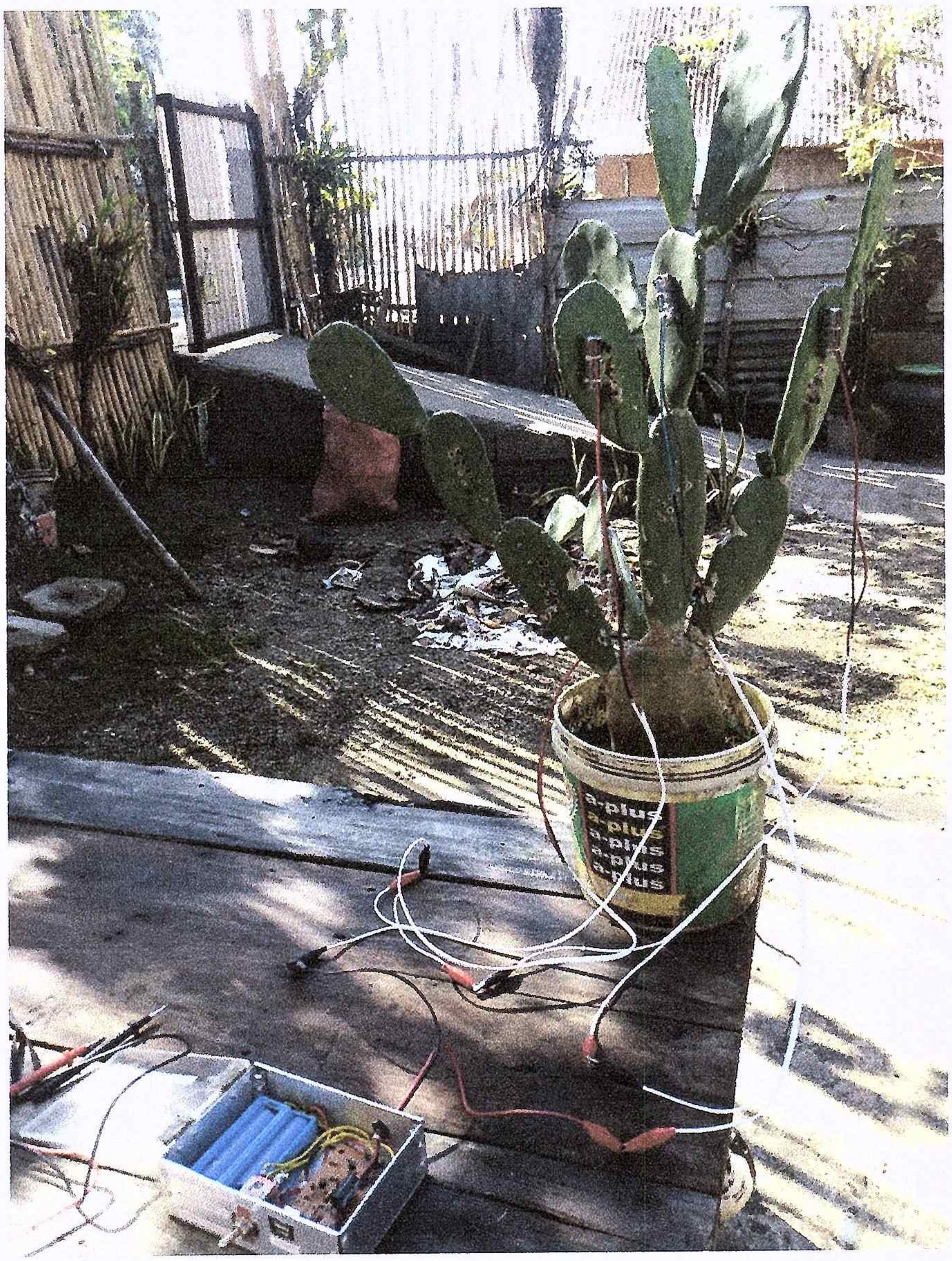
Soldering of the wire terminal to be connected into the groups of electrodes.



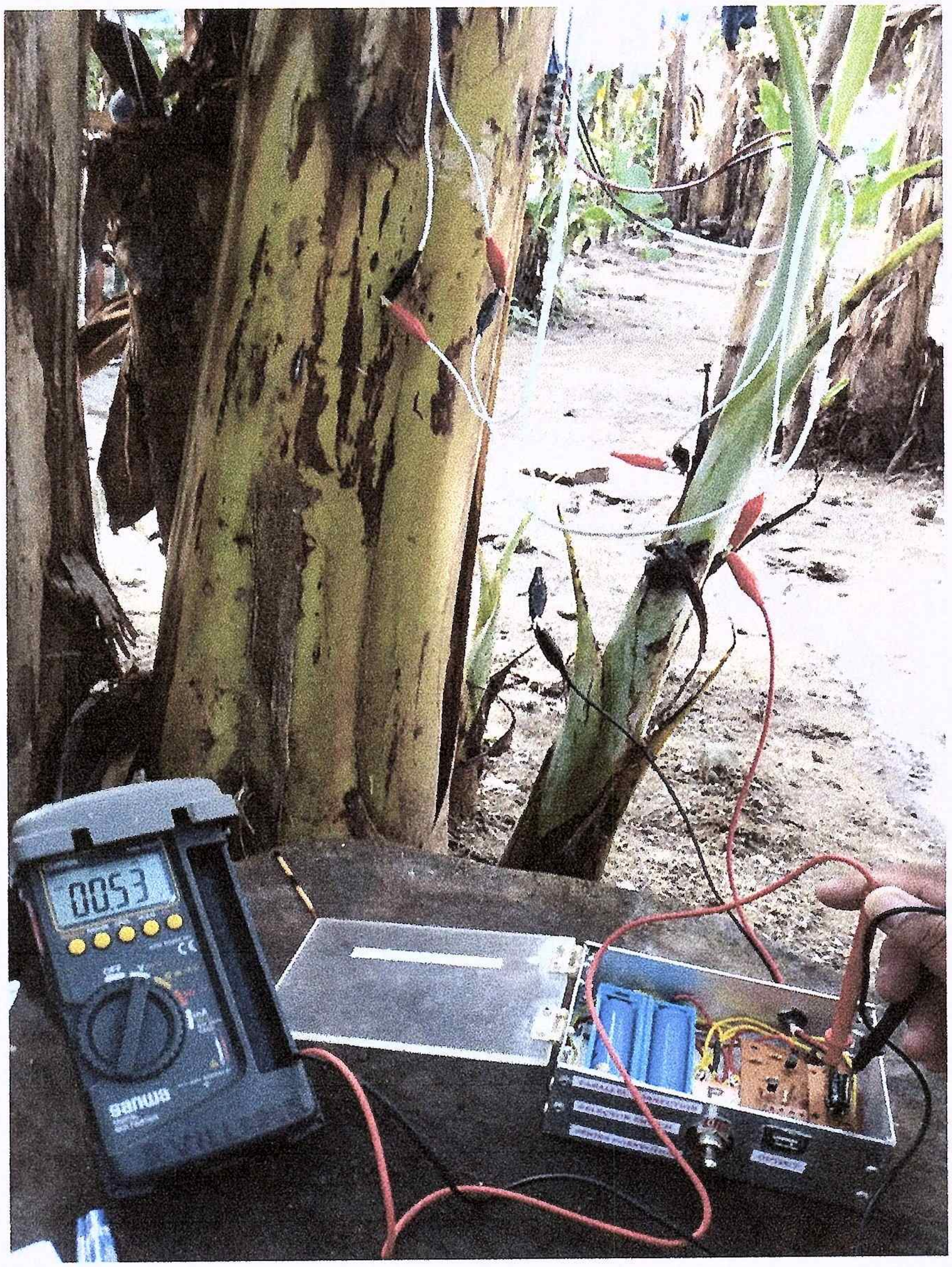
The electrodes harvester used in the study.

APPENDIX C

Types of Living Plants as Energy Sources



Cactus plant as an energy source.



Banana plant as an energy source.

Taro root crop as an energy source.

Water lily as an energy source.

Papaya as an energy source.

APPENDIX D

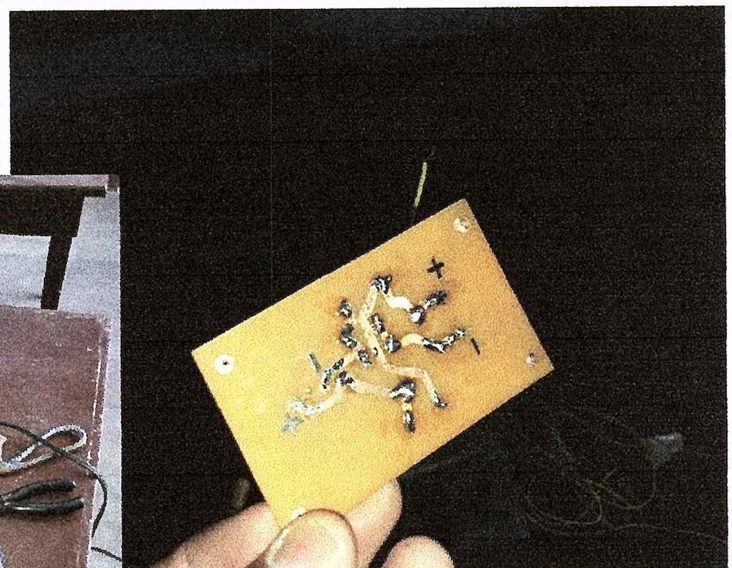
List of Electronics Components on the Harvesting Electric Energy from Living Plants

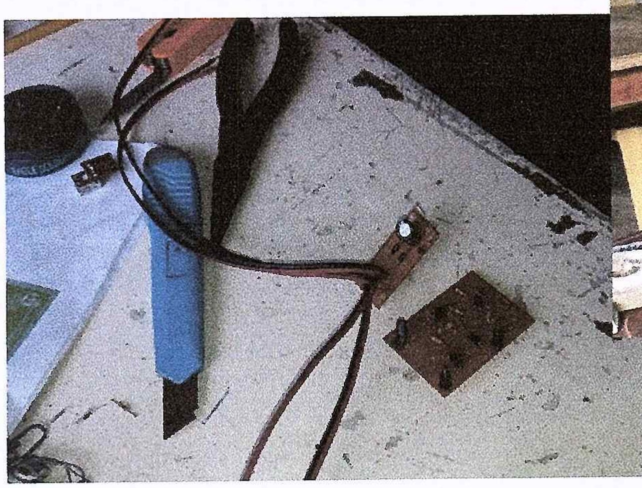
Quantity	Unit	Name and Description
1	Pc.	1μF Capacitor (100V)
1	Pc.	10μF Capacitor (25V)
1	Pc.	100Ω Resistor (1/4W)
1	Pc.	100μF Electrolytic Capacitor (100V)
1	Pc.	1k Resistor (1/4W)
1	Pc.	PCB, 2″x3″
1	Pc.	1N4734, 5V1 Zener Diode
1	Pc.	22k Resistor (1/4W)
1	Pc.	270nH Inductor
1	Pc.	Toggle Switch
20	Pcs.	Copper, 2.5 mm. x 0.5 mm.
2	Pcs.	Battery holder
20	Pcs.	Silver, 2.5 mm. x 0.5 mm.
2	Pcs.	Lithium Battery 3.7 Volt
1	Pc.	BC550B NPN Transistor
1	Pc.	BC560 PNP Transistor
4	Pcs.	Diode (Ideal)
2	Pcs.	1μF Capacitor, Ceramic
3	Pcs.	1KΩ Resistor (1/4)
3	Pcs.	Terminal Block
2	Pcs.	Hinges, 1"x1"
10	Pcs.	Alligator Clip
3	Meters	Soldering Lead 60/40
1.5	Meters	Speaker Wire, No. 22
1	Bottled	Ferric Chloride 75 ml.

APPENDIX E

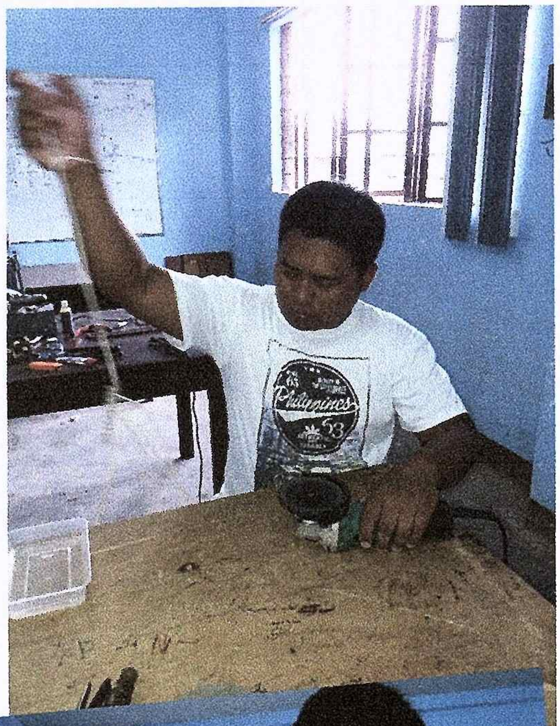
Pictorial during Trials of the Harvesting Electric Energy from Living Plants

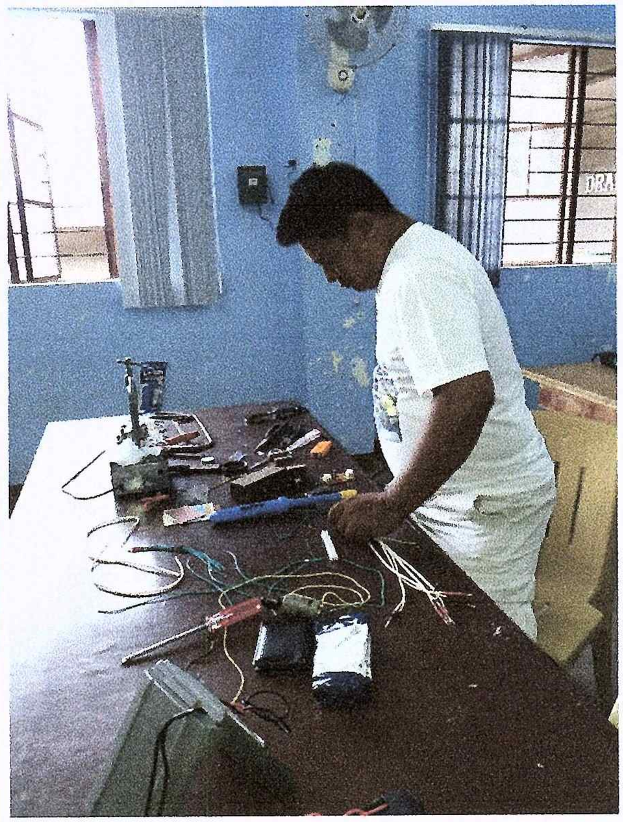
A. Materials for the Enhance Technology

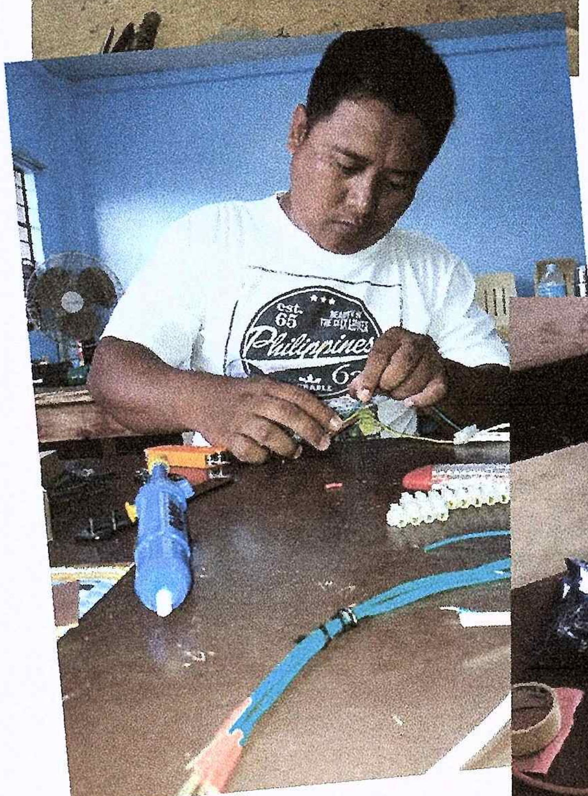


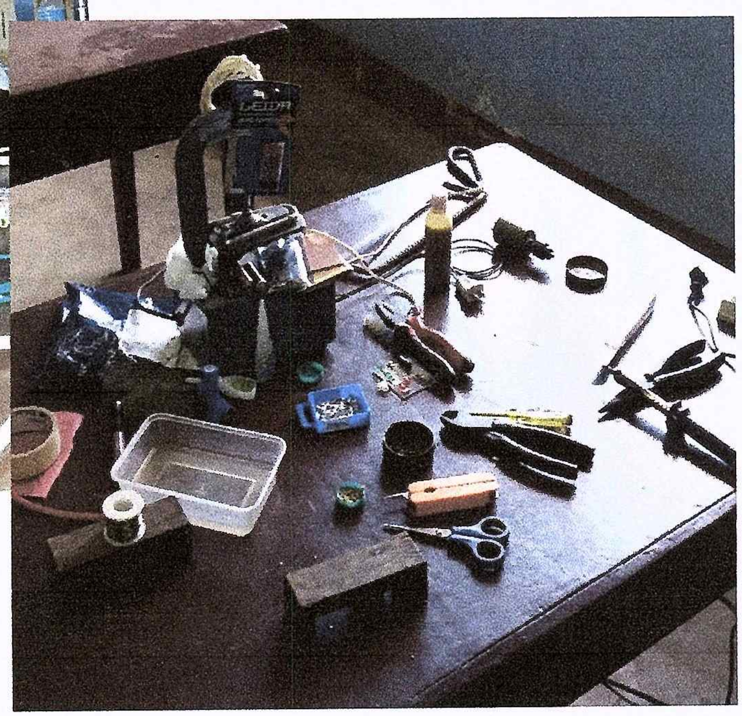


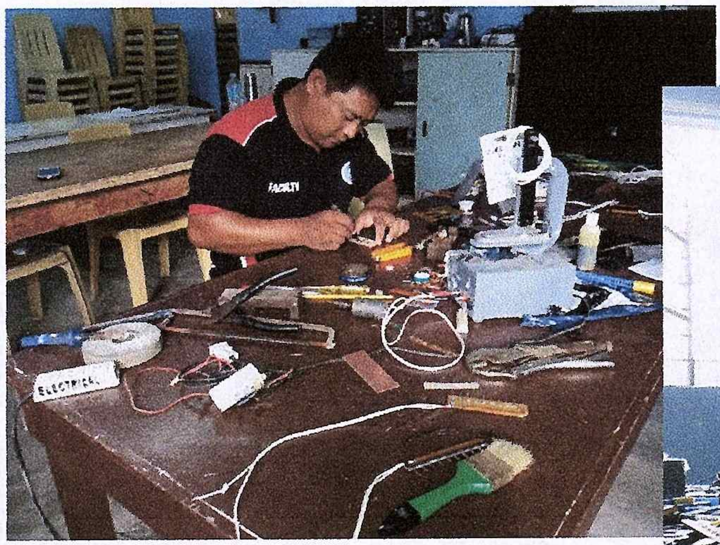
B. Development of the Harvester Electric Energy from Living Plants

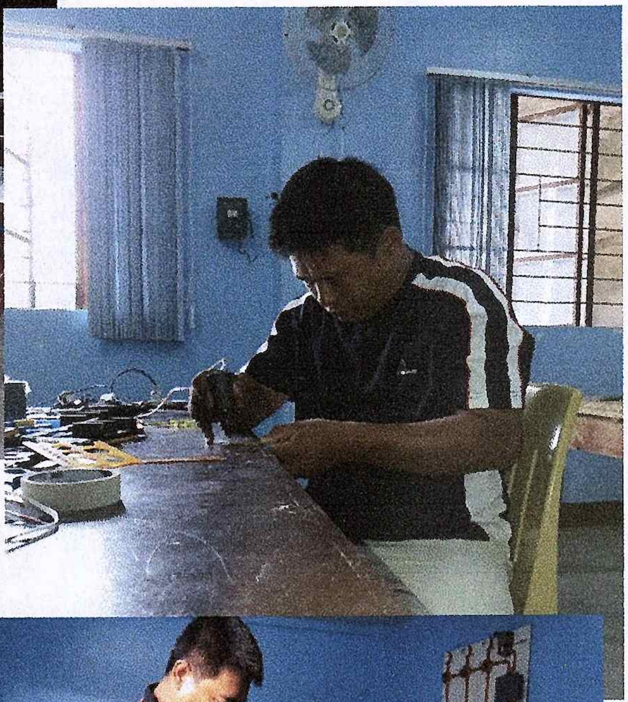


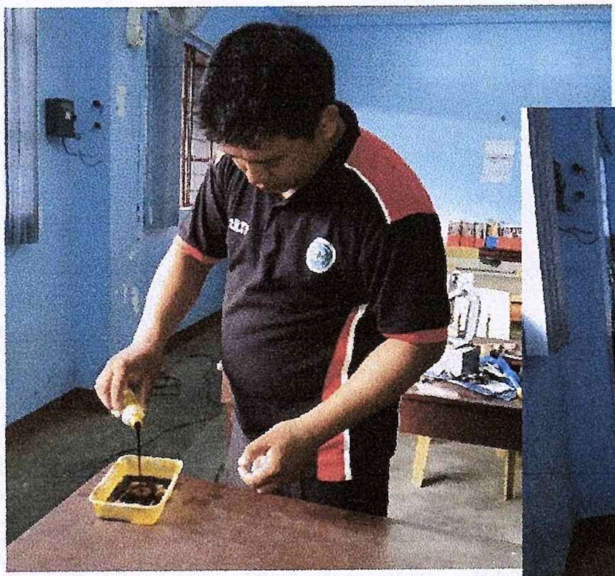


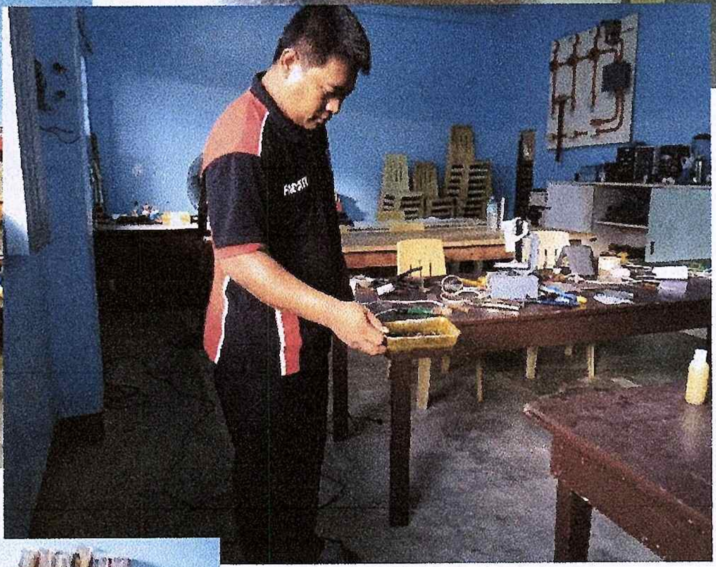


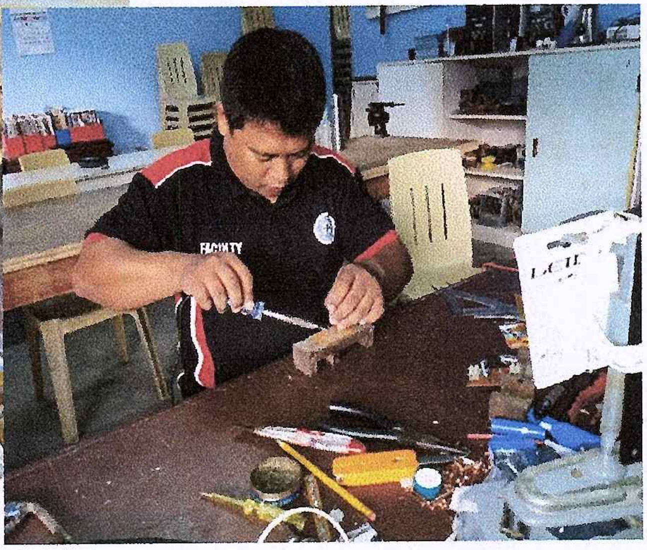




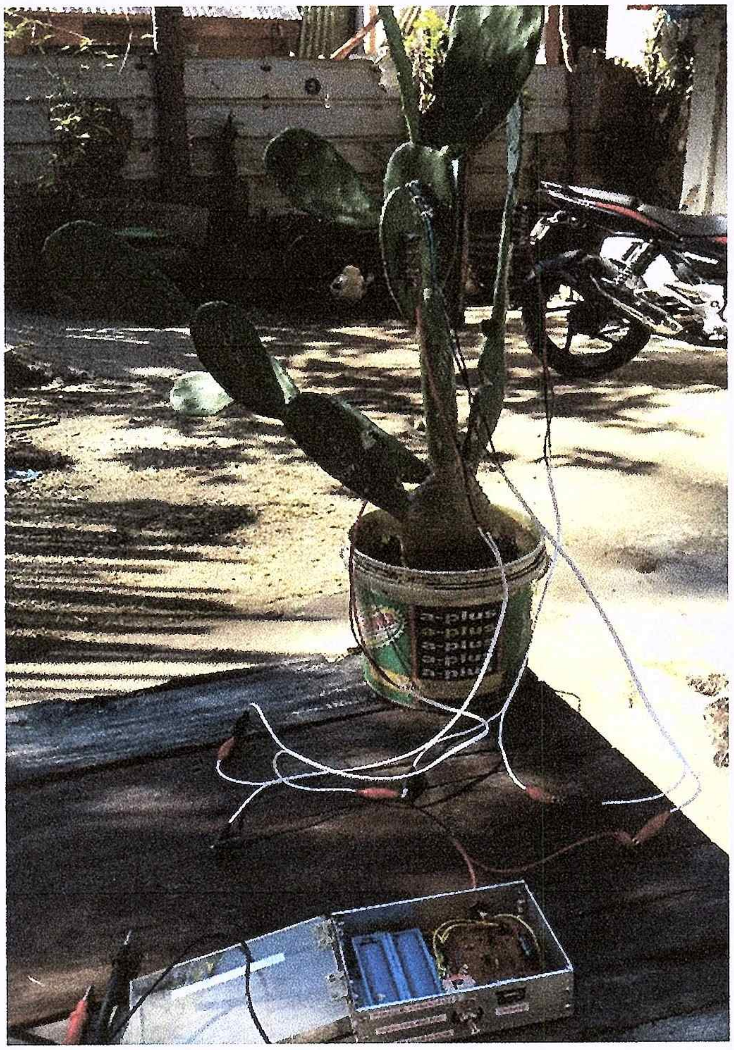








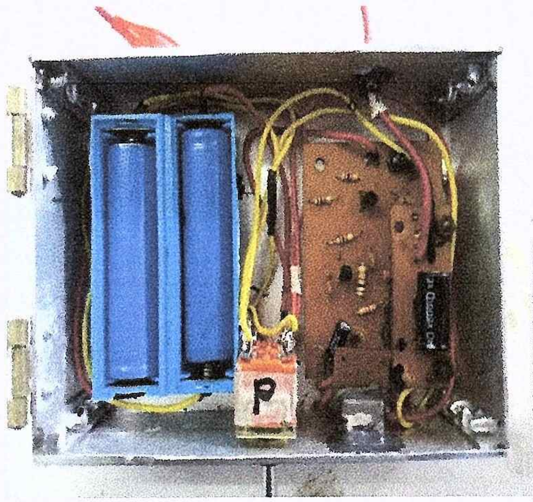
C. Trials Of The Harvesting Electric Five Living Plants

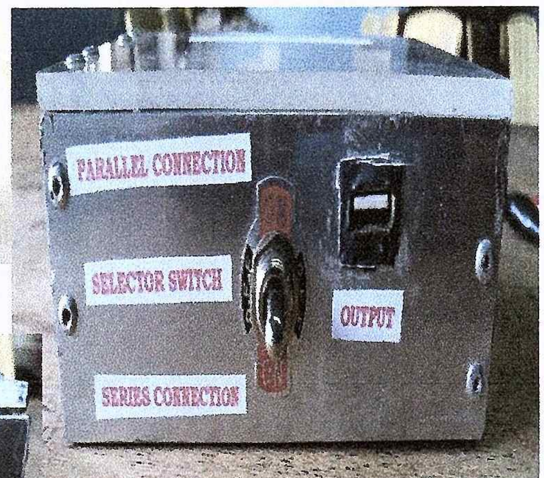


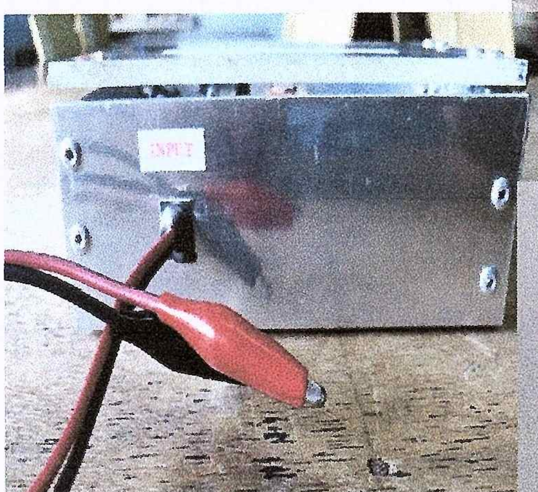
Trial on Cactus

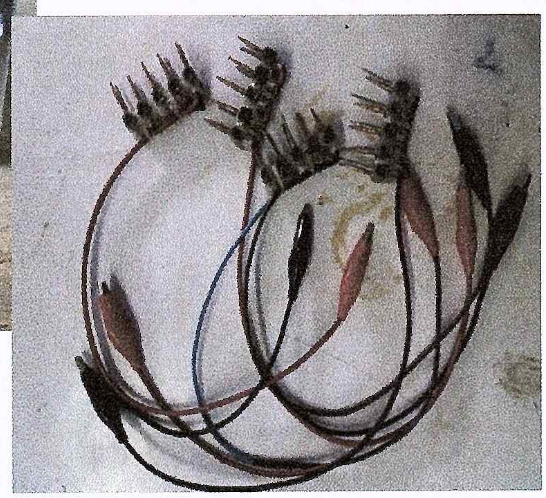
Trial on Water Lily

D. Prototype of the Harvester Electrical Energy from Living Plants









C U R R I C U L U M V I T A E

CURRICULUM VITAE

PERSONAL BACKGROUND

Name	:	**RAFFY A. VILLARUEL**
Date of Birth	:	March 31, 1979
Place of Birth	:	CALOOCAN CITY, METRO MANILA
E-mail address	:	raffyvillaruel31@gmail.com
Contact Number	:	0905 – 871 – 5645

EDUCATIONAL ATTAINMENT

Elementary	:	Carayman Elementary School
		SY: 1986 – 1992
Secondary	:	Tiburcio Tancinco Memorial Institute of Science and Technology
		SY: 1992 – 1996
Tertiary	:	Tiburcio Tancinco Memorial Institute of Science and Technology
		SY: 1996 – 2000
		Bachelor of Science in Industrial Technology
Major	:	Electrical Technology
Graduate Studies	:	Samar State University
		Masters in Technician Education

Major : Electrical

LANGUAGE SPOKEN : Waray, Tagalog and English

WORKING EXPERIENCE

2015 – Present

Temporary Instructor, Northwest Samar State University, Calbayog City

2014 – 2015

Part – Time Lecturer, Northwest Samar State University, Calbayog City

2000 – 2014

Industrial Electrician, Samar Coco Product Manufacturing Corporation, Calbayog City

LIST OF TABLES

List of Tables

LIST OF FIGURES

List of Figures