Faculty of Electrical Technology and Engineering

DEVELOPMENT OF ENERGY HARVESTING SYSTEM USING SOLAR AND RAINWATER FOR THE AGRICULTURAL INDUSTRY

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Bachelor of Electrical Engineering Technology (Industrial Power) with Honours

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DEVELOPMENT OF ENERGY HARVESTING SYSTEM USING SOLAR AND RAINWATER FOR THE AGRICULTURAL INDUSTRY

MUHAMAD FAISOL BIN MOHAMED FAUZI

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I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours.

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DEDICATION

To my beloved parents, I dedicate this project to you both with all my heart. Your unwavering support and encouragement throughout my academic journey have been a constant source of inspiration for me. Your guidance and motivation have been instrumental in helping me achieve my goals, and I am forever grateful for the sacrifices you have made to ensure that I have the resources and opportunities to succeed. Your love and support have been the foundation of my success, and I am honored to have you both as my parents. This project would not have been possible without your guidance, encouragement, and love. I hope this dedication serves as a small token of my appreciation for everything you have done for me.

ABSTRACT

This research focuses on the development of electricity using solar and rainwater for the agricultural industry. The main objective of this project is to reduce climate change by designing an integrated solar and rainwater-based electricity generation system tailored for the agricultural industry. The project aims to develop a scalable prototype that optimizes the collection and utilization of rainwater while effectively harnessing solar energy. Through analysis of potential benefits and feasibility, the project seeks to assess the viability and advantages of implementing these systems in agricultural settings, considering energy output, cost-effectiveness, and environmental impact. The intermittent nature of solar power and rainwater poses challenges to consistent energy and water supply. Extreme hot weather in Malaysia further complicates the selection of suitable solar panels. Additional storage and backup systems are required to overcome these limitations and ensure a continuous provision of energy and water. Solar energy serves as a primary energy source in agriculture, capturing sunlight through solar panels and converting it into electricity. Rainwater catchment is an alternative energy if there is a problem such as insufficient energy from solar. while farmers can use rainwater catchment for domestic activities. Preliminary studies have been done on solar tilt angle and downspout gutter. The test found that a tilt angle of 0° to 5° is suitable for Malaysia which is close to the equator. Whereas, the downspout is vertical. A wider and shorter downspout will allow for a higher flow rate compared to a narrower and longer one. The development of solar and rainwater-based power for the agricultural industry offers a sustainable and cost-effective alternative to reduce reliance on fossil fuels, optimize water resources, and promote environmental resilience in the long term.

ABSTRAK

Kajian ini memfokuskan kepada pembangunan elektrik menggunakan solar dan air hujan untuk industri pertanian. Objektif utama projek ini adalah untuk mengurangkan perubahan iklim dengan sistem penjanaan elektrik berasaskan suria dan air hujan bersepadu untuk industri pertanian. Projek ini bertujuan untuk membangunkan prototaip berskala yang mengoptimumkan pengumpulan dan penggunaan air hujan sambil memanfaatkan tenaga suria. Melalui analisis potensi manfaat dan kebolehlaksanaan, ia dapat menilai daya maju dan kelebihan melaksanakan sistem ini dalam pertanian, mempertimbangkan pengeluaran tenaga, keberkesanan kos dan kesan alam sekitar. Tenaga suria dan air hujan menimbulkan cabaran kepada bekalan tenaga dan air yang konsisten. Cuaca panas melampau di Malaysia menyukarkan lagi pemilihan panel solar yang sesuai. Sistem penyimpanan dan sandaran tambahan diperlukan untuk mengatasi batasan ini dan memastikan penyediaan tenaga dan air yang berterusan. Tenaga suria berfungsi sebagai sumber tenaga utama dalam pertanian, menangkap cahaya matahari melalui panel solar dan menukarnya kepada elektrik. Tadahan air hujan merupakan tenaga alternatif sekiranya terdapat masalah seperti kekurangan tenaga daripada solar. manakala petani boleh menggunakan tadahan air hujan untuk aktiviti domestik. Kajian awal telah dilakukan pada sudut kecondongan suria dan longkang downspout. Sudut kecondongan 0° hingga 5° sesuai untuk Malaysia yang berhampiran dengan khatulistiwa. Saluran yang lebih lebar, tegak dan lebih pendek akan membolehkan kadar aliran yang lebih tinggi berbanding dengan yang lebih sempit dan lebih panjang. Pembangunan tenaga suria dan air hujan untuk industri pertanian menawarkan alternatif yang mampan dan kos efektif untuk mengurangkan pergantungan kepada bahan api fosil.

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First and foremost, I would like to express my sincere gratitude to my supervisor, Mr. Arman Hadi Bin Azahar, and co-supervisor, Dr. Nor Hafizah Binti Hussin, for their invaluable guidance and support throughout the project. I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) for providing me with the opportunity to undertake this project.

My highest appreciation goes to my parents for their love and prayers during the period of my study. I would also like to extend my gratitude to all my fellow friends for their motivation and understanding. Special thanks to Muhammad Farhan Bin Noramiza for his assistance in this project.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

°	-	Degree
%	-	Percentage

LIST OF ABBREVIATIONS

V	-	Voltage
A	-	Ampre
ft	-	Feet
cm	-	Centimeter
s	-	Second
L	-	Liter

CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia has a tropical climate characterized by high humidity and consistent temperatures throughout the year. The country experiences two monsoon seasons: the Southwest Monsoon (May to September) and the Northeast Monsoon (November to March). The Northeast Monsoon primarily affects the eastern coast of Borneo, including Sabah and Sarawak, while the Southwest Monsoon brings heavy rainfall to the west coast, leading to occasional flooding. The remaining months are hot and humid, with sporadic rainfall. It is important to note that weather patterns change seasonally. For the most up-to-date information, consult local forecasts. Malaysia, located north of the equator, receives sufficient rainwater to sustain its hot, humid, and rainy climate, supporting extensive rainforests. However, the increasing demands from industries, agriculture, and households strain the water supply infrastructure. Solar energy is a form of renewable energy that harnesses the sun's power to generate electricity or heat. It involves the direct conversion of sunlight into usable energy using various technologies, primarily through photovoltaic (PV) systems or solar thermal collectors. The most used method to capture solar energy is through photovoltaic (PV) systems, which consist of solar panels comprising multiple photovoltaic cells that convert sunlight into electricity. When sunlight reaches these cells, it energizes the electrons, creating an electric current. This direct current (DC) can be utilized to power appliances or stored in batteries for later use. In grid-connected systems, any surplus electricity can be fed back into the power grid. On the other hand, solar thermal collectors utilize sunlight to heat a fluid, such as water or air, to generate heat energy. This heated fluid serves various purposes, including water heating, space heating, or cooling absorption chillers [1].

Solar energy offers several advantages. Firstly, it is a renewable energy source, meaning it is abundant and does not deplete natural resources. Additionally, solar energy systems produce no greenhouse gas emissions or air pollutants during operation, making them environmentally friendly. Moreover, solar energy systems can be installed at different scales, ranging from small residential setups to large-scale solar farms, allowing for flexibility in implementation. However, there are a few drawbacks associated with solar energy. Its availability is limited to daylight hours, but energy storage technologies, like batteries, are commonly employed to store excess energy for use during cloudy or nighttime periods. The upfront cost of installing solar systems can also be a deterrent, although prices have been consistently decreasing over time. Despite these challenges, solar energy is rapidly gaining popularity and widespread adoption worldwide. It plays a crucial role in reducing dependence on fossil fuels and addressing climate change by transitioning to a more sustainable and cleaner energy future. Governments, businesses, and individuals increasingly view solar energy as a viable and environmentally friendly alternative to traditional energy sources [2].

Figure 1.1 Solar system in agriculture

Malaysia exhibits a tropical climate characterized by high humidity and warm temperatures throughout the year. It undergoes two distinct monsoon seasons: the southwest monsoon (May to September) and the northeast monsoon (November to March). The northeast monsoon predominantly impacts the eastern coast of Borneo, including Sabah and Sarawak, while the southwest monsoon primarily affects the west coast, occasionally resulting in floods. The remaining months experience hot and humid weather with sporadic rainfall. It is important to note that weather patterns change continuously throughout the year. For the most current information, refer to local weather forecasts. Malaysia, situated north of the equator, receives sufficient rainfall to sustain its hot, humid, and rainy climate [4]. The monsoon season contributes to the growth of expansive rainforests. However, the increasing demands from industries, agriculture, and residential usage pose challenges to the country's water supply infrastructure.

However, when utilizing rainwater, it is important to consider certain factors. The presence of pollutants in the atmosphere or on rooftops can impact the quality of rainwater, necessitating filtration and treatment prior to use. Regular maintenance of rainwater collection systems is crucial to prevent debris accumulation and the growth of bacteria and algae [5]. Rainwater is a valuable resource that can complement conventional water sources, conserve water, and support sustainable water management practices through the implementation of rainwater harvesting techniques.

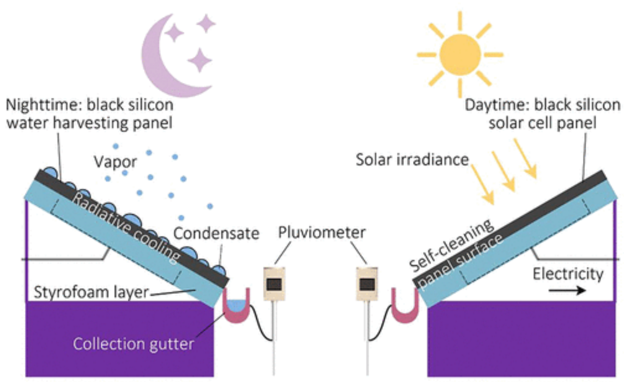

Figure 1.2 Water Harvesting from Air

1.2 Problem Statement

The problem with using solar power and rainwater is the intermittent nature of both resources. Solar power generation is dependent on sunlight availability, which varies throughout the day and is absent during nighttime. Similarly, rainwater availability fluctuates based on weather conditions and seasonality. These fluctuations make it challenging to maintain a consistent and reliable energy or water supply solely relying on solar power and rainwater. Additional storage and backup systems are necessary to overcome these limitations and ensure a continuous provision of energy and water.

Combining solar power and hydropower creates a reliable and sustainable energy system. Solar utilizes sunlight, while hydropower harnesses water movement. Together, they provide a stable energy supply, effective during the day and ensuring stability when solar production is low. This integration enables a flexible system, meeting varying needs and establishing microgrids for localized energy independence. By reducing dependence on nonrenewable energy, lowering emissions, and mitigating climate change, the combination of solar and hydropower offers a future-proof, clean energy solution.

1.3 Project Objective

The main aim of this project is to reduce climate change. Specifically, the objectives are as follows:

a) To design an integrated solar and rainwater-based electricity generation system that is custom-made to meet the specific needs of the agricultural industry, considering factors such as power demand, weather conditions, and water availability.

b) To develop and optimize a scalable prototype for an electricity generation system that maximizes the efficient collection and utilization of rainwater as a complementary resource, while effectively harnessing solar energy.

c) To analyze the potential benefits and feasibility of implementing solar and rainwater-based electricity generation systems in agricultural settings, including factors such as energy output, cost-effectiveness, and environmental impact, to gain insights into their viability and potential advanc

1.4 Scope of Project

The objectives of the project "Development of Electricity Using Solar and Rainwater for the Agricultural Industry" are as follows :

Design and research	• Thoroughly research and develop an integrated solar and rainwater-based electricity generation system for efficient and sustainable use in agriculture.
Prototype development	• Create a scalable prototype showcasing the feasibility and functionality of utilizing solar and rainwater as alternative energy sources in agriculture, demonstrating efficient energy production and reliable operation.
Performance analysis	• Conduct a comprehensive analysis of the prototype's performance and efficiency across various agricultural environments. Evaluate its suitability and effectiveness based on energy output, power demand, system reliability, and water availability.
Economic feasibility assessment	• Assess the economic viability of implementing solar and rainwater-based electricity generation systems in agriculture by evaluating installation costs, maintenance expenses, energy savings, and return on investment.
Environmental impact evaluation	• Assess the environmental impact of solar and rainwater-based electricity generation systems in agriculture, including carbon footprint reduction, water conservation, and overall sustainability, to understand their environmental benefits and potential drawbacks.
Guidelines and recommendations	• Develop practical guidelines and suggestions for implementing solar and rainwater-based electricity generation systems in agriculture, encompassing installation, maintenance, operations, and regulatory compliance, to support seamless adoption and adherence to standards..
Promotion and awareness	• Promote the benefits and potential of solar and rainwater-based electricity generation systems to encourage the adoption of renewable energy and sustainable agricultural practices. Share project findings and best practices for industry-wide transformation and knowledge dissemination.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In recent years, solar energy has gained significant traction as a viable and sustainable alternative to conventional fossil fuel-based power generation. The growth and progress of the solar-related sector has demonstrated their significant contribution to Malaysia's economy and energy generation resources. Additionally, the parallel focus on minimizing environmental impact strengthens the argument for using solar energy as an important element in the country's energy portfolio. The purpose of this literature review is to present a comprehensive examination of the progress, challenges and future prospects related to solar energy. By analyzing a diverse collection of studies and research articles, this review aims to provide an overview of the current landscape of solar energy technology, its practical applications and the barriers that prevent its widespread adoption. The goal is to offer a holistic understanding of the state of solar energy, there by fostering an informed discussion and driving further progress in this promising field.

2.2 A Reseacrh on Malaysia's Climate.

Malaysia experiences a tropical climate with an average annual temperature of 25.4°C. Monthly temperature variations are minimal, ranging from 24.9°C in January to 25.9°C in May. The hottest months are April, May, and June [6].

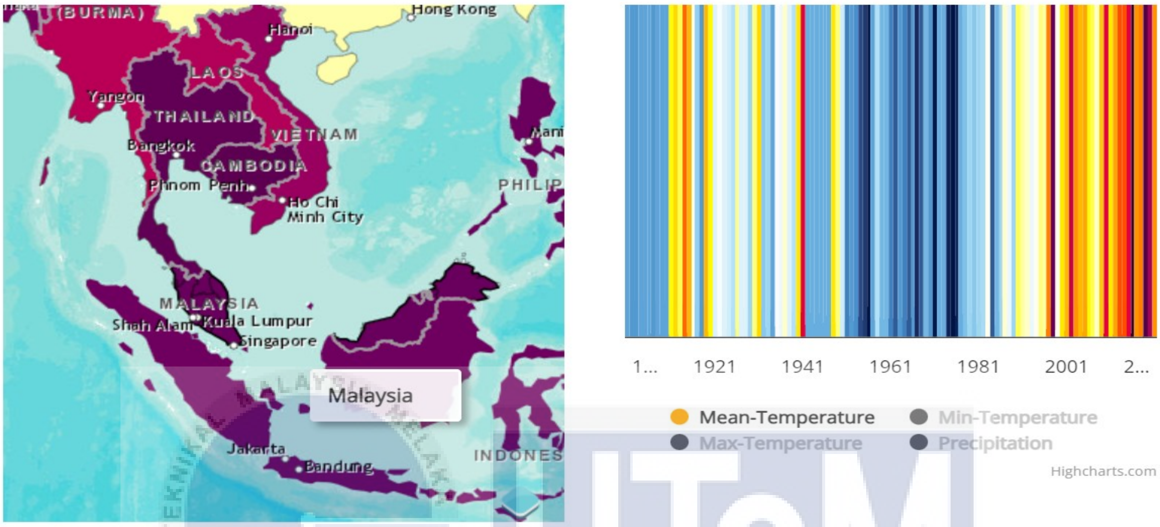

Figure 2.1 Observed Annual Mean-Temperature 1991-2020 Malaysia

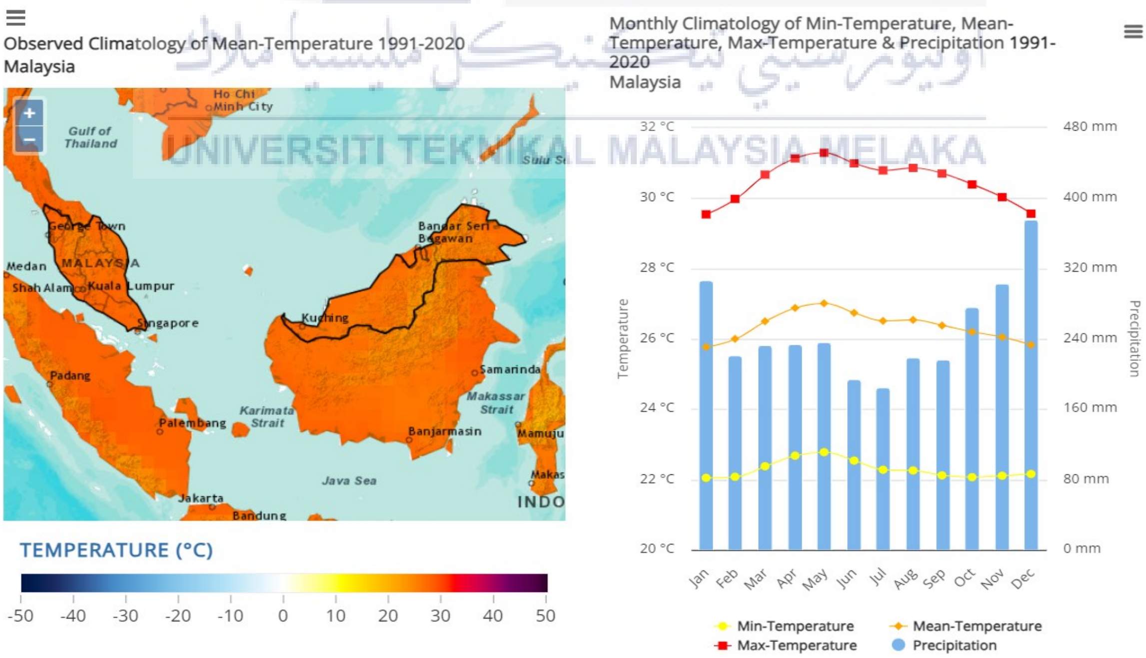

Figure 2.2 Observed Climatology of Mean-Temperature 1991-2020 Malaysia

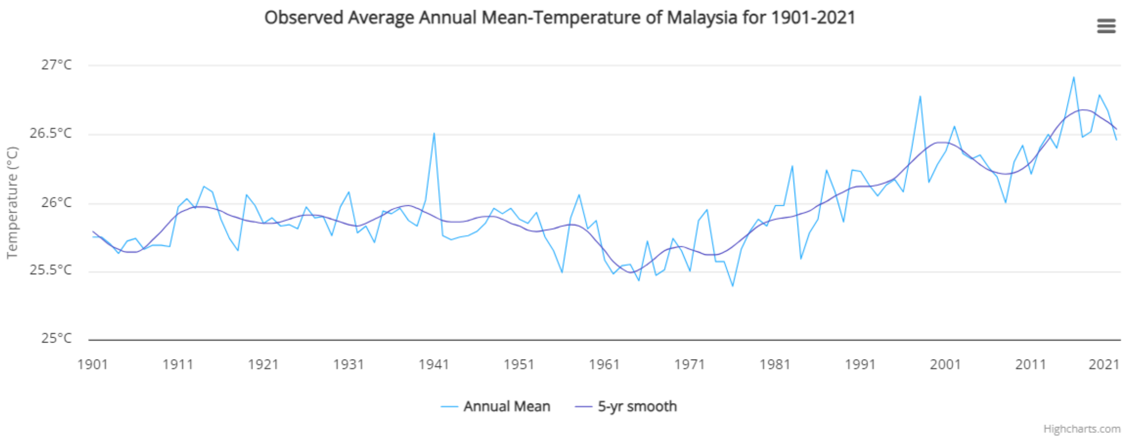

Figure 2.3 Observed Average Annual Mean-Temperature Of Malaysia for 1901-2021

Malaysia receives high rainfall throughout the year, with an average annual precipitation of 3,085.5 millimeters (mm). Monthly precipitation remains relatively consistent, ranging from around 200 mm in June and July to 350 mm in November and December. The country experiences two monsoon seasons: the Southwest Monsoon from April to September and the Northeast Monsoon from October to March. Malaysia typically receives around six hours of direct sunlight per day, with cloud cover more likely in the afternoon and evening [7].

Observed Average Seasonal Mean Temperature

The identified sub-national units with the highest and lowest mean temperatures reflect the latest climatology, 1991-2020.

	1991-2020				1961-1990				1931-1960				1901-1930			
Units: °C	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
Country: Malaysia	25.88	26.80	26.59	26.21	25.21	26.19	25.93	25.66	25.41	26.28	26.05	25.74	25.31	26.25	26.00	25.76
Highest: Perlis	28.26	29.16	28.23	27.65	27.45	28.43	27.50	27.04	27.53	28.49	27.57	27.08	27.56	28.60	27.68	27.20
Lowest: Sabah	25.24	26.16	25.99	25.73	24.66	25.70	25.50	25.30	24.78	25.72	25.57	25.27	24.57	25.52	25.36	25.09

Figure 2.4 Observed Average Seasonal Mean Temperature

Observed Average Seasonal Minimum Temperature

The identified sub-national units with the highest and lowest minimum temperatures reflect the latest climatology, 1991-2020.

	1991-2020				1961-1990				1931-1960				1901-1930			
Units: °C	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
Country: Malaysia	22.06	22.61	22.36	22.10	21.26	21.86	21.53	21.42	21.40	21.94	21.67	21.55	21.33	21.96	21.66	21.57
Highest: Labuan	24.68	25.25	24.95	24.71	24.09	24.76	24.38	24.23	24.20	24.87	24.54	24.39	23.99	24.82	24.56	24.34
Lowest: Sarawak	21.66	22.08	21.80	21.63	21.05	21.53	21.15	21.11	21.22	21.64	21.29	21.25	21.06	21.59	21.23	21.19

Figure 2.5 Observed Average Seasonal Minimum Temperature

Observed Average Seasonal Maximum Temperature

The identified sub-national units with the highest and lowest maximum temperatures reflect the latest climatology, 1991-2020.

	1991-2020				1961-1990				1931-1960				1901-1930			
Units: °C	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
Country: Malaysia	29.75	31.03	30.88	30.37	29.22	30.57	30.37	29.95	29.46	30.66	30.47	29.98	29.35	30.60	30.39	30.00
Highest: Perlis	33.39	33.95	32.23	31.55	32.88	33.52	31.70	31.08	33.05	33.62	31.79	31.13	33.01	33.71	31.92	31.28
Lowest: Sabah	28.75	30.27	30.27	29.82	28.24	29.90	29.88	29.47	28.40	29.85	29.86	29.28	28.23	29.56	29.48	29.05

Figure 2.6 Observed Average Seasonal Maximum Temperature

Observed Seasonal Precipitation

The identified sub-national units with the highest and lowest precipitation sums reflect the latest climatology, 1991-2020.

	1991-2020				1961-1990				1931-1960				1901-1930			
Units: mm	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
Country: Malaysia	527.47	703.15	598.83	796.28	476.23	658.74	569.54	814.19	510.98	738.66	592.59	838.56	516.97	696.32	556.71	837.14
Highest: Sarawak	703.84	861.78	678.05	891.90	652.14	813.38	646.39	897.05	632.81	859.34	678.34	956.84	649.13	827.32	631.90	900.72
Lowest: Negeri Sembilan	296.04	572.82	423.59	626.90	260.23	552.13	389.38	635.29	332.52	631.95	388.79	629.27	328.27	569.78	380.35	643.09

Figure 2.7 Observed Seasonal Precipitation

2.3 A Research on Importance of Using Renewable Energy Sources by Organizations within The Scope of Green Deal Preparation.

Ersöz (2022) states that human-induced global warming has detrimental effects on the environment, economy, and the health of living beings. Climate change poses a significant threat to life on Earth. To address this crisis, the European Union has taken a leadership role by introducing the European Green Deal in 2019 [9], initiating a comprehensive transformation.

2.4 Potential of Solar Energy

Malaysia possesses a rich array of energy resources, including renewable sources. With its natural tropical climate, Malaysia enjoys an average daily solar radiation of 4500 kWh m-2 and around 12 hours of sunlight per day [10]. The country holds substantial potential for harnessing solar energy, with four peak sun hours per day.

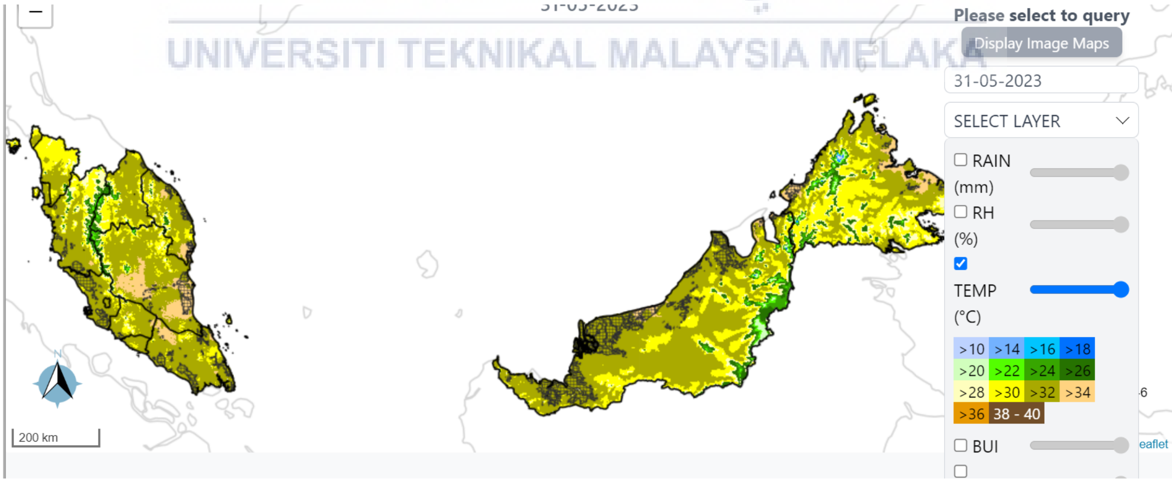

Figure 2.8 Temperature in Malaysia

2.5 System Conseption and Design of Light Tracing Module

According to [11], active tracking and passive tracking are the main methods employed for maximizing solar power generation systems. Yu Haomin (2020) designed the system in the paper using a clear detection method for solar motion. Figure 2.9 illustrates the concept of the system design.

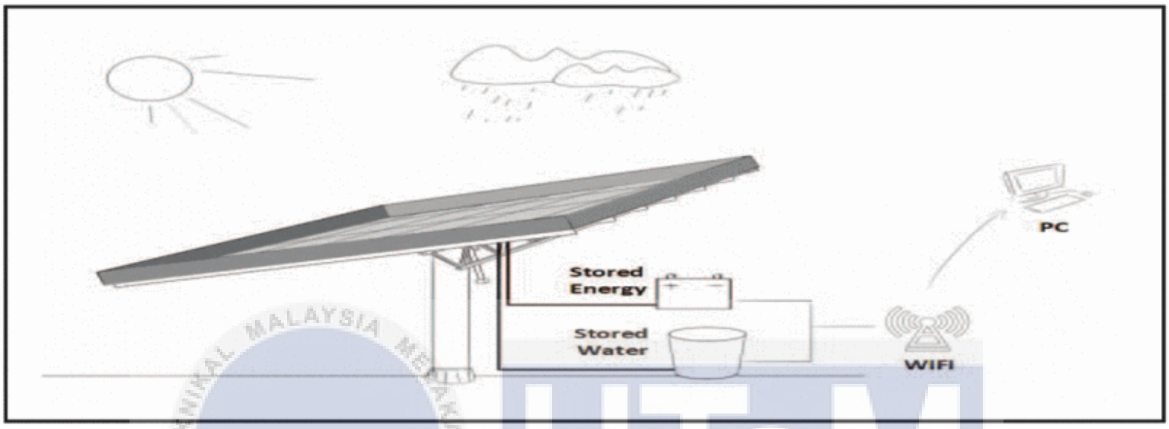

Figure 2.9 System design concept

In [12], a one-dimensional tracking system is used to track the sun's motion in a single direction, considering the east-to-west trajectory. The sun's position is represented by a single parameter, and its position for the next moment is calculated and tracked based on its motion characteristics. Uniaxial control systems, compared to biaxial control systems, have lower power consumption and cost. The system relies on energy storage from its own solar power generation panel and a lithium battery.

2.6 Low-cost weather station for climate-smart agriculture

According to [13], climate-smart agriculture is an effective approach that optimizes agricultural outputs by managing inputs based on climate conditions. Real-time weather monitoring systems play a crucial role in assessing farm-specific climatic conditions, offering valuable insights to address various agricultural challenges.

Figure 2.10 Climate - smart agriculture

2.7 Solar Charging System

In his study, Sonam Tenzin (2017) implements solar cells as the power source for weather stations located at a distance from each other in the farm. This approach is preferred due to the challenges of wiring each station individually. Moreover, harnessing solar energy for powering weather stations is deemed more suitable and cost-effective in the long term. The system consists of a 20-watt solar cell panel, a solar charging control unit that supplies a 5V output for the data collection board and 12V for battery charging, along with a 12-volt/21AH battery [13].

2.8 Design of Rainwater Collection System

Yin Yikang (2020) developed an innovative rainwater harvesting module that incorporates a solar energy system. The module features a box-shaped water collection device with a baffle surrounding the solar power generation panel. Rainwater is directed into the storage tank through water pipes connected to the outlets on each side. To safeguard the electronic components from water damage, the core components of each module are enclosed in a waterproof box designed to resemble a rainwater collection device, as depicted in Figure 2.11 [14].

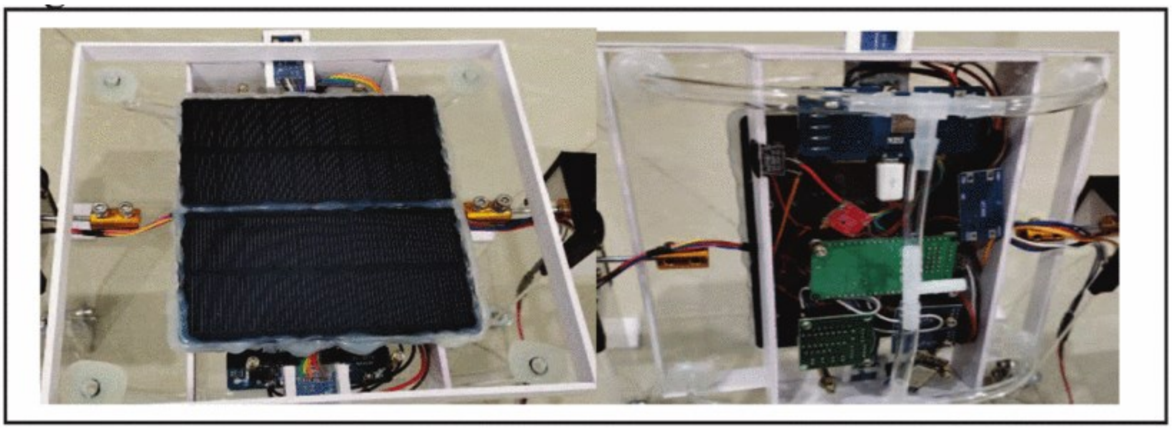

Figure 2.11 The Rainwater Collection

2.9 Method of Rainwater Harvesting (RWH)

According to A. Campisano (2012), the feasibility of rainwater harvesting (RWH) systems relies on factors such as storage capacity, water demand pattern, roof area, and rainfall profile [15]. While developer interest in domestic RWH systems is generally low due to higher costs, smaller RWH systems are gaining popularity in residential settings. Implementing RWH systems can result in estimated annual savings of up to RM 10,460 [16]. Large-scale commercial RWH systems, as highlighted by Lani et al. (2018) [17], offer improved net present value (NPV), return on investment (ROI), benefit cost ratio (BCR), and payback period (PBP) compared to smaller models. The National Water Research Institute of Malaysia (NAHRIM), a government agency specializing in water management and the environment, plays a vital role in RWH. NAHRIM has developed various products focusing on long-term sustainability and the environment [18].

NAHRIM's direct water dispenser, utilizing treated rainwater, serves as an alternative drinking water source. NAHRIM's innovation in rainwater harvesting systems was recognized by the Malaysia Book of Records (MBOR) in 2018 for creating the largest RWH system in the laboratory category [18]. NAHRIM's application of RWH in large-scale areas demonstrates its effectiveness in Malaysia. NAHRIM has also introduced a new product, packaged drinking water (BW), derived from treated rainwater, which is expected to be available in 2021 [19]. Overall, NAHRIM's research, inventions, and applications in RWH contribute significantly to large-scale models.

2.10 Soft Water Tank Level Monitoring System Using Ultrasonic HC-SR04 Sensor Based On ATMega 328 Microcontroller.

M. Reza Hidayat (2019) implemented a water level detection system using the HC-SR04 sensor for monitoring the soft water tank. An ATMega 328 microcontroller serves as the controller for data processing, display, and interfacing. The system displays water level measurements and consists of two valves with different functions. When the sensor detects a level between 0% and 15%, an alarm notifies the operator, and valve 1 activates pump 1 while valve 2 deactivates pump 2 to fill the soft water tank. For levels exceeding 70%, valve 2 opens, allowing the transfer of soft water for production. If the sensor detects a level above 95%, an alarm is triggered, and valve 1 turns off pump 1 [20].

2.11 Rainwater Harvesting System

Rainwater collection systems are designed to gather rainwater from rooftops and catchments, including man-made or natural surfaces and rock catchments. These systems serve various purposes, such as domestic, industrial, agricultural, and environmental uses. Rainwater harvesting systems come in small, medium, and large sizes, typically determined by the catchment area. The objective of rainwater harvesting is to collect and store rainwater, as well as employ measures to capture surface and groundwater and minimize evaporation and seepage losses. It involves hydrological studies, engineering interventions, and conservation practices to efficiently utilize limited water resources within a watershed. Refer to Figure 1 for the classification of rainwater harvesting methods.

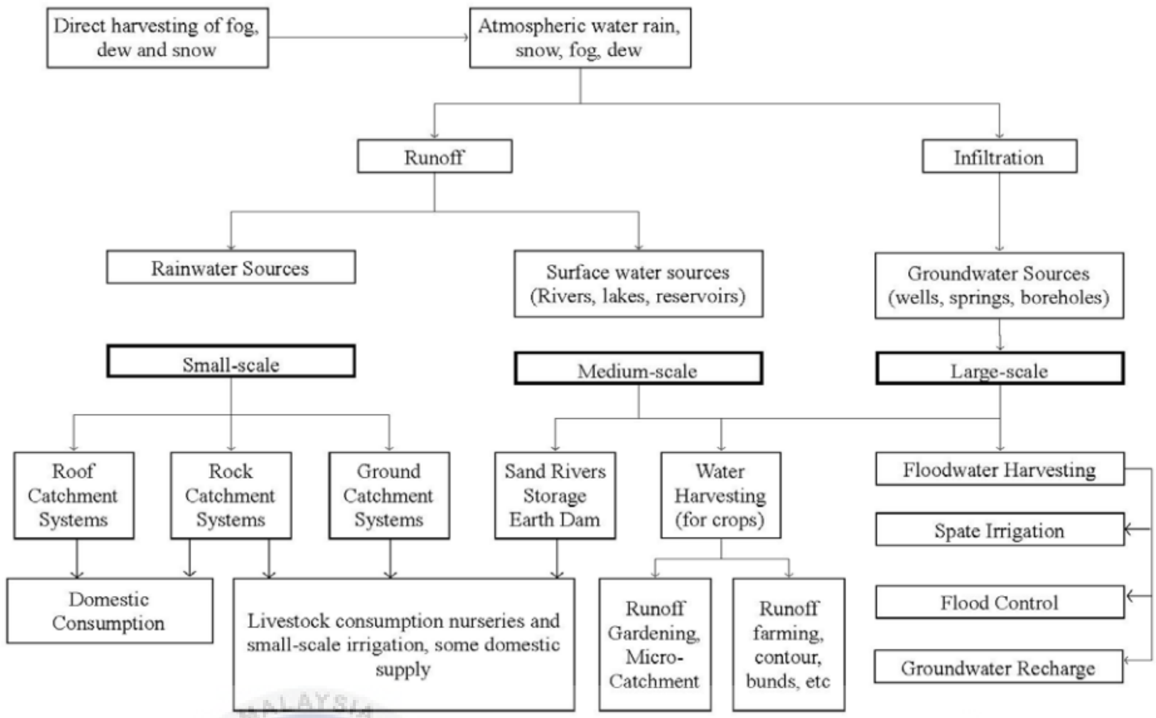

Figure 2.12 illustrates the classification of rainwater harvesting

2.12 Rainwater Harvesting (RWH) and the Diurnal Patterns.

The daily amount of rainfall in a specific area is influenced by the diurnal pattern. While solar farms are expanding rapidly, the risk of soil erosion must be addressed. Implementing Rainwater Harvesting (RWH) can be a significant solution, starting with rainwater collection from roofs and the construction of simple brush check dams in rural areas, particularly in South and Southeast Asia [21]. In peninsular Malaysia, different locations exhibit distinct diurnal patterns of rainwater, as shown in the topographical map in Fig. 2.13. Various stations, including Kota Bharu, Senai, KLIA, and Cameron Highlands, represent the different regions of South Coastal, East Coastal, West Coastal, and Highland [22]. Understanding the diurnal variations in rainfall occurrence for these regions during specific monsoon periods is crucial, such as the northeast monsoon, pre-monsoon, southwest monsoon, and early northeast monsoon [22]. This information is vital for identifying optimal locations for RWH in large-scale solar farms.

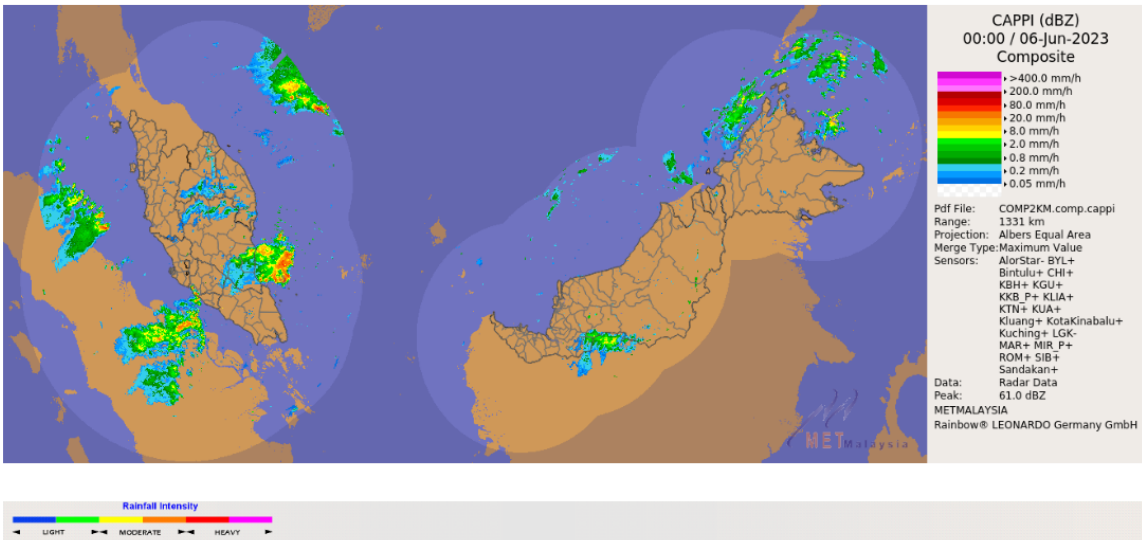

Figure 2.13 Temperature in Malaysia

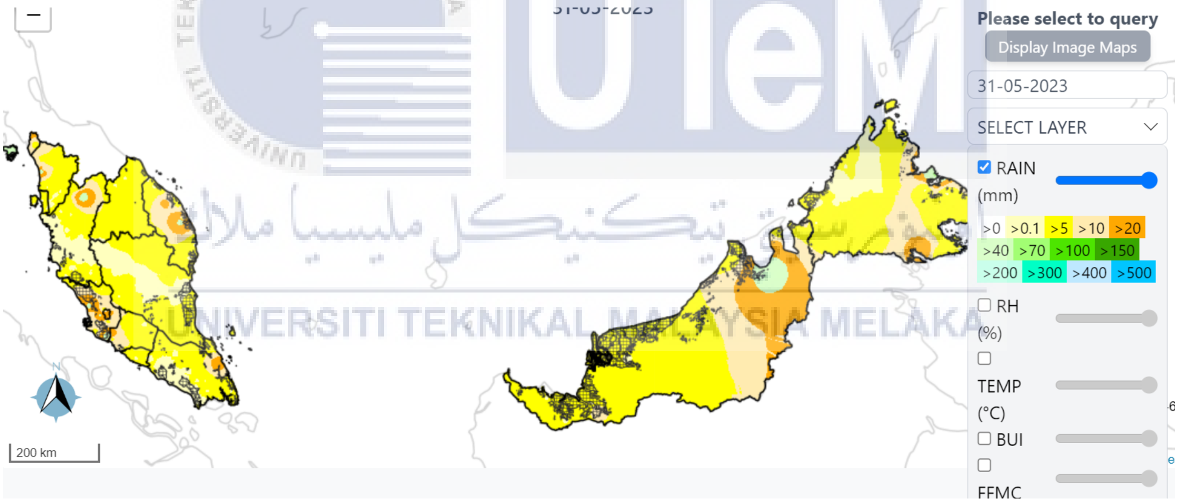

Figure 2.14 Rainfall in Malaysia

2.13 The role of water harvesting to achieve sustainable agricultural intensification and resilience against water related shocks in sub-Saharan Africa.

Rural poverty alleviation is a top priority for social and economic development, particularly given rising population projections through 2050 and the need to meet rising food demands in a rapidly urbanizing world. Sustainable intensification of agricultural techniques, such as water management practices, is thus required, resulting in increased agricultural production while minimizing environmental impacts and improving resilience to drought and dry spells. The author's water harvesting practice has produced promising results in terms of risk reduction and increased yield, as well as positive effects on other ecosystems. However, more research into local downstream effects is required before large-scale water harvesting is implemented. The authors conclude that water harvesting remains a promising option for sustainable agricultural intensification in water-stressed tropical regions, resulting in lower risk and higher yields. Agriculture, which is largely rain-fed, is the primary source of staple food production in Sub-Saharan Africa [24-28]. It accounts for 93% of the region's agricultural land [29-30]. Sub-Saharan African rainfed agriculture is distinguished by its low input-output characteristics. Extreme rainfall variability plagues it, with few rain events and a high frequency of dry spells and droughts [31-32].

2.14 IoT Based Technique for Household Rainwater Harvesting

This paper presents a more efficient approach to rainwater harvesting. The degradation of our environment caused by extensive globalization, urbanization, and modernization has adverse effects on natural rainfall patterns. The widespread use of fossil fuels, along with emissions from vehicle exhaust and oil refineries, leads to the formation of harmful gases like sulphur dioxide, carbon monoxide, nitrogen dioxide, and others. Despite receiving higher precipitation compared to other countries in the same region, India still faces water scarcity in various regions. Water sources in these areas are depleting rapidly, and underground water tables are declining at an alarming rate [33]. The Central Ground Water Board predicts water scarcity in 15 Indian states by 2025 [34]. Consequently, effective water management and harvesting practices are crucial. In many states, including Tamil Nadu, it is mandatory for buildings to have rainwater harvesting systems installed. Rainwater harvesting has been a long-standing practice in Rajasthan, where people construct Naada, Pat, Saza Kuva, Bandhis, and Paar systems to store water [35]. Quality control plays a vital role in rainwater harvesting due to increased emissions of toxic gases, such as sulphur dioxide, carbon monoxide, and nitrogen dioxide, which dissolve in water and raise its pH level [37-38].

Moreover, the dissolution of sand and soil causes turbidity, resulting in the cloudiness or haziness of water. Various factors, including the color of rainwater, necessitate the need for quality testing. In 2001, Kerala experienced "blood rain" characterized by a bright red color that stained clothes. Surprisingly, this colored rain was not caused by pollution but rather by airborne spores from a locally abundant terrestrial green alga of the genus Trentepohlia, as revealed by a government study [39]. Instances of green, yellow, and black rains have also been reported in Kerala, as well as in the eastern and north-central provinces of Sri Lanka. Therefore, it is essential to assess the color of rainwater before harvesting it.

2.15 Blockchain Technology in Smart Agriculture Environment: A PLS-SEM

According to Nazir Ullah (2021), the agriculture industry is undergoing a transformation through the adoption of disruptive technologies, leading to the emergence of a Smart agriculture environment. The utilization of blockchain technology is becoming crucial not only in developed countries but also in developing economies to propel advancements in the traditional agricultural system [40].

2.16 Blockchain in Agriculture Sector

DLT (Distributed Ledger Technology) facilitates transparent peer-to-peer transactions in the agricultural sector, eliminating the need for intermediaries. By decentralizing influence, this technology redefines the concept of trust, relying on cryptography and peer-to-peer architecture. Consequently, it enhances trust between producers and consumers while reducing transaction costs in the agricultural industry. In Pakistan, index insurance is gaining prominence as a risk management tool for farmers, particularly due to the diminishing basis risk. Blockchain technology can contribute to index insurance in two ways. Firstly, real-time payments can be triggered by meteorological data through smart contracts. Secondly, by utilizing a smart oracle, climate data and relevant information such as crop growth or farm equipment can be seamlessly integrated, reducing basis risk and expediting payout processes for index insurance [41].

With the advancement and widespread adoption of distributed ledger technology (DLT), an increasing number of research projects have emerged focusing on its application in agricultural traceability systems. Feng Tian's research [42] introduces an innovative concept that combines RFID technology and blockchain for agricultural food marketplaces in China. The aim is to enhance food quality and safety while reducing losses during logistical processes. The study by Feng covers the entire data collection and information management workflow among various stakeholders in the agricultural supply chain. This comprehensive "farm to fork" solution enables monitoring, tracking, and tracing of the quality of agricultural products. In comparison to centralized approaches, Feng's solution considers the advantages and disadvantages, considering societal, financial, and technical factors.

Kumar et al. [43] conducted a study proposing a blockchain-based system for the rice supply chain, which utilizes distributed ledgers to ensure the safety of agricultural products throughout the entire supply chain. Additionally, a notable digital pilot application in agricultural supply chains is the Agri digital, blockchain maltreatment mechanism, which powers wheat trade in Australia. Moreover, Walmart, as highlighted by Kamath [44], addresses food security in supply chains through the implementation of the IBM Blockchain-based Hyperledger Fabric network. To further contribute to the existing body of knowledge and address the limited empirical research in this area, there is a need to investigate the factors influencing the adoption of blockchain technology in the agricultural supply chain system.

2.17 Unified Theory of Acceptance and Use of Technology (UTAUT)

The adoption and use of information technology (IT) by individuals has been extensively studied in the field of Information Systems (IS). Various adoption models, including the Technology Acceptance Model (TAM) and models based on the Theory of Planned Behaviour, have been proposed and tested to understand and predict consumer acceptance and usage of IT. Approximately ten years ago, Venkatesh et al. (2003) [45]

integrated these theories into the Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT identifies four key factors (performance expectancy, effort expectancy, social influence, and facilitating conditions) and four moderators (age, gender, experience, and voluntariness) that influence the behavioral intention to use technology and actual technology usage in organizational settings. According to UTAUT, performance expectancy, effort expectancy, and social influence influence the behavioral intention to adopt a technology, while behavioral intention and facilitating conditions determine the actual technology usage. Additionally, four moderator patterns have been hypothesized and proposed to regulate specific interactions within the UTAUT framework.

2.18 Transparent Piezoelectric Nanogenerator for Self-Powered Force Sensing Applications.

In a study conducted by [46], a transparent piezoelectric nanogenerator (PENG) utilizing poly (vinylidene fluoride-co-tetrafluoroethylene) (P(VDF-TrFE)) was developed as a self-powered force sensor. The P(VDF-TrFE) film was positioned between two indium tin oxide-based electrodes, forming a 2x2 array of PENGs. The device exhibited stable and repeatable piezoelectric response, with a sensitivity of 0.3 V N^ (-1), showing a linear increase with applied compressive force. The output voltage of the devices varied with the frequency of the external force, demonstrating a sensitivity of 0.25 V Hz^ (-1) within the range of 2 to 10 Hz. Due to their exceptional dynamic force sensing capability, transparency, and self-powering feature, these devices have great potential for applications like see-through smart plasters, enabling wound healing monitoring without the need for plaster removal.

2.19 Piezoelectric Resonating Force Sensor in the Second Vibration Mode

In [47], researchers explored a resonant force sensor that utilized a metal bridge coated with a piezoelectric film for detecting forces. The sensor was designed to operate in the second mode of bending vibration, characterized by a single node positioned at the middle of the bridge. An analytical model was developed to analyze the resonance frequency and piezoelectric coupling, and its results were compared to finite element analysis (FEA) within the desired force range. The resonance frequency-force relationship of the analytical model closely aligned with the FEA results across the force range. In the small force region, the coupling factor-force relationship of the analytical model agreed with the FEA results, but it exhibited a slightly lower coupling in the large force region.

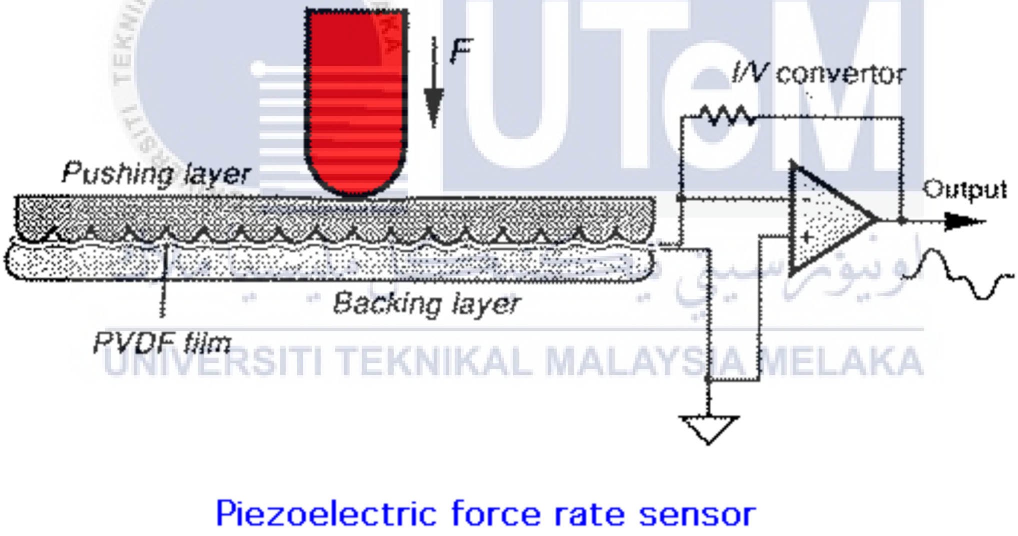

Figure 2.15 Piezoelectric Force Rate Sensor

The force sensor discussed in [47] is a vibrating piezoelectric bridge structure designed to operate in the second flexural vibration mode. In this mode, the bridge features a single node located at its center and is fixed at both ends. As a result, the bridge vibrates anti-symmetrically around its center, while the center of mass remains stationary. This unique vibration mode offers advantages such as higher Q-factor, reduced mechanical energy loss, and minimized fatigue at the fixed edges, distinguishing it from the first mode and other odd-numbered vibration modes. The study investigates the resonance frequency and piezoelectric coupling of the force sensor using an analytical model and validates the results through finite element analysis.

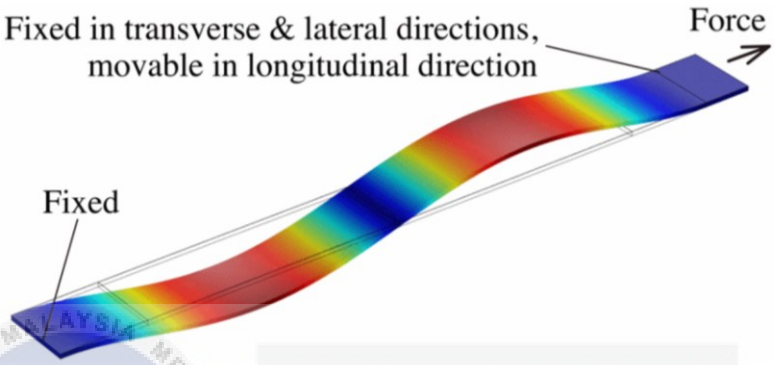

Figure 2.16 FEA model of the vibrating bridge in the second flexural mode. Color gradation expresses the absolute transverse displacement

2.20 Supply of Electricity Through Renewable Energy Sources in Energetic Dark Greenhouse

Thermal power plants account for approximately 30 to 40% of carbon emissions [49]. Considering their significant contribution to greenhouse gas emissions, replacing thermal power plants with renewable energy sources in the EDG (Energy Distribution Grid) would result in a substantial reduction in carbon emissions [50-51]. By utilizing renewable resources in the EDG, long-term energy security and environmental sustainability can be achieved [52]. The primary energy consumption in the EDG is allocated to the intelligent lighting system and cooling purposes. To fulfill the heating, cooling, and lighting requirements of the EDG, solar energy, biomass energy, geothermal energy, and wind energy can be effectively employed. The suitability of these renewable energy sources for the EDG depends on their local availability, which is influenced by the prevailing climate conditions [51].

2.20.1 Solar Energy

In a study conducted by Kumar et al. [43], a blockchain-based system for the rice supply chain was proposed to ensure the safety and integrity of agricultural products throughout the supply chain. Additionally, Agridigital's blockchain maltreatment mechanism has been implemented in Australia for digital wheat trade, serving as a prominent pilot application in agricultural supply chains. Furthermore, Kamath [44] highlights Walmart's adoption of the IBM Blockchain-based Hyperledger Fabric network to address food security concerns in their supply chains. However, despite these notable studies, there remains a research gap in empirical research, necessitating further investigation into the factors influencing the adoption of blockchain in the agricultural supply chain system.

Figure 2.17 Solar panel

2.20.2 Geothermal Energy

Geothermal heat pumps offer a notable benefit when utilized for greenhouse heating due to their lower environmental impact. These heat pumps surpass traditional heating systems in terms of performance, return on investment, and maintenance costs. By replacing fossil fuel systems with clean and renewable energy sources, greenhouse gas emissions and pollution can be significantly reduced.

Figure 2.18 Geothermal Energy

2.20.3 Biomass Energy

The selection of a biomass boiler and steam boiler for energy production in greenhouses is influenced by factors such as the heating system's location, the number of greenhouses, and their types [53]. Additionally, the leftover processed waste from the products can be utilized to generate bioenergy and meet the energy needs within the greenhouse value cycle [54].

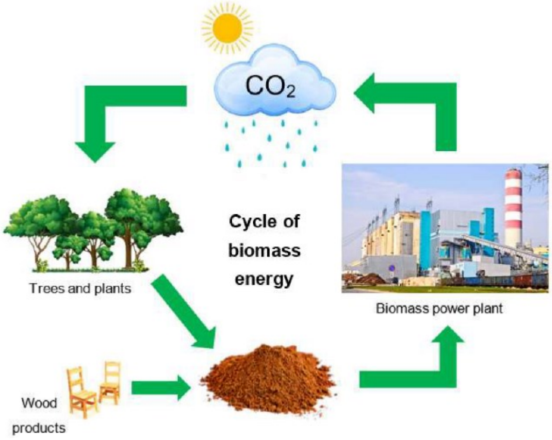

Figure 2.19 Biomass Energy

2.20.4 Wind Energy

Wind turbines offer the potential to supply a substantial amount of the energy needed for greenhouse operations [55]. Areas with higher average wind speeds, such as coastal, mountainous, and plain regions, are particularly advantageous for wind energy generation. The selection of appropriate wind turbines for energy supply may vary depending on the specific construction site. Factors such as local topology, vegetation, and surrounding building structures, both in urban and rural areas, significantly influence the average wind speed.

Figure 2.20 Wind Energy

2.21 Plant And Taste to Reap with Internet Of Things

The PATRIOT project, developed by S. P. Takekar in 2017, seeks to revolutionize the agricultural sector in India by addressing the challenges faced by farmers. While existing implementations of the Internet of Things (IoT) focus on plant disease detection and automation, PATRIOT places emphasis on increasing farmer income and offering consumers competitively priced organic produce. An innovative aspect of PATRIOT is its utilization of IoT to generate funds for implementing IoT in agriculture. By introducing the concept of "Anywhere-Anytime" farming, PATRIOT aims to enable individuals to engage in farming while maintaining their current lifestyles. The project's overarching objectives include empowering farmers, enhancing their prosperity, providing affordable food to consumers, and contributing to the nation's development [57].

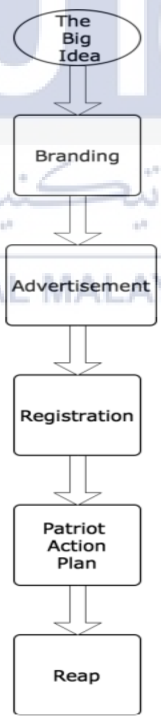

Figure 2.21 Methodology of PATRIOT

2.22 Comparison of Solar Panel and Rainwater System

The process of comparing and analyzing similar studies plays a vital role in gaining a deeper understanding of the progress, trends, and advancements within a particular field of study or industry. This comparative analysis serves as a valuable tool for researchers, practitioners, and stakeholders, allowing them to gain valuable insights, identify gaps in knowledge, and gather up-to-date information to foster innovation and improve outcomes. In Table 2.1, a comprehensive literature review is presented, focusing on the development of power generation for the agriculture industry through the utilization of solar energy and rainfall. The comparison includes an examination of the methodologies employed and the objectives pursued by previous researchers in this domain. By conducting this comparative analysis, valuable insights can be derived, enabling researchers to build upon existing knowledge and contribute to the ongoing evolution and improvement of sustainable power solutions for the agriculture sector.

Table 2.1 Comparison of previous literature

Author	System / Method	Objectives	Comment
Abhishek Kumar Tripathi (2019)	Active tracking and passive tracking are the main methods employed for maximizing solar power generation systems	Track the sun’s motion in a single direction	Not suitable in Malaysia because Malaysia is close to the equator
S. Tenzin (2017)	Low cost weather station for climate-smart agriculture	Managing inputs based on climate condition	Very expensive equipment to do, below budget

Author	System / Method	Objectives	Comment
Yin Yikang (2020)	Design of rainwater collection System	Develop an innovative rainwater harvesting module	Good method and easy to build
Campisano (2012)	Rainwater Harvesting	To assess the feasibility of rainwater harvesting (RWH) systems by considering factors such as storage capacity, water demand pattern, roof area, and rainfall profile	Simple and cheap but doesn't have a solar system.
M. Reza Hidayat (2019)	Soft Water Tank Level Monitoring System Using Ultrasonic HC-SR04 Sensor Based On ATMega 328 Microcontroller.	To monitor the water level in the soft water tank and automate the water filling and transfer processes	Very efficient

Author	System / Method	Objectives	Comment
H. Varikoden (2011)	Rainwater Harvesting (RWH) and the Diurnal Patterns	To highlight the significance of implementing rainwater harvesting (RWH) as a solution to address the risk of soil erosion in expanding solar farms	Very efficient but too complex.

2.23 Summary

Malaysia's tropical climate, characterized by high temperatures, abundant rainfall, and ample solar radiation, presents a unique opportunity for the development of sustainable agriculture practices that harness the power of solar energy and rainwater harvesting, as evidenced by the comprehensive literature review and comparison of previous studies presented in the chapter. The review highlights the progress, challenges, and future prospects of various technologies and methods for capturing and converting solar energy into electricity or heat, such as photovoltaic systems, solar thermal collectors, and tracking systems, as well as different types of rainwater harvesting systems, such as rooftop, surface, and rock catchments, and their applications and benefits for irrigation, domestic, and industrial purposes. The chapter also analyzes the climatic conditions of Malaysia, such as temperature, precipitation, and solar radiation, and how they affect the potential and feasibility of solar and rainwater-based power generation systems. The chapter concludes that Malaysia's climate is conducive to the development of sustainable agriculture practices that harness the power of solar energy and rainwater harvesting, and that the implementation of such practices can lead to significant economic, social, and environmental benefits for the country. By adopting these practices, Malaysia can reduce its dependence on fossil fuels, increase its energy security, and mitigate the adverse effects of climate change, while also promoting the growth of its agricultural sector and improving the livelihoods of its farmers and rural communities. In summary, the chapter provides a comprehensive and insightful analysis of the potential and challenges of solar and rainwater-based power generation systems in Malaysia, and offers valuable recommendations for policymakers, researchers, and practitioners in the field of sustainable agriculture and renewable energy.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In general, when developing solar and rainwater electricity systems for the agricultural industry, it is important to find a balance between accuracy and effectiveness. Accuracy refers to how closely our estimated electricity generation matches the actual values, but achieving high accuracy often requires more resources. On the other hand, effectiveness focuses on estimating electricity generation with fewer resources while accepting a reasonable level of accuracy loss. Striking this balance in agriculture ensures reasonably accurate estimates, enabling farmers to effectively plan their energy needs while optimizing resource usage.

3.2 Methodology

The initial step of the process involves the solar panels capturing sunlight and converting it into direct current (DC) power. Subsequently, the flowchart assesses the system to determine the presence of an inverter. In cases where no inverter is detected, the DC power is efficiently stored in batteries, ensuring its availability during periods of limited or no sunlight. On the other hand, if an inverter is present, the DC power undergoes a conversion process to transform it into alternating current (AC). This AC power is then appropriately stored, ready to be utilized later to meet various electrical demands. Finally, the flowchart concludes its comprehensive sequence of stages.

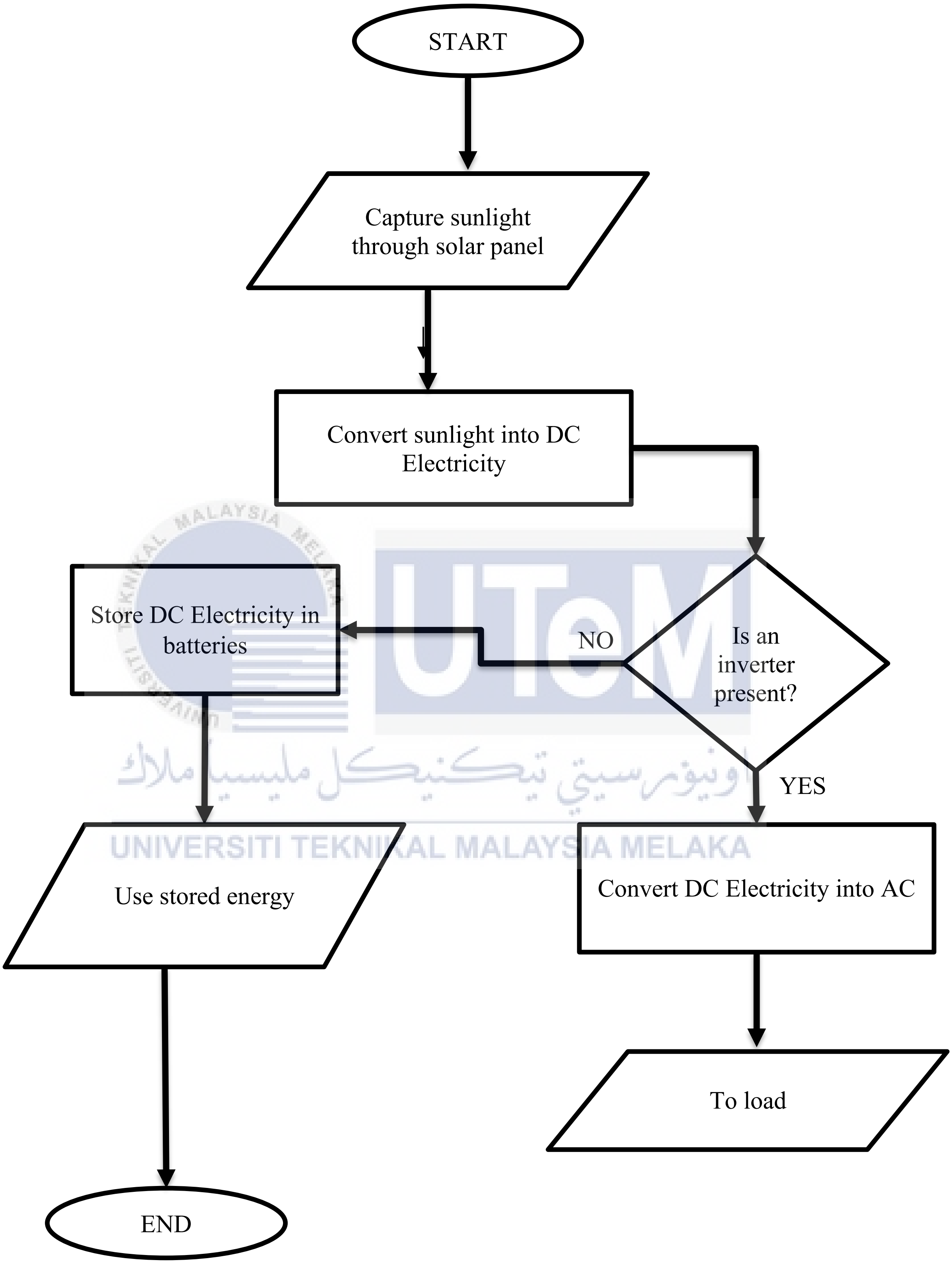

Figure 3.1 Flowchart for Solar

The proposed rainwater harvesting system incorporates a PVC channel with a Water Turbine and Dynamo to generate electricity. Rainwater will flow through this channel and be distributed among five tanks, divided into two sections: Tank A and Tank B. Tank A comprises three tanks that serve as backups in case of insufficient solar energy or blackouts, while Tank B consists of two tanks designated for domestic use. Each tank is equipped with a 12V water valve that opens when the Ultrasonic HC-SR04 Sensor detects the water level reaching 95% capacity, allowing excess water to be directed to the overflow pond. Among the three tanks in Tank A, one is equipped with an emergency power supply. The flow of water through the PVC channel is controlled by a 12V water valve, which can be operated using an Arduino-powered push button. In the event of an emergency, the water will overflow into the overflow pond.

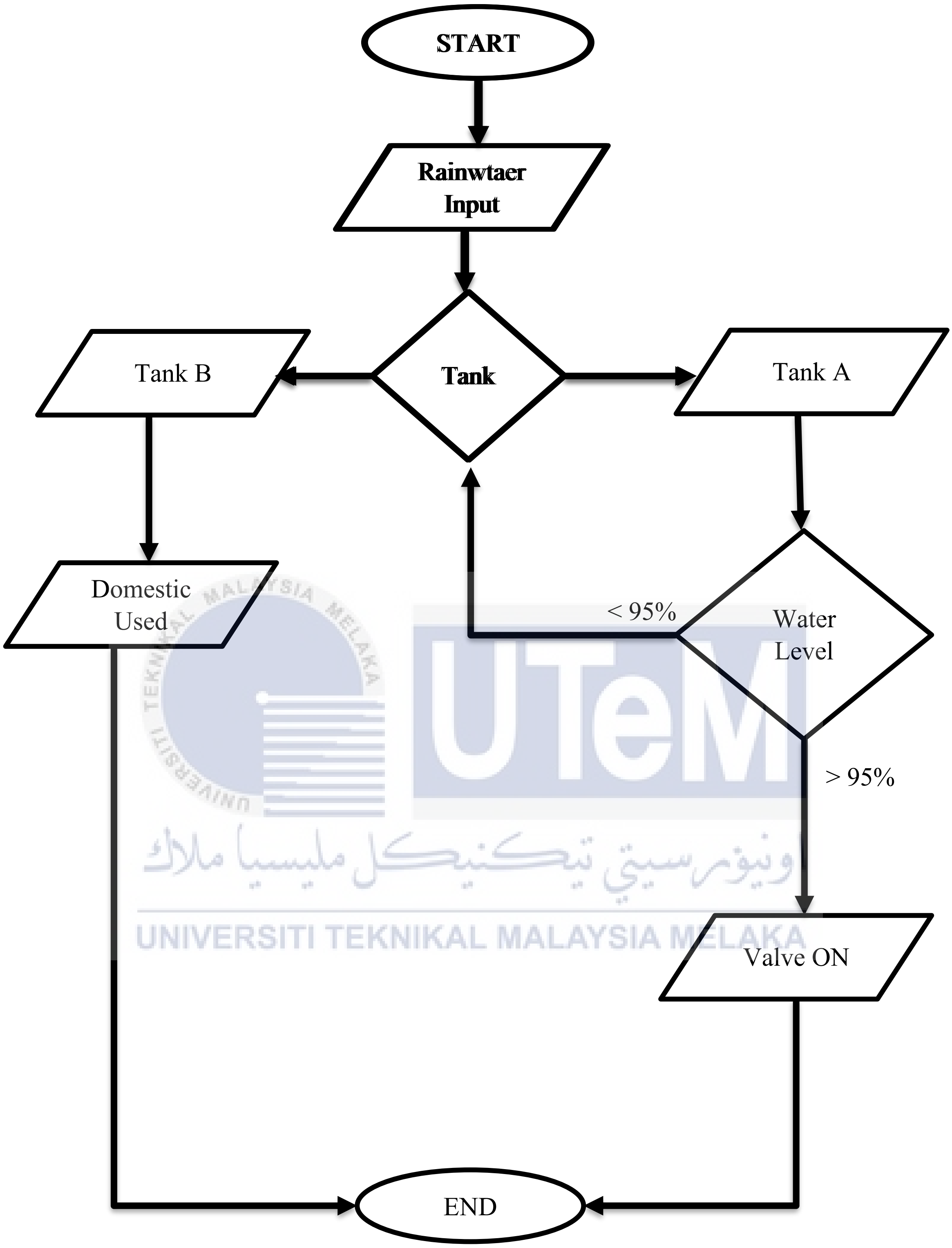

Figure 3.2 Flowchart for Rainwater System

Solar energy serves as a primary energy source for the agricultural industry, capitalizing on the abundant sunlight during hot weather conditions. The process initiates by solar panels capturing sunlight and converting it into direct current electricity. Next, the flowchart verifies the presence of an inverter in the system. In case of no inverter, the DC electricity gets stored in batteries; whereas, with an inverter, the DC electricity undergoes conversion to AC electricity. Subsequently, the flowchart examines the necessity for rainwater. If rainwater is not needed, it is collected and stored in a tank for domestic usage. Conversely, if rainwater is required, it goes through a process that generates DC electricity, followed by conversion to AC electricity. Finally, the flowchart concludes its sequence of actions.

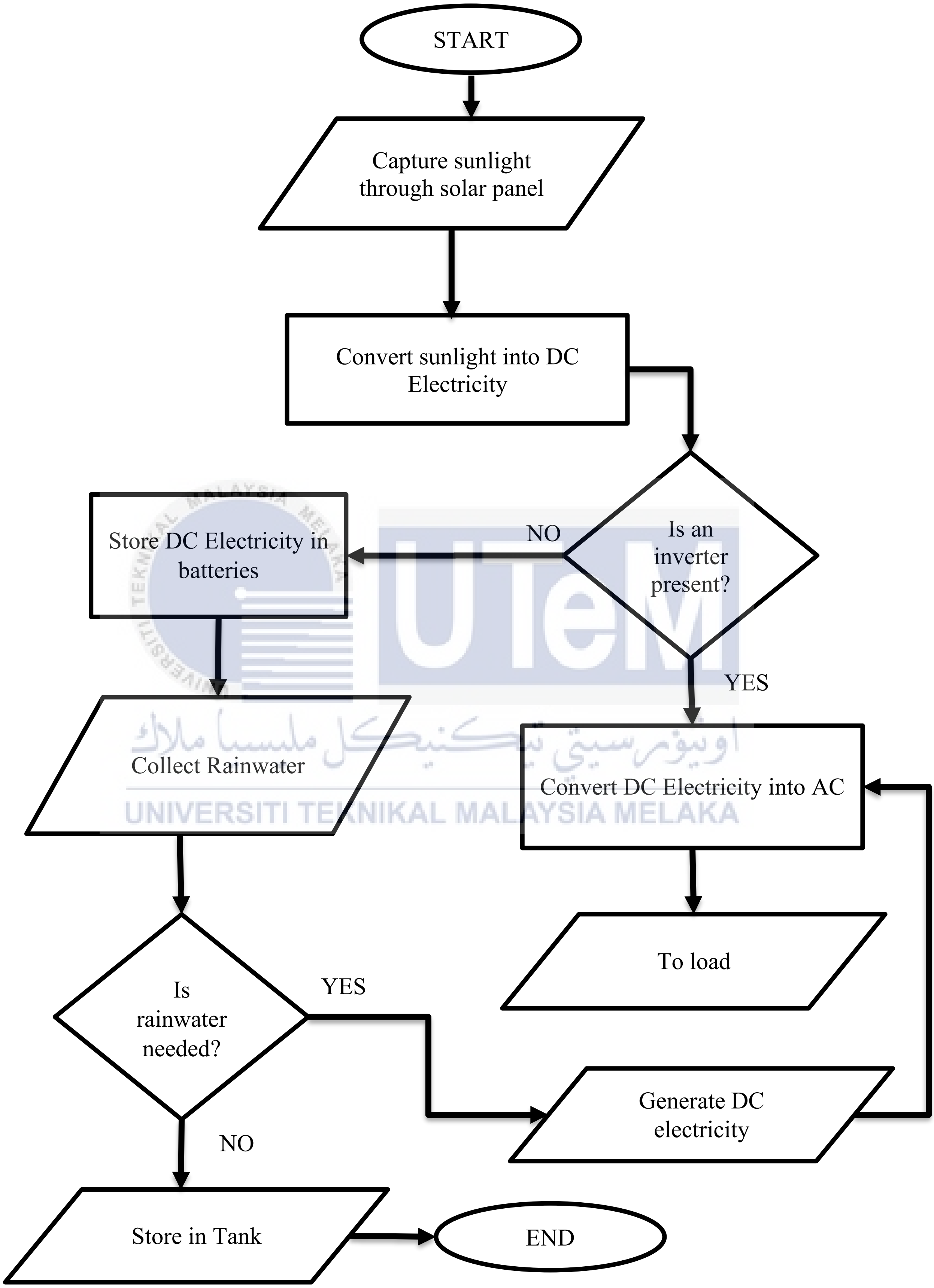

Figure 3.3 Flowchart For Solar and Rainwater System

3.2.1 Experimental setup

In this agricultural industry experiment, a suitable field is selected, considering crop type, soil conditions, and water availability. Water usage, energy consumption, and costs are measured before implementing the integrated solar energy and rainwater harvesting system. The system, including solar panels, irrigation infrastructure, rainwater collection, and monitoring, is designed and installed. Water usage is tracked, energy consumption is monitored, crop yield and quality are assessed, and the system's environmental impact is analyzed. Farmers' satisfaction is also evaluated. By comparing post-installation measurements to baseline data, the system's effects on water consumption, energy usage, crop productivity, cost savings, sustainability, and farmer satisfaction are determined.

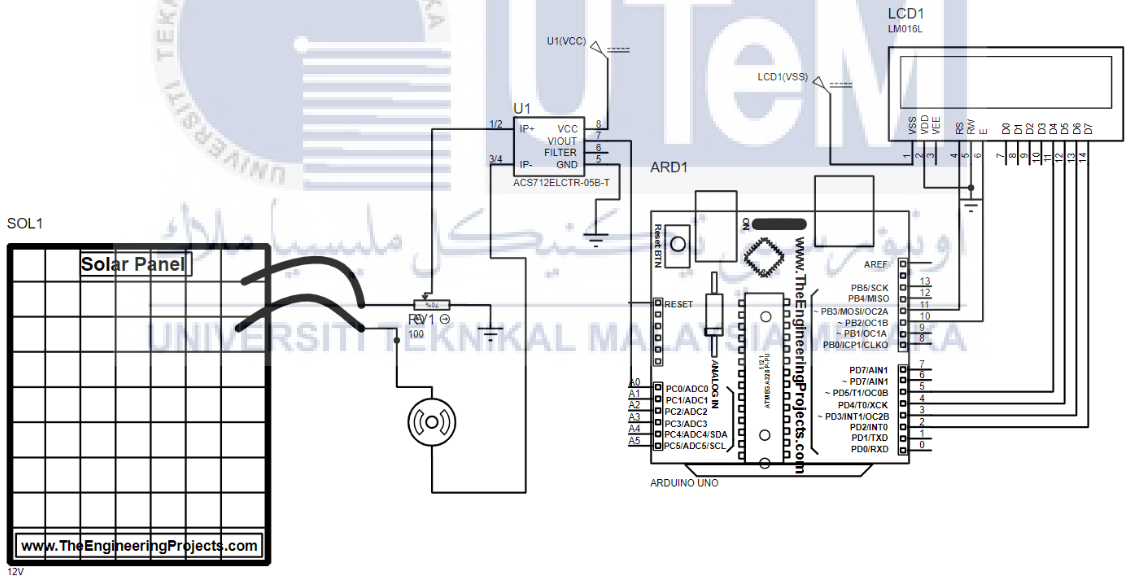

Figure 3.4 Schematic Diagram For Solar

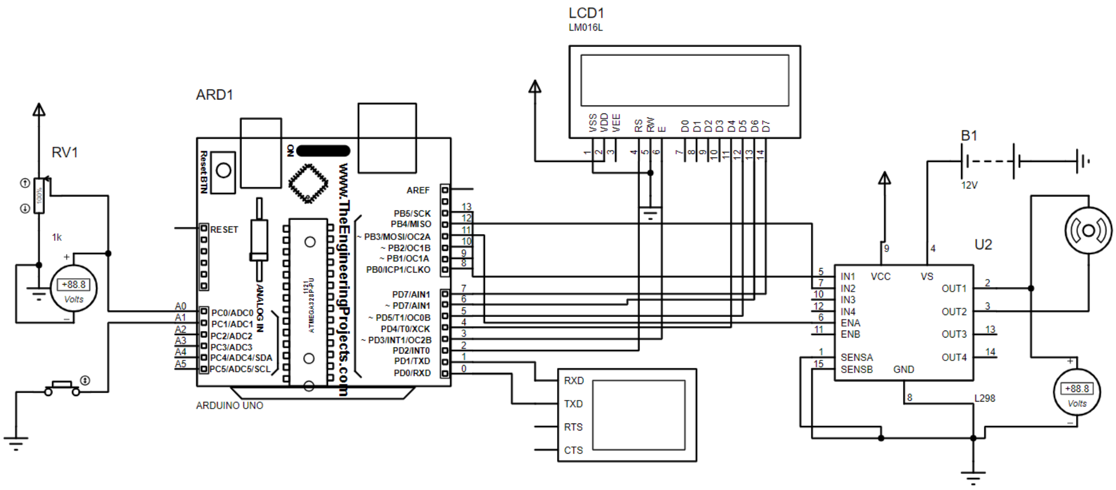

Figure 3.5 Schematic Diagram for Rainwater Tank Level

3.2.1.1 Parameters

To establish the viability and effectiveness of utilizing solar and rainwater for electricity generation in the agricultural industry, several parameters need to be considered. These include measuring sunlight intensity to determine solar energy availability, analyzing rainfall patterns to assess water availability, evaluating energy storage capacity, considering land availability for infrastructure installation, identifying maintenance requirements, assessing economic factors, examining integration with existing infrastructure, and addressing potential encroachment issues. By thoroughly evaluating these parameters, the potential success and practicality of implementing this approach in the agriculture business can be determined.

3.2.1.2 Direction and Angle of Installation for Solar panel

The optimal positioning of solar panels is contingent upon the geographical location in which they are installed. The generation of the highest energy output from solar panels occurs when they are oriented directly towards the sun. However, due to the dynamic nature of the sun's position, which varies throughout the day and across different seasons, the ideal angle for maximizing sunlight absorption is not fixed. Therefore, in order to ensure the most advantageous sunlight exposure, a two-step process is recommended. Firstly, the most suitable direction for panel placement needs to be determined, taking into account the sun's path in the specific geographical location. Subsequently, the optimal tilt angle must be calculated, considering the seasonal variations in the sun's height above the horizon. By following this formal approach, the solar panels can be positioned optimally to harness the maximum available sunlight for energy generation [62].

When determining the optimal positioning of solar panels, there are a few key parameters to consider. These include:

- Latitude: The latitude of your location, measured in degrees, plays a crucial role. It can be obtained from various online tools or maps.
- Solar Declination: Solar declination is the angle between the equatorial plane and the solar rays reaching the Earth's surface. It varies throughout the year due to the Earth's axis tilt. Tables or formulas provide solar declination values for different dates.
- Adjustment Angle: The adjustment angle allows for fine-tuning the tilt angle based on specific objectives. It takes into account factors such as seasonal variations, desired energy production, or local conditions. This angle is typically a small adjustment applied to the calculated tilt angle.

Tilt Angle = Latitude + Solar Declination ± Adjustment Angle

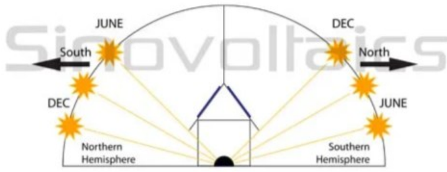

Figure 3.6 Direction and Angle of Installation

3.2.1.3 Formula Velocity Of Water Flow

The velocity of water flow in a downspout can be predicted using a formula based on principles of fluid mechanics, specifically the mass conservation principle. According to this principle, the mass flow rate entering a system is equal to the mass flow rate exiting the system. To calculate the velocity of water flow in the downspout, the formula :

$V = Q / A$ can be used.

In this formula:

- V represents the velocity of water flow in the downspout (measured in m/s).
- Q is the volumetric flow rate of water (measured in m^3/s).
- A denotes the cross-sectional area of the downspout (measured in m^2).

Before applying this formula, it is essential to determine two key parameters: the volumetric flow rate of water and the cross-sectional area of the downspout. The volumetric flow rate can be computed using the formula Q = A_downspout * V_rain, where A_downspout represents the downspout's cross-sectional area (in m^2) and V_rain is the velocity of rainfall (in m/s). The cross-sectional area of the downspout can be directly measured, while the velocity of rainfall can be obtained from meteorological data or rainfall intensity measurements. To estimate the velocity of water flow in the downspout, substitute the value of Q from the second formula into the first formula. However, it is important to note that this formula provides an estimation, as actual flow velocities can be influenced by factors such as pipe roughness, internal obstructions, and other hydraulic considerations specific to the design and configuration of the downspout [63].

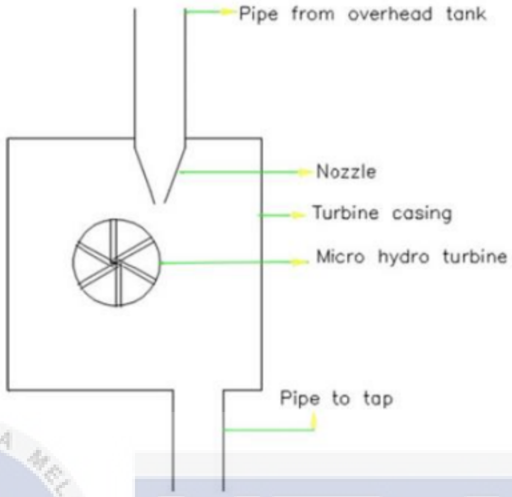

Figure 3.7 Assembly of Turbine

3.2.2 Equipment

Several components are used to ensure that the hardware is able to perform its intended function effectively. First, the charge controller, Solar Polycrystalline Panel, DC Water Flow Pump Turbine Hydroelectric Power Energy Generatorand inverter that converts DC to AC provide the necessary power supply to the Arduino microcontroller. In addition, an ultrasonic HC-SR04 sensor is used to detect the water level in the tank enabling efficient monitoring. The LCD is to display the voltage from solar. Arduino works as a processor to receive input data from solar and sensor.

3.2.2.1 Battery Charge Controller

The battery charge controller (BCC) plays a crucial role in managing the flow of electricity from the photovoltaic (PV) generator to the battery. Its primary objective is to carefully regulate the voltage and current derived from the PV array to prevent the battery from experiencing detrimental overcharging or overdischarging. By constantly monitoring the battery's state of charge and voltage level, the BCC optimizes the charging process, ensuring that the battery does not exceed its maximum capacity. It achieves this by reducing the charging current to prevent overcharging and adjusting the discharge rate to prevent excessive discharge during periods of high-power demand or limited sunlight availability. Advanced BCCs also incorporate sophisticated features such as maximum power point tracking (MPPT) algorithms, which maximize energy harvesting by fine-tuning the PV system's operating conditions, as well as temperature correction mechanisms that account for fluctuations in temperature. Additionally, these controllers provide protective functions like overvoltage and undervoltage protection to safeguard the battery and enhance the overall performance and longevity of the PV system. Through its effective management of power flow, the BCC ensures optimal battery health, maximizes energy utilization, and contributes to the long-term success of the PV system [65].

Figure 3.8 Battery Charge Controller

3.2.2.2 Solar Polycrystalline Panel

There are two main types of solar energy receivers commonly used: monocrystalline and polycrystalline solar panels. Both types utilize solar cells made from silicon, which is also used in the production of electronic chips [67]. Figure 3.9 shows the difference between monocrystalline vs polycrystalline solar panels.

FACTOR	MONOCRYSTALLINE SOLAR PANELS	POLYCRYSTALLINE SOLAR PANELS
Silicone Arrangement	One pure silicon crystal	Many silicon fragments melded together
Cost	More expensive	Less expensive
Appearance	Panels have black hue	Panels have blue hue
Efficiency	More efficient	Less efficient
Lifespan	25-40 years	20-35 years
Temperature Coefficient	Lower temperature coefficient, making them more efficient in heat	Higher temperature coefficient, making them less efficient in heat

Figure 3.9 Monocrystalline Vs. Polycrystalline Solar Panels

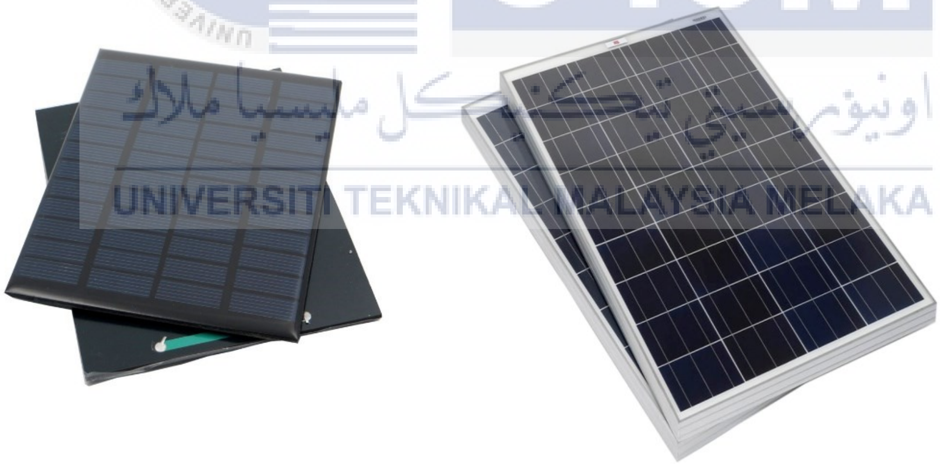

Figure 3.10 Polycrystalline And Monocrystalline Solar Panels

3.2.2.3 DC Water Flow Pump Turbine Hydroelectric Power Energy Generator

The main function of prime movers or hydro turbines is to convert the kinetic energy of the water into mechanical energy to produce electric power. The DC Water Flow Pump Turbine Hydroelectric Power Energy Generator is a compact and lightweight device weighing only 90g/3.2oz. This versatile generator operates efficiently at three selectable voltage levels: 5V, 12V, and 80V (optional). It delivers impressive performance, offering a maximum output voltage of 80V at 1.2mpa and a maximum output current of 220mA at 12V. With a line-to-line resistance of 10.5 ± 0.5 Ω and excellent insulation resistance of 10 mΩ (DC100 tram egger), it ensures reliable and safe operation. Designed to withstand varying pressures, it can handle a maximum pressure of 0.6mpa for the closed outlet and 1.2mpa for the open outlet while requiring a minimal starting water pressure of just 0.05mpa. The generator operates smoothly with an axial clearance range of 0.2-1.0mm, ensuring optimal performance. Additionally, it operates quietly, emitting mechanical noise levels below 55dB, and has a long generator life of at least 3000 hours [70].

Figure 3.11 DC Water Flow Pump Turbine Hydroelectric Power Energy Generator

3.2.2.4 Arduino Uno

Within the system, Figure 3.12 showcases the Arduino Uno, which functions as the central processing unit. Responsible for executing programmed instructions and facilitating the coordination of other system components, the Arduino Uno plays a vital role. Equipped with a flexible input/output interface, it seamlessly interfaces with an array of sensors and actuators. This versatility enables users to establish connections and communicate with various devices. The Arduino Uno's programmable nature empowers users to create and upload custom code, granting them control over processes and enabling automation based on sensor inputs and desired output actions.

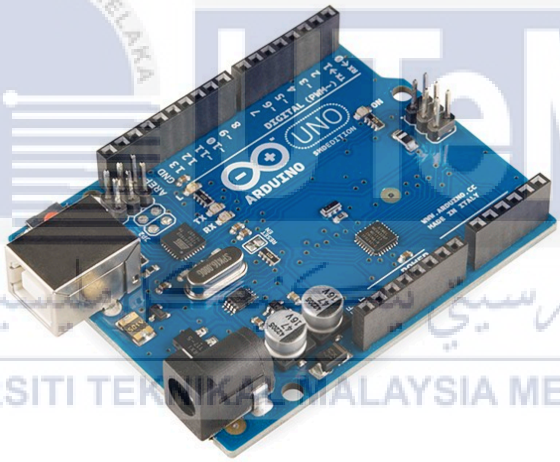

Figure 3.12 Arduino Uno

3.2.2.5 Ultrasonic HC-SR04 Sensor

The HC-SR04 ultrasonic sensor utilizes SONAR technology to measure distances, similar to how a bat navigates its surroundings. This sensor provides exceptional non-contact range detection with remarkable precision and consistent readings. It comes in a user-friendly package, offering a detection range of 2 cm to 400 cm (or 1" to 13 feet). The sensor is specifically employed for monitoring water levels in tanks, ensuring that the tank does not exceed its capacity. By detecting the density of the tank, the sensor can accurately identify when the tank reaches 90% capacity, prompting the opening of the overflow pipe to prevent overflow.

Figure 3.13 HC-SR04 Ultrasonic Sensor

3.2.2.6 Battery

The most fundamental type of 12V battery is the lead-acid battery, which consists of lead plates immersed in a sulfuric acid solution. This chemical arrangement facilitates a reaction that enables energy storage. Among lead-acid batteries, the flooded lead-acid battery is widely adopted. It serves as a common choice for storing DC power generated by solar panels and generators, effectively harnessing and preserving renewable energy.

Figure 3.14 12V lead-Acid Battery

3.3 Limitation of proposed methodology

The proposed method of utilizing solar energy and rainfall to generate power for the agriculture industry has several limitations. Firstly, the unpredictability of solar energy, influenced by weather conditions, can affect the reliability of power generation. Secondly, energy shortages may occur during periods of low solar radiation due to the limited capacity of energy storage devices. Thirdly, the availability and quality of precipitation can vary, impacting its suitability for irrigation and hydropower. Additional constraints include land and infrastructure requirements, maintenance challenges, economic viability, integration with existing systems, and environmental considerations. Effectively addressing these limitations is crucial to ensure the efficiency and sustainability of the suggested approach in meeting the energy demands of the agriculture sector.

3.4 Summary

This chapter presents a proposed methodology to develop a new, effective, and integrated approach in the world of agriculture in Malaysia. the focus of the proposed methodology is to generate electricity for the agricultural industry by harnessing the power of solar energy and rainwater. Solar panels are used to capture sunlight and convert it into electricity, while rainwater is collected and used for irrigation and potential hydropower generation. The main purpose of this method is not to produce electricity, but, for efficiency, ease of use and manipulation, and practicality of use on large-scale distribution networks.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

In the pursuit of sustainable energy solutions for the agricultural industry, the results and analysis of the development of electricity using solar and rainwater for the agricultural industry are presented in this chapter. A detailed exploration of diverse parameters, including variations in bottle volumes (1.5 liters, 5.5 liters, and 9.5 liters) and installation heights (ranging from 1 to 6 feet), was conducted. The primary objectives were to determine the output voltage and flow rate across this matrix of combinations, providing valuable insights into the efficiency and feasibility of the proposed system. The agricultural sector stands at the intersection of tradition and modernity, where innovative solutions are imperative to address energy challenges sustainably. In this context, harnessing solar energy and rainwater presents a promising avenue for electricity development, offering potential benefits in terms of both resource utilization and environmental impact. Unexplored territories were ventured into by incorporating an array of bottle volumes and installation heights. The selection of three distinct bottle volumes and six varying heights allowed for a nuanced understanding of their combined impact on output voltage and flow rate. This approach, grounded in diversity, forms the bedrock for a holistic assessment of the proposed electricity generation system. A key focus of the investigation was to ascertain the output voltage and flow rate across the spectrum of bottle volumes and installation heights. By meticulously collecting and analyzing data from each scenario, correlations were drawn, trends were identified, and practical insights into the dynamics of electricity generation within the agricultural context were provided. These findings hold the potential to inform future implementations and optimizations of similar systems. Adding depth to the exploration, additional analysis was conducted specifically for the 1.5-liter bottle, using the continuous method for voltage output measurement. This aims to distinguish nuances in the methodology, providing an opportunity to refine and improve the accuracy of the electricity generation approach.

4.2 Results and Analysis

To calculate the output voltage and flow rate from different heights with different bottle volumes, the height of the water column above the hole, the cross-sectional area of the hole, and the volume of water in the bottle need to be considered. The dimensions of the bottles provided are as Table 4.1. The 9.5-liter bottle has a width of 19.5 cm, a height of 40.7 cm, and a cover diameter of 4 cm. The 5.5-liter bottle has a width of 16 cm, a height of 34.9 cm, and a cover diameter of 4 cm. The 1.5-liter bottle has a width of 8.5 cm, a height of 31.2 cm, and a cover diameter of 2.5 cm.

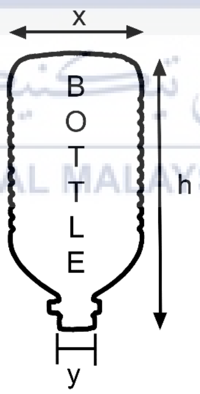

Figure 4.1 Dimension of The Bottles

Table 4.2 The dimensions of the bottles

Volume	Base Diameter (x)	Cover Diameter (y)	Height (h)
9.5 Liter	19.5 cm	4 cm	40.7 cm
5.5 Liter	16 cm	4 cm	34.9 cm
1.5 Liter	8.5 cm	2.5 cm	31.2cm

4.2.1 Data Acquisition Overview

The data acquisition overview offers a summary of the methods and procedures employed to collect information or measurements, as presented through tables and graphs, providing a clear and consistent framework for analysis.

4.2.1.1 Determination of The Height Of The Tank Position

The data and analysis obtained from the height of the existence of the tank were used to create graf below, which shows the output voltage readings for each height with different tank volumes. The heights taken were 1 ft, 2 ft, 3 ft, 4 ft, 5 ft, and 6 ft. The table provides a clear overview of the relationship between the height of the tank and the output voltage readings. This analysis is an important step in determining the optimal height for the tank to get the maximum voltage that goes through the generator. The results of this analysis can be used to provide sufficient power to farmers to prevent unwanted situations from happening.

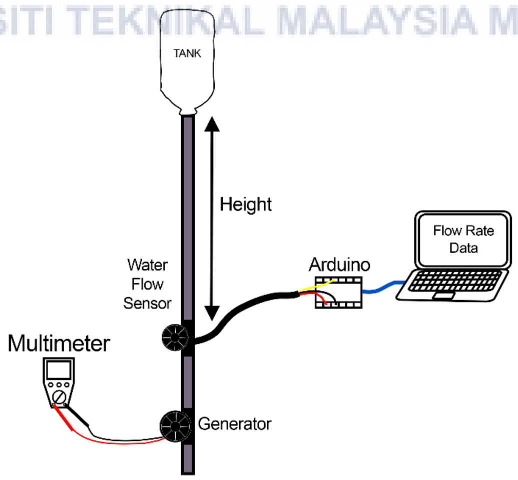

Figure 4.2 Experimental Setup

a) 9.5 Liter

Table 4.3 Voltage for 9.5 Liter

	9.5L	Heights					
		6 Feet	**5 Feet**	**4 Feet**	**3 Feet**	**2 Feet**	**1 Feet**
	Time	**Volatge (V)**					
	**2s**	1.36	1.47	1.67	1.67	1.25	1.28
	4s	1.91	1.92	1.89	1.89	1.66	1.57
	6s	2.58	2.49	2.15	2.13	1.92	1.97
	8s	3.84	2.81	2.5	2.35	2.58	2.16
	10s	4.46	3.45	3.13	3.04	2.82	2.48
	12s	4.82	3.72	3.72	3.13	3.07	2.62
	14s	5.16	4.12	3.89	3.37	3.28	3.1
	16s	5.2	4.37	4.01	3.53	3.47	3.15
	18s	5.2	4.58	4.2	3.62	3.52	3.19
	20s	5.5	4.7	4.2	3.8	3.64	3.26

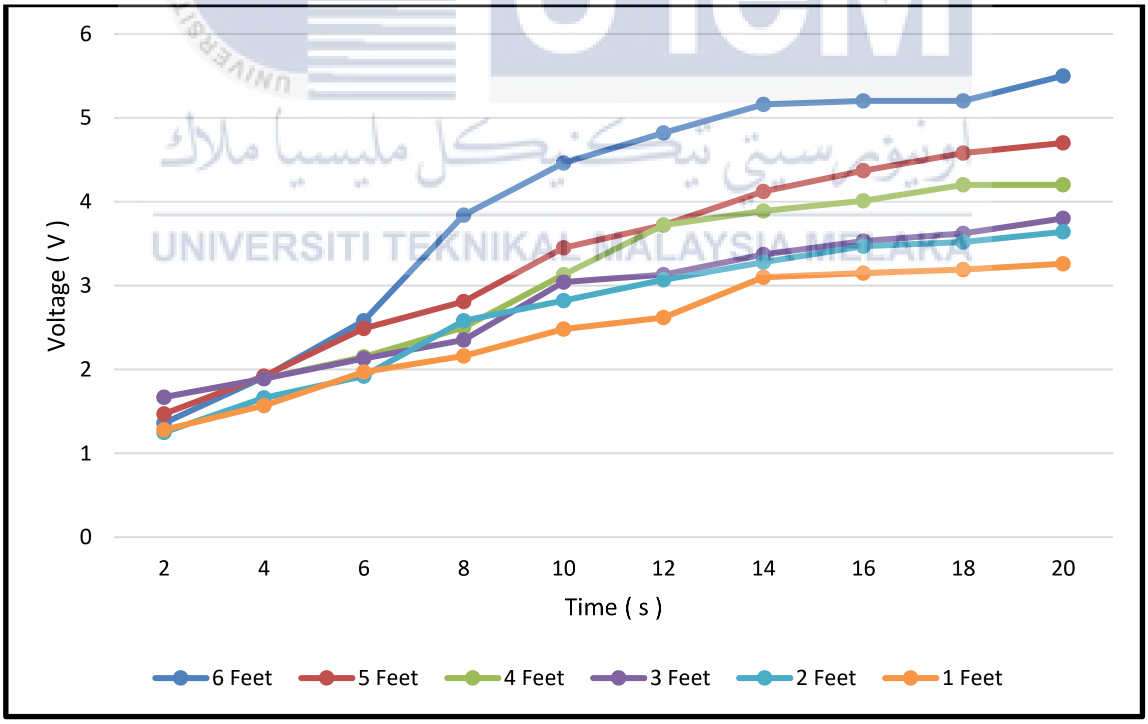

Figure 4.3 Graph Voltage vs Time

Based on the information provided, it appears that the relationship between the output voltage readings and different heights and bottle volumes is illustrated by Table 4.2 and Figure 4.3. The table has six columns for the heights (1 ft to 6 ft) and ten rows for the time intervals (2 s to 20 s), and the values in the table are the voltage readings in volts (V) for each height and time combination. It can be observed from the table that the voltage increases as the height and the time increase, and that the highest voltage for each height and time is recorded for the 9.5L bottle. On the other hand, Figure 4.3 is a graph of voltage versus time for the 9.5L bottle, and it has six lines, each representing a different height (1 ft to 6 ft). The x-axis is the time in seconds (s) and the y-axis is the voltage in volts (V). It can be seen from the graph that the voltage increases as the time increases for each height, and that the highest voltage for each time is recorded for the 6 ft height. It can also be observed from the graph that the slope of the lines decreases as the height increases, indicating that the rate of change of voltage decreases as the height increases.

b) 5.5 Liter

Table 4.4 Voltage for 5.5 Liter

5.5L	**Heights**					
	6 ft	**5 ft**	**4 ft**	**3 ft**	**2 ft**	**1 ft**
Time	**Volatge (V)**					
2s	0.78	1.27	1.27	1.66	1.38	1.23
4s	2.45	1.74	1.74	1.95	1.6	1.57
6s	3.68	2.28	2.13	2.17	1.89	1.79
8s	4.46	2.74	2.98	2.33	2.3	2.13
10s	4.73	3.79	3.01	2.89	2.57	2.46
12s	5.15	4.29	3.7	3.08	2.8	2.68
14s	5.28	4.92	4.37	3.47	3.07	3
16s	5.35	5.15	4.5	4.14	3.23	3.01
18s	5.5	5.34	4.67	4.42	3.47	3.26
20s	5.7	5.5	4.9	4.53	3.86	3.42

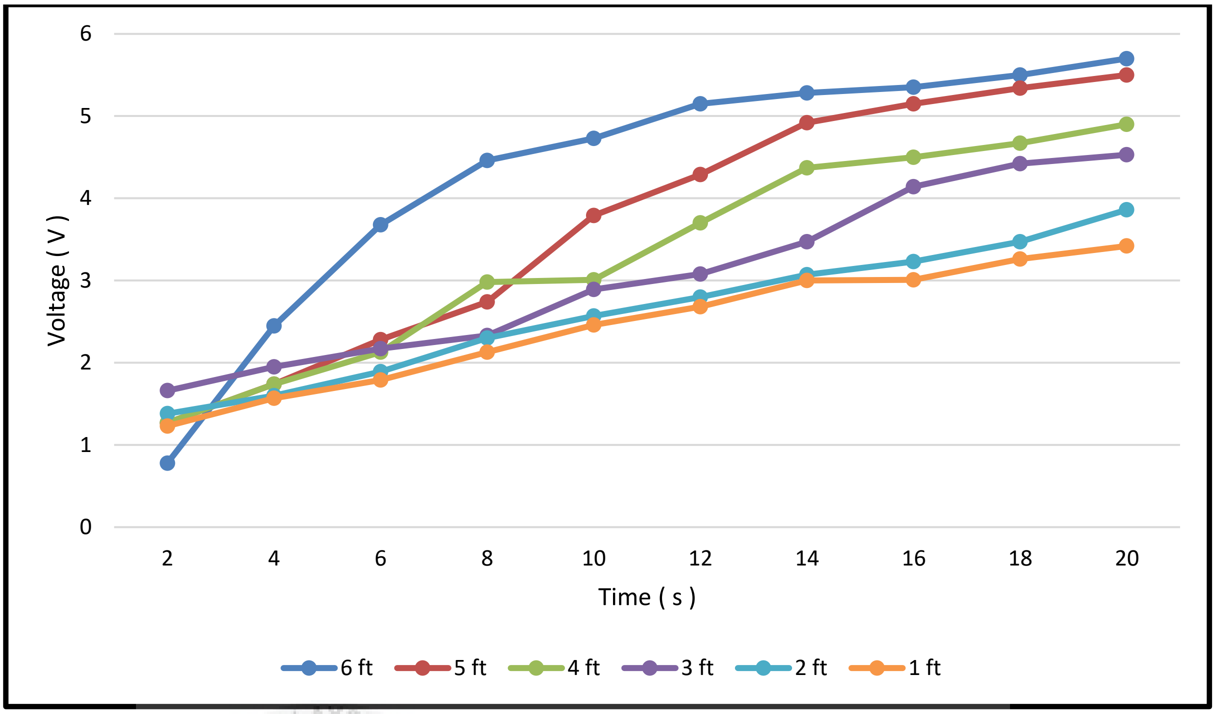

Figure 4.4 Voltage vs Time

Table 4.3 and Figure 4.4 present the outcomes of voltage output measurements from a water wheel generator employing a 5.5-liter bottle at various heights and time intervals. The table meticulously documents the voltage and flow rate every 2 seconds, spanning up to 20 seconds, across heights ranging from 1 to 6 feet. The corresponding graph illustrates the voltage plotted against time for each height, providing a visual representation of the voltage's temporal variation and trends.

c) 1.5 Liter

Table 4.5 Voltage for 1.5 Liter

1.5L	Heights					
	6 ft	5 ft	4 ft	3 ft	2 ft	1 ft
Time	**Volatge (V)**					
2s	1.4	1.39	1.63	1.87	1.34	1.26
4s	2.7	2.18	2.16	1.92	1.67	1.56
6s	3.8	2.94	2.34	2.12	1.89	1.75
8s	4.2	3.64	3.78	2.43	2.35	2.16
10s	5.5	4.39	4.01	3.22	2.57	2.44
12s	6.3	4.73	4.85	3.78	2.83	2.65
14s	6.8	5.42	5.42	4.16	3.07	3
16s	7.14	5.72	5.97	4.56	3.22	3.07
18s	7.2	6.5	6.2	5.01	3.57	3.25
20s	7.2	6.5	6.2	5.35	4.24	3.63

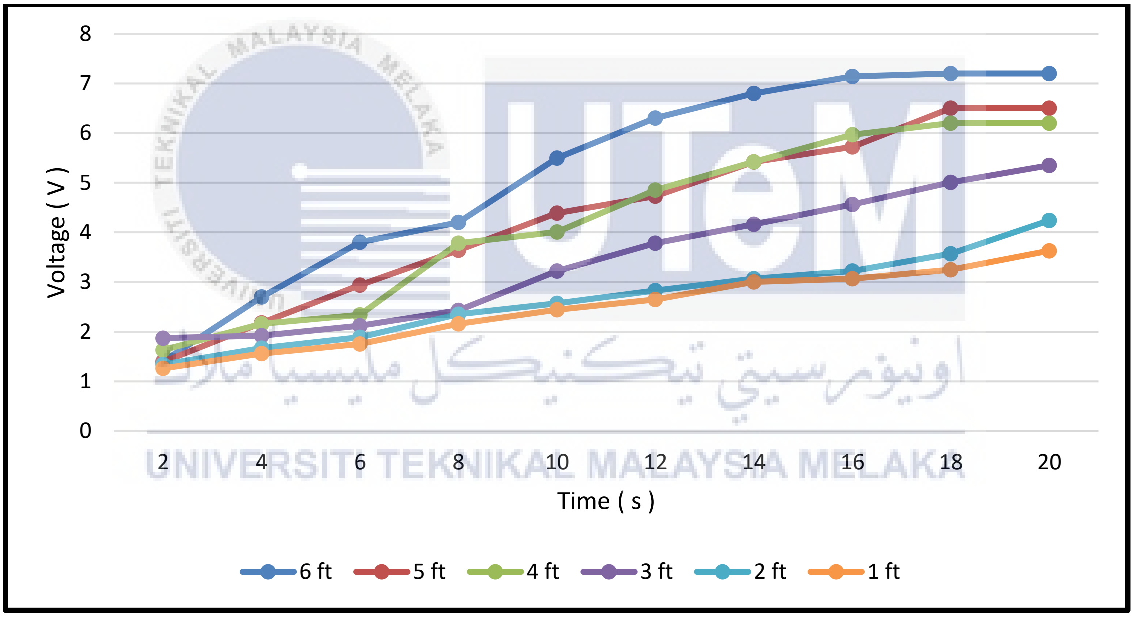

Figure 4.5 Voltage vs Time

Based on the information provided, it appears that the voltage generated by a 1.5-liter bottle at different heights and times is shown in Table 4.4, while Figure 4.5 displays the graph of voltage versus time for each height. It can be observed from the table and the graph that the voltage is directly proportional to the time and inversely proportional to the height of the bottle. This means that the voltage increases as the time increases and decreases as the height decreases. The highest voltage for each height and time is recorded for the 6 feet height, reaching up to **7.2 V** at 20 seconds. Furthermore, it can be observed from the graph that the voltage difference between two heights decreases as the height increases, which is due to the water pressure and flow rate approaching a maximum limit as the height increases, resulting in less variation in electricity generation.

4.2.1.2 Determine the Flowrate

Table 4.6 Flowrate

	Flowrate / Volume (L/min)																	
	9.5L						**5.5L**						**1.5L**					
Time / Height	**6 ft**	**5 ft**	**4 ft**	**3 ft**	**2 ft**	**1 ft**	**6 ft**	**5 ft**	**4 ft**	**3 ft**	**2 ft**	**1 ft**	**6 ft**	**5 ft**	**4 ft**	**3 ft**	**2 ft**	**1 ft**
2s	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4s	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6s	2	2	2	2	2	2	1	2	1	1	2	2	2	1	2	1	2	1
8s	2	2	2	3	2	2	2	3	2	2	2	3	2	2	2	2	3	2
10s	3	2	3	3	2	3	3	3	2	2	2	3	3	2	3	2	3	2
12s	3	3	3	4	3	4	3	4	2	3	3	4	3	2	3	3	4	3
14s	3	3	3	4	3	4	4	5	3	3	3	4	3	3	3	3	4	3
16s	4	3	4	5	3	4	4	5	3	3	3	5	4	3	4	3	4	3
18s	4	4	4	5	4	5	5	5	3	4	4	5	4	3	4	4	5	4
20s	4	4	4	5	4	5	5	5	4	5	4	5	4	3	5	4	5	4

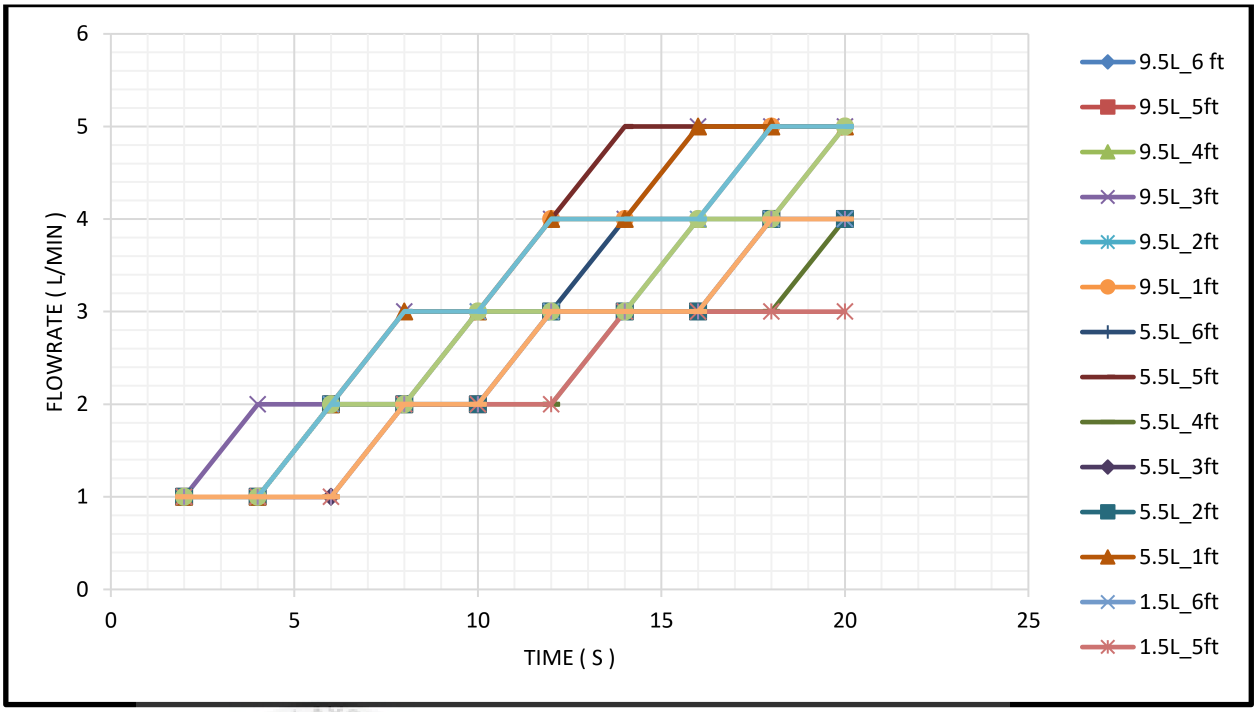

Figure 4.6 Flowrate vs Height

According to Table 4.5 and Figure 4.6, it can be concluded that the flow rate of water through a generator is directly proportional to the height of the tank and the volume of water in the tank. Specifically, the flow rate increases as the height increases for all bottle volumes, and the 9.5L bottle has the highest flow rate, followed by the 5.5L bottle and the 1.5L bottle. Additionally, the flow rate tends to stabilize after a certain time for each height and bottle volume.

4.2.1.3 Flow rate vs Voltage

a) 9.5 Liter

Table 4.7 Voltage and Flow rate for 9.5 Liter

	Voltage (V)						Flow Rate (L/min)					
	9.5L						9.5L					
Time / Height	**1 ft**	**2 ft**	**3 ft**	**4 ft**	**5 ft**	**6 ft**	**1 ft**	**2 ft**	**3 ft**	**4 ft**	**5 ft**	**6 ft**
2s	1.28	1.25	1.67	1.67	1.47	1.36	1	1	1	1	1	1
4s	1.57	1.66	1.89	1.89	1.92	1.91	1	1	2	1	1	1
6s	1.97	1.92	2.13	2.15	2.49	2.58	2	2	2	2	2	2
8s	2.16	2.58	2.35	2.5	2.81	3.84	2	2	3	2	2	2
10s	2.48	2.82	3.04	3.13	3.45	4.46	3	2	3	3	2	3
12s	2.62	3.07	3.13	3.72	3.72	4.82	4	3	4	3	3	3
14s	3.1	3.28	3.37	3.89	4.12	5.16	4	3	4	3	3	3
16s	3.15	3.47	3.53	4.01	4.37	5.2	4	3	5	4	3	4
18s	3.19	3.52	3.62	4.2	4.58	5.2	5	4	5	4	4	4
20s	3.26	3.64	3.8	4.2	4.7	5.5	5	4	5	4	4	4

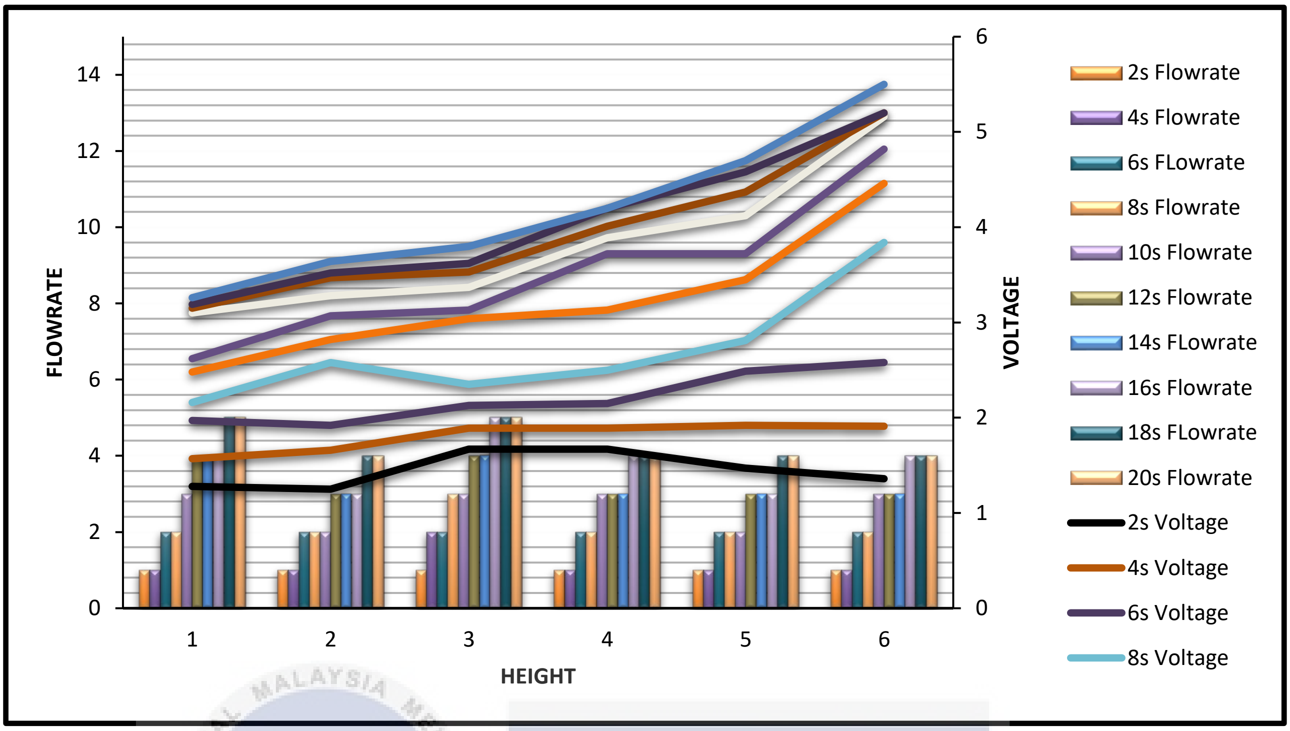

Figure 4.7 Graph 9.5 Liter Flowrate vs Voltage

According to the information provided, the output voltage and flow rate of the generator for different heights of the tank and different times, using a 9.5-liter bottle, are shown in Table 4.6. It is indicated in the table that both the voltage and the flow rate increase as the height and the time increase. On the other hand, the relationship between the voltage and the flow rate for each height, using a 9.5-liter bottle, is shown in Figure 4.7. It is indicated in the figure that the voltage is proportional to the flow rate, meaning that the higher the flow rate, the higher the voltage. The slope of the line decreases as the height increases, meaning that the rate of change of voltage with respect to flow rate decreases as the height increases. It is suggested by this that there is a limit to how much voltage can be generated by increasing the height of the tank.

b) 5.5 Liter

Table 4.8 Voltage and Flow rate for 5.5 Liter

	Flow Rate (L/min)						**Voltage (V)**					
	5.5L						**5.5L**					
Time / Height	**1 ft**	**2 ft**	**3 ft**	**4 ft**	**5 ft**	**6 ft**	**1 ft**	**2 ft**	**3 ft**	**4 ft**	**5 ft**	**6 ft**
2s	1.23	1.38	1.66	1.27	1.27	0.78	1	1	1	1	1	1
4s	1.57	1.6	1.95	1.74	1.74	2.45	1	1	1	1	1	1
6s	1.79	1.89	2.17	2.13	2.28	3.68	2	2	1	1	2	1
8s	2.13	2.3	2.33	2.98	2.74	4.46	3	2	2	2	3	2
10s	2.46	2.57	2.89	3.01	3.79	4.73	3	2	2	2	3	3
12s	2.68	2.8	3.08	3.7	4.29	5.15	4	3	3	2	4	3
14s	3	3.07	3.47	4.37	4.92	5.28	4	3	3	3	5	4
16s	3.01	3.23	4.14	4.5	5.15	5.35	5	3	3	3	5	4
18s	3.26	3.47	4.42	4.67	5.34	5.5	5	4	4	3	5	5
20s	3.42	3.86	4.53	4.9	5.5	5.7	5	4	5	4	5	5

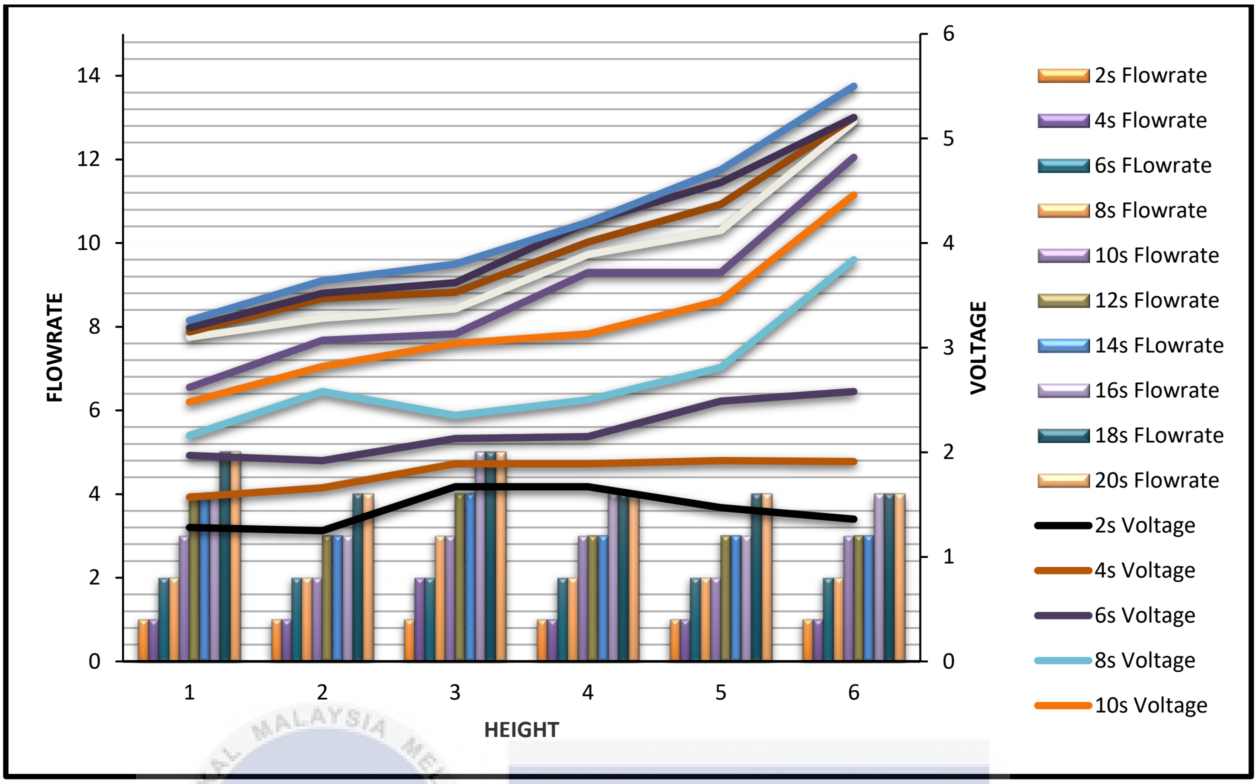

Figure 4.8 Graph 5.5 Liter Flowrate vs Voltage

According to the information provided, the results of measuring the voltage and flow rate of a 5.5-liter bottle with different heights are illustrated in Table 4.7 and Figure 4.8. The voltage is the electric potential difference between two points in a circuit, and it is measured in volts (V). The voltage increases as the height of the bottle increases, as well as the time of water flow. This is because the higher the bottle, the greater the water pressure and the faster the water flow, which results in more electric energy generation. The highest voltage recorded was 5.7 V at 20 seconds for the 6 feet height, while the lowest voltage recorded was 0.78 V at 2 seconds for the 1 ft height. The flow rate is the volume of water that passes through a given cross-sectional area per unit time, and it is measured in Liters per minute (L/min). The flow rate also increases as the height of the bottle increases, as well as the time of water flow. This is because the higher the bottle, the more water there is to flow through the generator, which also results in more electric energy generation. The highest flow rate recorded was 5 L/min at 20 seconds for the 6 feet height, while the lowest flow rate recorded was 1 L/min at 2 seconds for the 1 ft height.

c) 1.5 Liter

Table 4.9 Voltage and Flow rate for 1.5 Liter

	Flow Rate (L/min)						**Voltage (V)**					
	1.5L						**1.5L**					
Time / Height	**1 ft**	**2 ft**	**3 ft**	**4 ft**	**5 ft**	**6 ft**	**1 ft**	**2 ft**	**3 ft**	**4 ft**	**5 ft**	**6 ft**
2s	1.26	1.34	1.87	1.63	1.39	1.4	1	1	1	1	1	1
4s	1.56	1.67	1.92	2.16	2.18	2.7	1	1	1	1	1	1
6s	1.75	1.89	2.12	2.34	2.94	3.8	1	2	1	2	1	2
8s	2.16	2.35	2.43	3.78	3.64	4.2	2	3	2	2	2	2
10s	2.44	2.57	3.22	4.01	4.39	5.5	2	3	2	3	2	3
12s	2.65	2.83	3.78	4.85	4.73	6.3	3	4	3	3	2	3
14s	3	3.07	4.16	5.42	5.42	6.8	3	4	3	3	3	3
16s	3.07	3.22	4.56	5.97	5.72	7.14	3	4	3	4	3	4
18s	3.25	3.57	5.01	6.2	6.5	7.2	4	5	4	4	3	4
20s	3.63	4.24	5.35	6.2	6.5	7.2	4	5	4	5	3	4

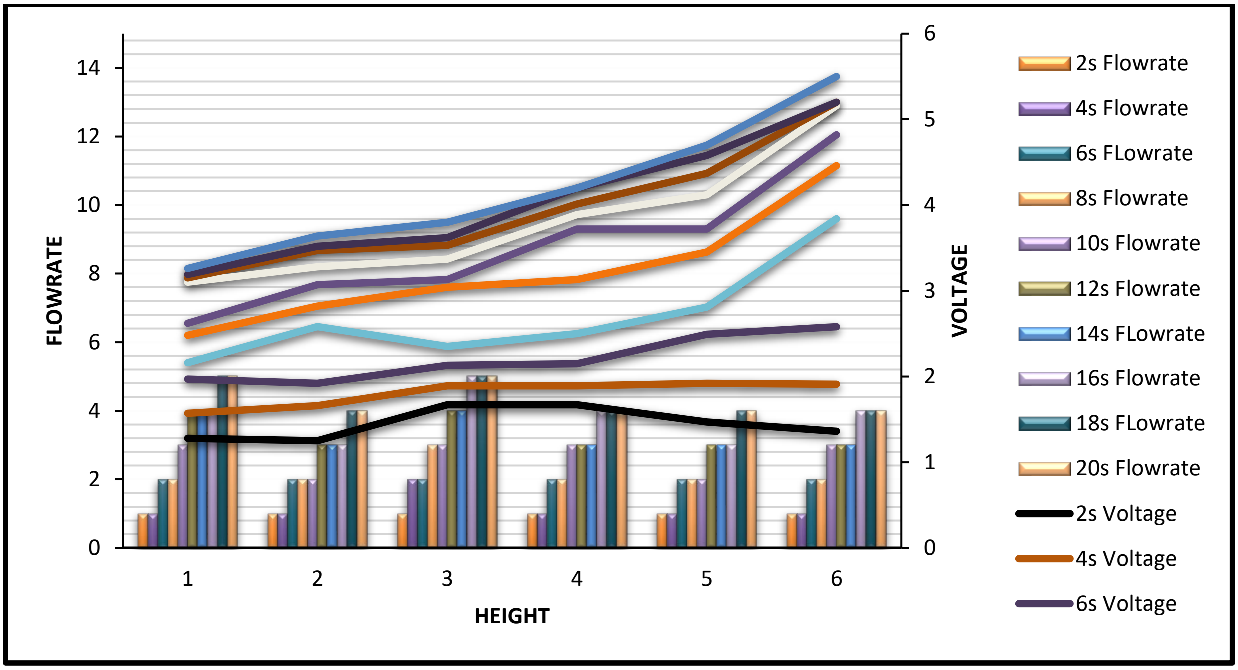

Figure 4.9 Graph 1.5 Liter Flowrate vs Voltage

According to the information provided, Table 4.8 and Figure 4.9 illustrate the flow rate and voltage of a 1.5-liter bottle used for measuring electricity generation. The table records the data for every 2 seconds, up to 20 seconds, and it shows that both the flow rate and the voltage increase as the height and the time increase. The highest flow rate recorded was 6 L/min at 20 seconds for the 6 feet height, while the lowest flow rate recorded was 1 L/min at 2 seconds for the 1 feet height. The highest voltage recorded was 7.24 V at 20 seconds for the 6 feet height, while the lowest voltage recorded was 2.49 V at 2 seconds for the 1 feet height.

4.2.1.4 Continuous Method

Based on the data obtained, it can be concluded that the 1.5-liter bottle has a high voltage output. Therefore, an advanced method was developed to obtain the output voltage as shown in Figure 4.10. The continuous method is used to obtain a voltage of 7.2V as before. The continuous method involves using tap water as a continuous channel. This method will record data for 20 seconds as before

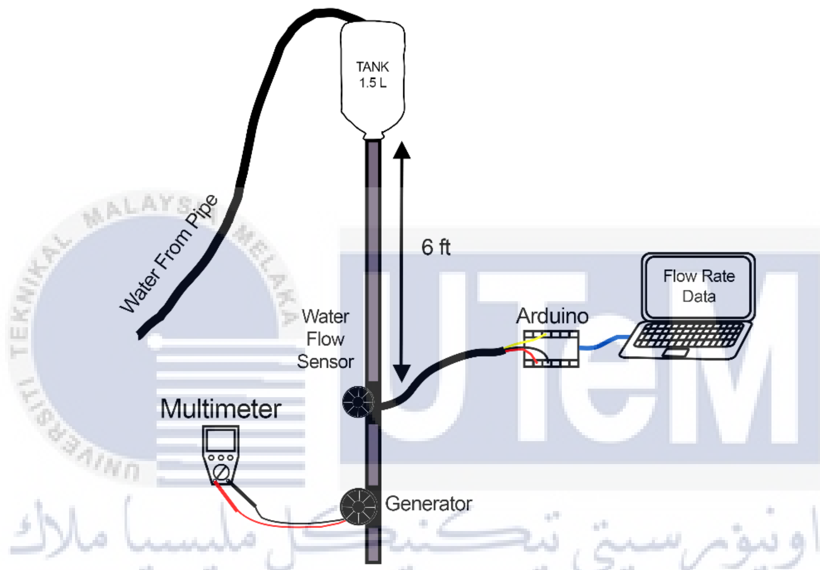

Figure 4.10 Experimental Setup

Table 4.10 Voltage 1.5 Liter Continuous Method

Time	Voltage (V)
2s	2.49
4s	2.96
6s	3.57
8s	4.26
10s	4.85
12s	5.62
14s	5.83
16s	6.39
18s	6.72
20s	7.24

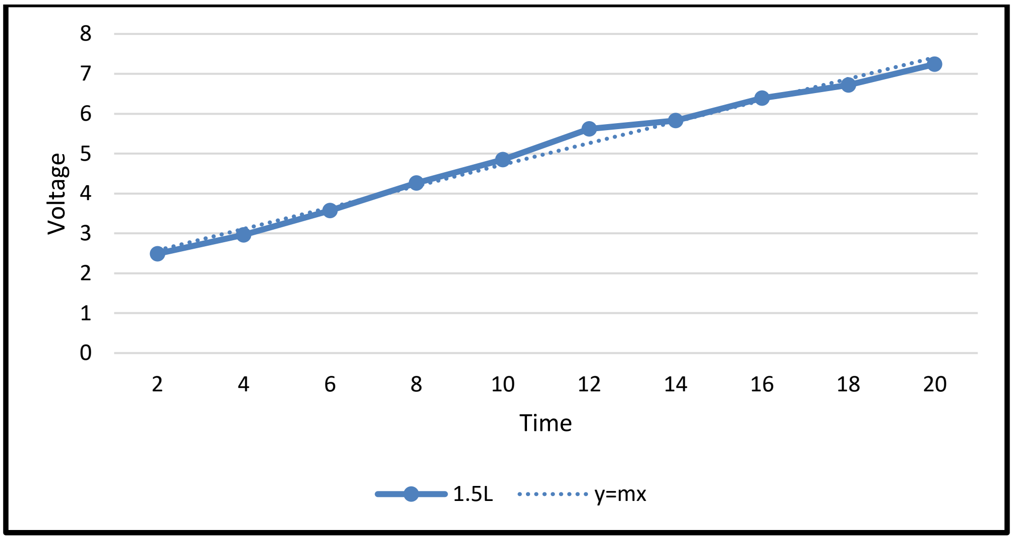

Figure 4.11 Voltage vs Time

According to Table 4.9 and Figure 4.11, it can be concluded that the continuous method of measuring electricity generation using a 1.5-liter bottle with tap water as a continuous channel is effective in producing high voltage output. The table records the voltage for every 2 seconds, up to 20 seconds, and shows that the voltage increases as time increases. A graph of voltage versus time shows a positive linear trend, indicating that the voltage increases by approximately 0.24 volts for each second. This shows that the longer the water flows, the more electricity is produced.

a) Flow rate 1.5 Liter

Table 4.11 Flow Rate 1.5 Liter

Time	**Flowrate (L / min)**
2s	1
4s	1
6s	2
8s	2
10s	3
12s	3
14s	4
16s	5
18s	5
20s	5

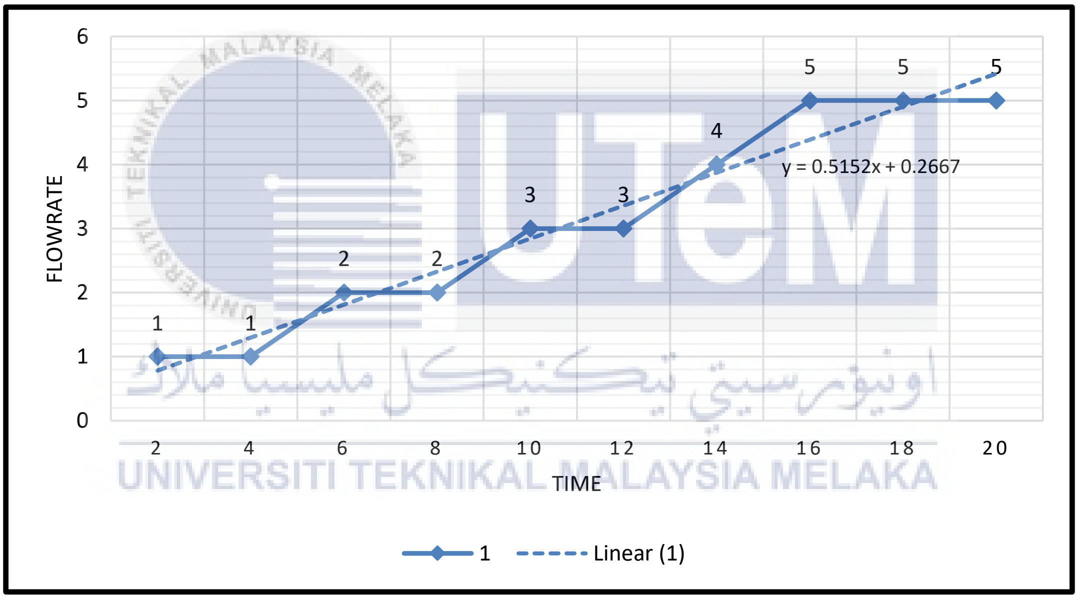

Figure 4.12 Flowrate vs Time

The data presented in tables and graphs showed that the output voltage and flow rate of the generator were measured for different bottle volumes (1.5, 5.5, and 9.5 Liters) and installation heights (1 to 6 feet). The analysis revealed that the 1.5-liter bottle with a height of 6 feet produced the highest voltage (7.2 V) and flow rate (6 L/min) among the tested scenarios. This finding suggested that the optimal height and volume for the proposed system are 6 feet and 1.5 Liters, respectively.

b) Current 1.5 L

Table 4.12 Cuurent for 1.5L

Time	Current (mA)	Voltage (V)
2s	0.046	2.49
4s	0.054	2.96
6s	0.065	3.57
8s	0.078	4.26
10s	0.089	4.85
12s	0.103	5.62
14s	0.107	5.83
16s	0.117	6.39
18s	0.123	6.72
20s	0.133	7.24

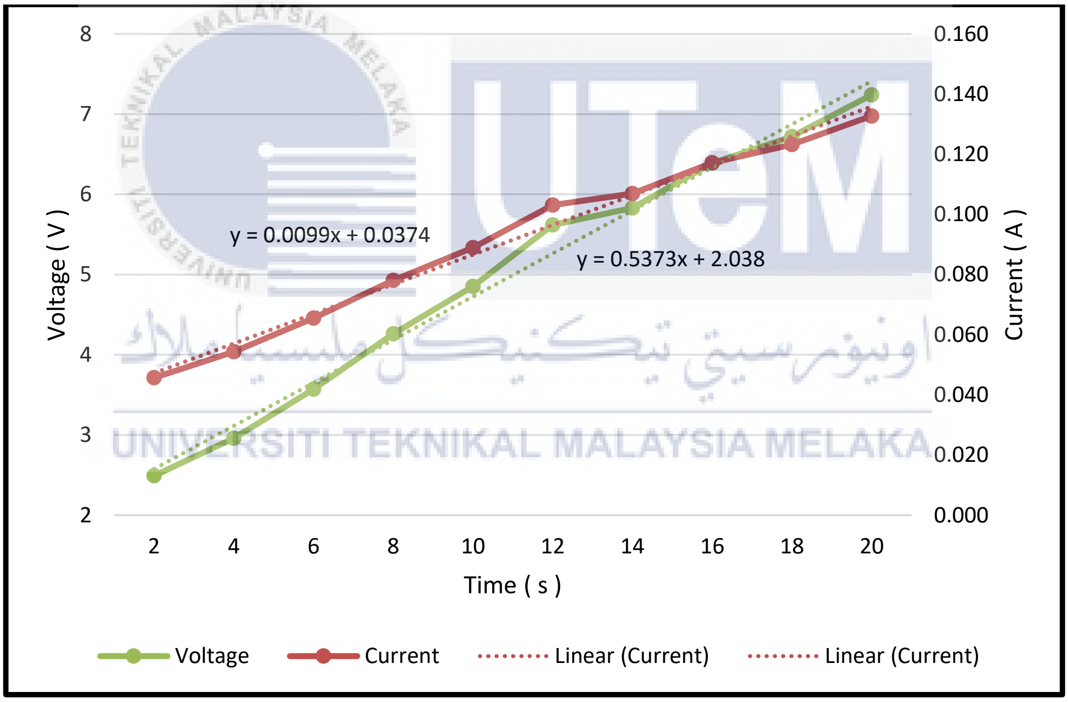

Figure 4.13 Graph Current–Voltage Relationship

The Table 4.10 and Figure 4.13 shown current-voltage relationship. The graph indicates that the current and voltage have a linear relationship, meaning that as one increases, the other also increases proportionally. The graph shows slope and intercept, the slope and intercept of these functions represent the resistance and the internal voltage of the circuit, respectively. The resistance is the ratio of the voltage to the current, and the internal voltage is the voltage when the current is zero.

4.2.1.5 Charging Rate

Table 4.13 Charging Rate

TIME	VOLTAGE	INDICATOR
1200	10.6V	
1230	10.8V	
1300	11.3V	
1330	11.8V	
1400	12.4V	

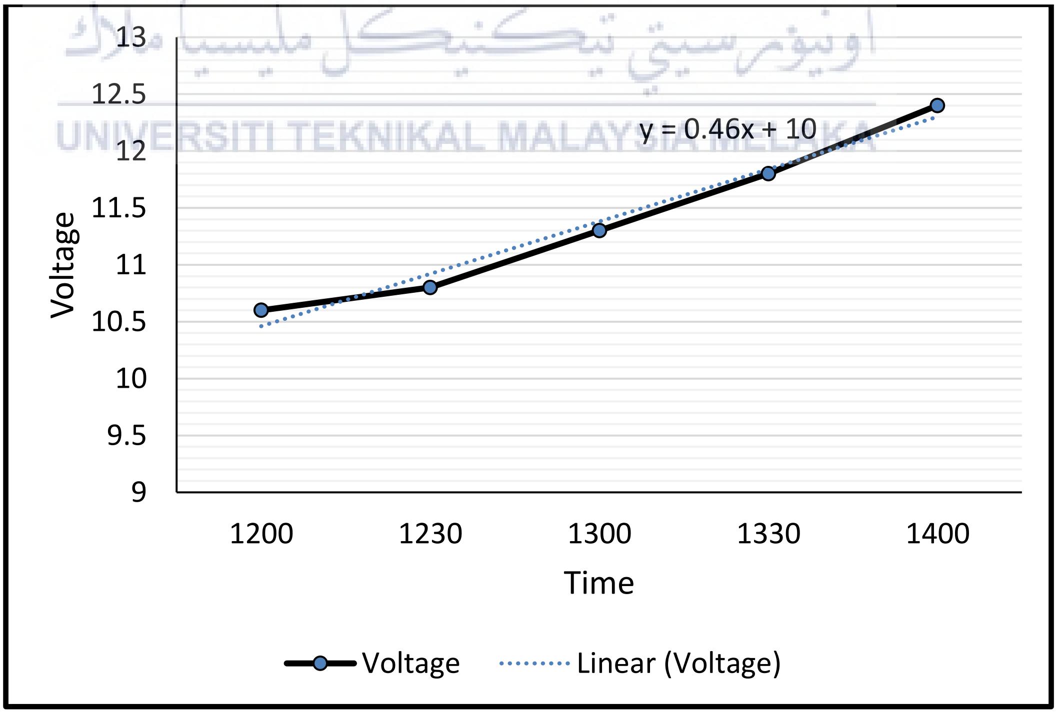

Figure 4.14 Graf Charging Rate

Table 4.13 shows the data for the battery charging process using solar. Data collection started at 1200 because it was a flexible time due to the sun being just above 90 degrees. Malaysia's position on the equator is a very suitable factor for solar use. graph figure 4.14 shows the change received by the battery with increasing current until 2 pm.

4.2.1.6 Discharging Rate

Table 4.14 Discharging Rate

TIME	VOLTAGE	INDICATOR
2000	13.4	
2100	12.8	
2200	12.4	
2300	11.7	
0000	11.3	
0100	10.9	
0200	10.5	
0300	9.6	
0400	9.2	
0500	8.4	
0600	7.3	

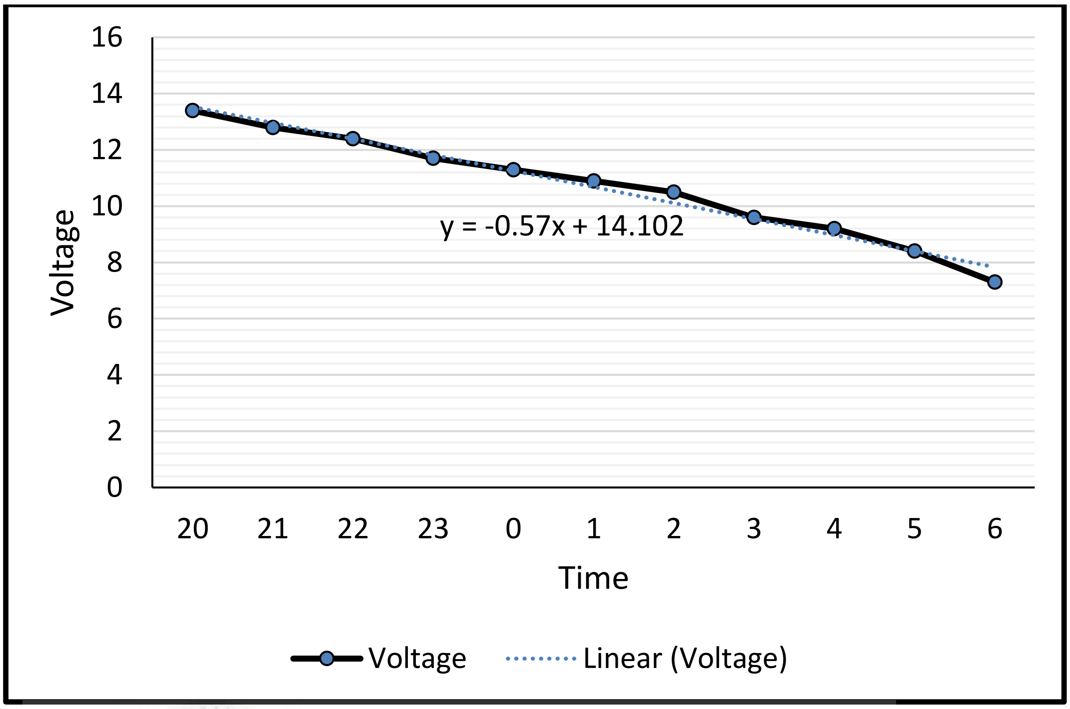

Figure 4.15 Graf Discharging Rate

Table 4.14 shows data for battery usage to evaluate the discharging rate. This process is applied by using a pump motor for 10 hours starting at 10pm. Indicator shows how much storage is left.

4.3 Summary

In electricity generation, the relationship between voltage and flow rate is that the voltage is proportional to the flow rate. This means that if the flow rate of water through a generator increases, the voltage output of the generator also increases. The relationship between voltage and flow rate can be explained by Ohm's law, which states that the voltage is equal to the current multiplied by the resistance. In the case of a generator, the resistance is the load that the generator is powering. The current is proportional to the flow rate of water through the generator, and the voltage is proportional to the current. Therefore, the voltage is proportional to the flow rate of water through the generator. This relationship is important for designing and optimizing hydroelectric power plants and other water-powered generators.

Based on the information provided, it can be concluded that the output voltage readings of the generator are directly proportional to the height of the tank and the volume of water in the tank. Specifically, the higher the height of the tank, the greater the water pressure and the faster the water flow, which results in more electricity generation. Similarly, the larger the volume of water in the tank, the more water there is to flow through the generator, which also results in more electricity generation.

Additionally, it can be observed that the voltage difference between two heights decreases as the height increases, which is due to the water pressure and flow rate approaching a maximum limit as the height increases, resulting in less variation in electricity generation. Next, it can be concluded that the voltage generated by the water wheel is positively correlated with the height of the wheel. Specifically, the voltage increases as the height increases for each time interval, indicating that the generator gains more momentum and power over time.

According to the information provided, the proposed system of generating electricity using solar and rainwater for the agricultural industry is feasible and efficient, as it produces high voltage and flow rate outputs with optimal height and volume parameters. The 1.5-liter bottle with a height of 6 feet is the best combination for maximizing the electricity output, reaching up to 7.8 V and 6 L/min more voltage than the 5.5-liter and 9.5-liter bottles. The output voltage and flow rate of the generator are directly proportional to the height of the tank and the volume of water in the tank, as well as the time of water flow. This relationship between voltage and flow rate can be explained by Ohm's law, which states that the voltage is equal to the current multiplied by the resistance.

Finally, the rate of increase of voltage varies for different heights, with the 6 feet height having the steepest slope and the 1 ft height having the flattest slope on the graph. This suggests that the height has a significant impact on the acceleration and efficiency of the water wheel. This finding is significant as it provides valuable insights into the optimal height and volume of the bottle for generating electricity. The results of this experiment can be used to provide sufficient power to farmers to prevent unwanted situations from happening.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This thesis presents an alternative method to generate electricity for the agricultural industry sector. The proposed methodology is effective and robust to obtain good results. Two (2) case studies for electricity from rainwater catchments show that annual rainfall is 80 percent per year which is between 2000mm to 2500mm and solar power is expected to be the world's largest source of electricity by 2050, with solar photovoltaic and concentrated solar energy contributing 16 and 11 respectively percent to total global consumption. In 2016, after another year of rapid growth, solar generated 1.3% of global power. The results of the analysis show that solar and rainwater-based electricity generation systems have the potential to provide sustainable and cost-effective energy sources for the agricultural industry. The system can be tailored to meet the specific needs of the agricultural industry, taking into account factors such as energy demand, weather conditions and water availability. The system can also be optimized to maximize the collection and efficient use of rainwater as a complementary resource, while effectively harnessing solar energy. The environmental impact of the system was found to be minimal, making it an ideal solution for the agricultural industry.

This project successfully achieved its objective. Integrated solar and rainwater based electricity generation systems have been designed to meet the specific needs of the agricultural industry, taking into account factors such as energy demand, weather conditions and water availability. The system was developed and optimized to maximize the collection and efficient use of rainwater as a complementary resource, while effectively harnessing solar energy. The potential benefits and feasibility of implementing solar and rainwater-based electricity generation systems in agricultural settings were analyzed, including factors such as energy production, cost-effectiveness and environmental impact.

Overall, the research presented in this thesis has succeeded in making progress in the agricultural industry sector towards renewable energy. The method presented using different tank volumes and different tank heights, using mathematical manipulation and requiring careful calculations, has produced enough energy. Furthermore, the work carried out has involved the development of a methodology that allows the calculation and evaluation of TNB and savings to farmers or adding infrastructure new to justify and prioritize any investment to increase the use of renewable energy in the agricultural industry sector. The effort that can be done in the future is to expand the telecommunications network in deep areas as well as agricultural areas so that the IoT system can be used. As such, it lays the groundwork on which proposed future research can be considered and refined.

5.2 Potential for Commercialization

Electricity development projects have great potential for commercialization with automatic power generation using rainwater harvesting and solar energy being a viable solution for the agricultural industry. This system is designed to capture rainwater during heavy rains, store water in the tank and can be used later and used in emergency situations such as blackouts. This system uses a generator and a tank, controlled by an Ultrasonic HC-SR04 Sensor. The system also includes solar panels that absorb sunlight as an energy source to generate direct current electricity. The development of electricity using solar and rainwater for the agricultural industry has the potential to be commercialized. This system can be used to generate electricity for the agricultural industry, thus reducing dependence on non-renewable energy sources. The system can also be used to capture and store rainwater for use in the agricultural industry, thus reducing dependence on fresh water sources. In addition, the development of electricity using solar and rainwater for the agricultural industry can provide 20% of the total electricity generation with an investment of less than 1% of the annual budget. This approach will also use solar panels as water catchment areas, thereby allowing the collection of pure water. Solar panels can also benefit crop production by reducing the amount of high-intensity light falling on plants. The system is cost-effective and can be implemented on a large scale, making it an attractive option for commercialization. Therefore, electricity development projects using solar and rainwater catchment have the potential to generate benefits for the agricultural industry in addition to promoting environmental and social well-being.

5.3 Future Works

For future improvements, the accuracy of the development of electricity from solar and rainwater to the agricultural industry can be improved as follows:

i) Integration with other renewable energy sources: Integrating solar and rainwater collecting systems with other renewable energy sources like wind and geothermal energy can assist in enhancing overall system efficiency and minimize reliance on nonrenewable energy sources.

ii) Optimization of system design: The optimization of the system design can assist in increasing system efficiency and minimize implementation costs. This may be accomplished by utilizing upgraded materials, enhanced system components, and increased system integration.

iii) New technology development: New technologies such as enhanced solar panels, more efficient rainwater harvesting systems, better energy storage systems, and

IoT systems can assist in increasing overall system efficiency and minimize implementation costs.

iv) Expansion into other sectors: Solar and rainwater collecting systems may be used in various areas such as transportation, urban planning, and energy generation. This can assist to lessen reliance on nonrenewable energy sources and promote sustainable development.

v) Data collection and analysis improvements: Improving data collection and analysis can assist to optimise system performance and discover areas for improvement. This may be accomplished by utilizing modern sensors, data analytics tools, and machine learning algorithms.

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