Faculty of Engineering

BIOMASS ENERGY SYSTEM: MINI STEAM TURBINE GENERATOR SYSTEM POWERED BY DRIED OIL PALM FRUITS

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BIOMASS ENERGY SYSTEM: MINI STEAM TURBINE GENERATOR SYSTEM POWERED BY DRIED OIL PALM FRUITS

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ABSTRACT

The primary objective of this project is to provide a comprehensive examination of the current status of various forms of biomass energy in Malaysia, along with a detailed analysis of the recent local environmental regulations pertaining to biomass energy (from 2016 onwards). Moreover, the article places specific emphasis on the development of a cutting-edge multistage condensate injection system for effectively cooling superheated boiler steam within a three-tier steam cooling system. This innovative technique enables automatic temperature regulation, thereby enhancing the overall efficiency of boiler operations. The simulation findings presented in this article demonstrate the feasibility of utilizing palm solid biomass wastes and biogas derived from mill effluent as renewable and sustainable fuels in the palm oil manufacturing process. Furthermore, a comprehensive analysis of the prototype has been conducted, providing valuable insights into both its limitations and potential areas for further development. The significance of this article lies in its potential to promote the utilization of biomass as a viable energy source, ensuring the future growth and success of the biomass energy market in the country. Additionally, it addresses the pressing issue of waste disposal while simultaneously creating new job opportunities. By offering valuable insights and practical solutions, this article contributes towards the successful implementation of biomass energy, ultimately fostering sustainable development and environmental conservation in Malaysia.

ABSTRAK

Objektif utama projek ini adalah untuk memberikan pemeriksaan menyeluruh mengenai status semasa pelbagai bentuk tenaga biojisim di Malaysia, berserta analisis terperinci mengenai peraturan alam sekitar tempatan yang terkait dengan tenaga biojisim (mulai dari tahun 2016). Selain itu, artikel ini memberikan penekanan khusus terhadap pembangunan sistem suntikan kondeansat berperingkat pelbagai tahap yang terkini untuk menyejukkan stim ketel terhampar dalam sistem penyejukan stim tiga peringkat. Teknik inovatif ini membolehkan pengawalan automatik suhu, dengan demikian meningkatkan keseluruhan kecekapan operasi ketel. Penemuan simulasi yang diketengahkan dalam artikel ini membuktikan kerealisasian penggunaan sisa biojisim pepejal kelapa sawit dan biogas yang dihasilkan daripada efluen kilang sebagai bahan api yang boleh diperbaharui dan mampan dalam proses pengeluaran minyak kelapa sawit. Selanjutnya, analisis menyeluruh terhadap prototaip telah dijalankan, memberikan pandangan berharga tentang kelemahan dan bidang pembangunan berpotensi. Keunggulan artikel ini terletak pada potensinya untuk mempromosikan penggunaan biojisim sebagai sumber tenaga yang boleh digunakan, memastikan pertumbuhan dan kejayaan pasaran tenaga biojisim di negara ini. Selain itu, ia menangani isu penjanaan sisa dengan serentak mencipta peluang pekerjaan baru. Dengan menyediakan pandangan berharga dan penyelesaian praktikal, artikel ini menyumbang kepada pelaksanaan berjaya tenaga biojisim, yang pada akhirnya mendorong pembangunan mampan dan pemuliharaan alam sekitar di Malaysia.

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LIST OF ABBREVIATIONS

TNB	-	Tenaga Nasional Berhad
SEB	-	Sarawak Energy Berhad
SESB	-	Sabah Electricity Sendirian Berhad
IPPs	-	Independent Power Producers
COP	-	Conference of the Parties
MESTECC	-	Ministry of Energy, Science, Technology Environment, and Climate Change
Btu	-	British thermal units
EFB	-	Empty fruit bunches
POME	-	Palm Oil Mill Effluent
ABG	-	Above Biomass Ground
CO_2	-	Carbon Dioxide
CPO	-	Crude Palm Oil
PKS	-	Palm Kernel Shell
PK	-	Palm Kernel Fibre
H_2O	-	Water
AC	-	Alternating Current
DC	-	Direct Current
WIFI	-	Wireless Fidelity
PWM	-	Pulse Width Modulation
MOSFET	-	Metal Oxide Semiconductor Field-Effect
CHP	-	Combined Heat and Power
IDE	-	Integrated Design Environment

CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia has had significant progress in rural development, particularly in lowering poverty and extending electricity. Malaysia's electrical supply development is focused on guaranteeing a safe, stable, and cost-effective supply of energy, with the goal of increasing the economy's competitiveness and resilience. The Malaysian government is focused on using energy resources efficiently, and promoting the use of alternative fuels, particularly renewable energy. Transmission and distribution of power are controlled by monopolies in West Malaysia (Tenaga Nasional Berhad [TNB]), Sabah (Sabah Electricity Sendirian Berhad [SESB]), and Sarawak (Sarawak Energy Berhad [SEB]), and these companies are major players in power generation. However, most of the country's electricity is generated by independent power producers (IPPs) with significant private ownership.

As an emerging and developing nation, Malaysia is undergoing tremendous economic development and industrialisation. Demand for energy increases annually in step with the nation's expanding population and economy. The overall energy generation (excluding self-generating plants) in 2019 was 171,672 GWh, a 5.1% increase from 2018's total of 163,358 GWh [1]. Coal remained the predominant source of energy production, accounting for 44.5% of the total. Natural gas ranked second with a percentage of 38.6%, followed by hydropower with 15.3%, renewables with 1.2%, and oil with 0.5% [1]. Figure 1.1 depicts a visual representation of this facts.

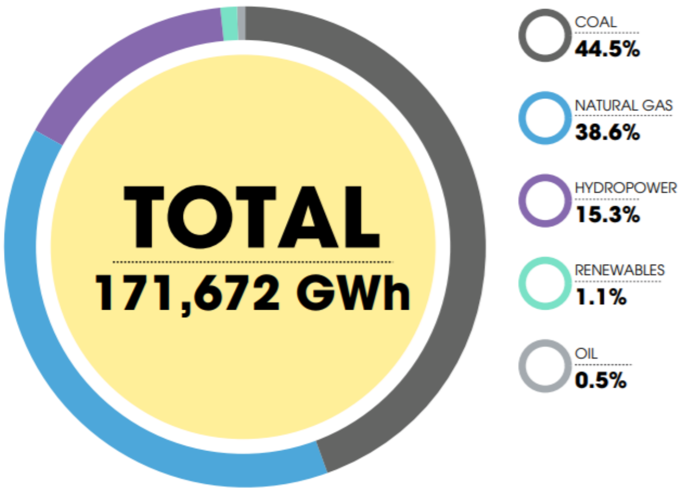

Figure 1.1: Available Capacity in Malaysia as of 31 December 2019 [2]

Malaysia's demand for electricity, mostly derived from natural gas and coal, is expanding significantly. This expansion, along with restricted natural gas supplies in high-demand regions, is compelling the government to diversify its fuel mix for power generation and improve electrical capacity to avert future power shortages. According to the Malaysia Energy Commission, the industrial sector consumed the most electricity between 2010 and 2020, accounting for around 47% of industrial demand. Demand from commercial and residential properties was 31.16% and 47%, respectively, while demand from transportation and agricultural was less than 1% at 0.36% and 0.22%, respectively.[3].

Table 1.1: Electricity Consumption in Malaysia on 2010-2020

Year	Final Electricity Consumption (ktoe)					
	Agriculture	Commercial	Transport	Industrial	Residential	Total
2010	24	3020	18	3994	1937	8993
2011	26	3172	18	4045	1974	9235
2012	30	3325	21	4509	2126	10011
2013	32	3466	21	4809	2262	10590
2014	36	3566	22	5072	2346	11042
2015	41	3663	23	5200	2471	11398
2016	47	3817	29	5822	2679	12394
2017	50	3762	39	6145	2610	12606
2018	53	3958	41	6547	2553	13152
2019	57	4086	41	6748	2715	13647
2020	59	3480	34	6403	3124	13100
Total Percentage	0.36%	31.16%	0.24%	47.00%	21.24%	

At the 26th United Nations Climate Change Conference of the Parties (COP), countries committed to limiting temperature rise to 1.5°C, with over 100 countries including Malaysia, the United States, Australia, and other European countries making zero net 2050 commitments. In Malaysia, the Ministry of Energy, Science, Technology, Environment, and Climate Change (MESTECC) has set a goal of 20% renewable power generation by 2030, up from 2% today [4]. Hydropower technologies currently account for 86% of renewable capacity and provide 18% of Malaysia's overall energy mix. Malaysia also aims to increase non-hydropower renewables to 20% of the power generation mix by 2025. Biomass, which is organic material obtained from plants and animals, accounts for approximately 14% of Malaysia's annual energy consumption of 340 million barrels of oil equivalent (BOE). Biomass was the dominant source of energy in the United States until the middle of the nineteenth century, and it remains a vital cooking and heating fuel in many developing nations. As a strategy to minimise carbon dioxide emissions from fossil fuels, the use of biomass [4] for transportation and energy generation is expanding in industrialised nations. In 2021, biomass supplied roughly 5 quadrillion British thermal units (Btu) and nearly 5% of the United States' total primary energy consumption. Sun-derived chemical energy is stored in biomass. Photosynthesis generates plant biomass. Various technologies can convert biomass into sustainable liquid and gaseous fuels, or biomass can be burnt directly for heat. Biomass is abundantly accessible in a variety of forms and cheaper to manufacture than fossil fuels. Using biomass as a source of energy decreases landfill waste. Biomass is carbon neutral and aids in mitigating the consequences of climate change since it only emits the CO_2 that it absorbs [4]

Malaysia produced 25.8% of the world's palm oil in 2020 and exported 34.3% of the world's palm oil. Including all other oils and fats produced in the country, Malaysia contributed 9.1% and 19.7% of the world's total oil and fat production and exports in the same year [4]. The oil palm industry is the major provider of biomass in Malaysia, generating vast quantities of oil palm biomass each year. However, only a tiny portion of this biomass is turned into goods with added value; the remainder is wasted. Oil palm tree biomass may be used for a variety of projects, such as the production of biofuel, biogas, fertilisers, composite materials, and briquettes, as well as the conversion of fuels like coal into electricity. Examples of oil palm biomass include empty fruit bunches (EFB), mesocarp fibres, kernel shells, oil palm fronds, oil palm trunks, and palm oil mill effluent

(POME). Oil palm fronds make up 70% of the total biomass produced from oil palms, followed by EFB at 10% and oil palm trunks at 5%.This means that the remains of the palm oil biomass can generate electricity for those who are not connected to the grid, such as farmers living in remote areas with a sufficient amount of palm oil biomass, thus producing cleaner energy and contributing to renewable energy [4].

1.2 Problem Statement

Compared to other sources of power, diesel generators have a major impact on pollution hence significantly dirtier per unit of energy being produced. Older diesel backup generators without contemporary emission control may significantly increase the pollutant concentration due to interactions between fresh air intake and exhaust outlet for the building housing the backup generators as well as the dispersion of exhaust plumes in the surrounding environment [5]. The carbon footprints of diesel generators were computed using a constant load demand of 1.05 kW per hour (6.3 kW/day) and six hours of diesel generator operation per day. Estimates of carbon dioxide were used to measure the rate of fuel use and carbon footprints (CO_2). The carbon footprint emissions grew by five when the emission factor rose from 1 kg to 5 kg CO_2/litre. Because CO_2 emissions behave as a blanket in the atmosphere, trapping heat and warming the globe, they are bad for the biosphere. The Earth cannot cool because of this layer, which raises global temperatures. Global warming would have an impact on the ecosystem, food and water supply, weather patterns, and sea levels. Malaysia's carbon CO_2 emissions in 2019 were 253,270.00, rising 3.63% from 2018 and it is quite worrying [5].

The accessibility to electrification for rural and remote area especially the farmers is regarded one of the pillars supporting a Malaysia socioeconomic development. Rural electrification schemes were expanded by the Government of Malaysia, particularly in Sabah and Sarawak, between 2001 and 2005 [5]. Grid expansion and the deployment of stand-alone system generators comprised of solar photovoltaic, mini-hydro, and hybrid systems were included. The Federal Government contributed a total of RM 856.6 million for rural electrification initiatives, which helped 103,126 rural families. The total installed grid systems at the end of 2008 were 775, 73 kW, while off grid PV installations are anticipated to be 8 MW [5]. According to Sabah Renewable Energy Rural Electrification Roadmap surveys, 71% of the approximately 120,000 rural inhabitants without grid power live in the state's poorest regions. These populations either rely on agricultural and forest products for a livelihood or live in mangrove areas and on islands in remote coastal regions where fisheries are the primary source of income. According to field surveys, 91% of such communities have at least one diesel generator, allowing them to operate for six hours or less each day [6]. Aside from fossil fuel generator been used, biomass is greater option which is greener option to power up the generator. Since Malaysia is rich with palm oil, the remains could be use as the biomass energy and helps the farmers that are off grid to replace their fossil fuels powered generator to biomass powered generator which is more economical.

With Biomass energy to power up the generator, it can be an add up on the flexibility in having an electrical supply. Whenever there is a power outage, biomass energy could be the back on generating electricity. Independent Biomass powered generator gives the independency of our household from the power supplier company.

1.3 Objectives

The following are the main objectives of this project:

- To design a mini steam turbine powered by biomass energy.
- To utilize dried oil palm fruit to power a system.
- To evaluate and test the biomass energy system.

1.4 Scope of Study

The scopes for this project are focusing hardware development.

This project will be conducted with the following steps:

(i) Hardware implementation

- Design and implementation of the mini steam turbine powered by dried oil palm fruit.
- The mini steam turbine would consist of carefully selected boiler which fits the application the most and turbine that generate an efficient conversion of energy state. The energy conversion will be from chemical energy to heat energy, then potential energy follows with kinetic energy and finally to electrical energy.

(ii) Overall testing of the developed system

- To identify the implementation of renewable energy resources specifically bioenergy in the form of biomass which is uncommon in Malaysia.
- To build an independent energy system to supply a household fully by using bioenergy.

1.5 Report Outline

This project report is divided into five chapters, with an appendix including references and various attachments. The project is structured in the following order: the introduction is followed by a review of relevant literature, the methodology used is outlined, the results and discussion are presented, and it concludes with a conclusion. The summary of each chapter is described as follows. Chapter 1 (introduction) entails the background study of the proposed project, including the importance of this system. This chapter also includes the problem statement, objectives of this project, and scope of the study. Chapter 2 (literature review) includes the reviews and studies that have been done for better comprehension of proposed project. This chapter introduces the background of components of the system for better understanding. The existing systems related to the project is also studied and presented to measure the capability and limitation of the project. Chapter 3 (methodology) outlines the proposed methodology and succinct process that involved in the project accomplishment. Further details on the method and technique used for the proposed project are discussed in this chapter. This chapter also consists of project flowchart and system design that will be used throughout the project completion. Chapter 4 (results and discussion) emphasizes on the further and detailed discussion regarding the outcomes of the proposed project. This chapter also presents description on the tests performed on the project. Chapter 5 (conclusion) summarizes the entire project and conclude the obtained results. This chapter also provides few recommendations for future improvements to overcome the limitations of the system and improve its efficiency.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Portable generators are utilised to provide a source of temporary, readily transportable electric power and are widely found in use on a variety of work and recreational venues. It is a device that changes mechanical energy or energy from a fuel source into electrical energy for use in an external circuit. Most of household in rural areas and farmhouses are disconnected with the grid due to isolated areas such as in oil palm estate and low demand from the consumers. Thus, some households decided to use portable generators powered by petrol or diesel fuel which are not renewable energy. In order to keep the environment clean by using renewable energy instead of depending on limited sources such as petroleum, instead by implementing biomass source as a replacement to generate electricity. For instance, using dried palm fruit kernels as a bio energy fuel replacement as fossil fuels.

2.2 Background Studies

2.2.1 Above Ground Biomass (AGB) and Stem Volume of Oil Palm Stand

Based on article [7], The cultivation of oil palm and the manufacturing of Crude Palm Oil (CPO) create a substantial quantity of biomass, which is typically categorised as agricultural waste. If allowed to remain on the fields, this biomass might cause issues. The oil palm tree (Elaeis guineensis) is indigenous to the African tropical rainforest. The fruit of the oil palm tree grows in tiny, plum-sized clusters (15-30 mm). A single palm fruit, as seen in Figure 2.1, is a drupe containing pulp and a nut. The pulp consists of the exocarp and mesocarp, which contain palm oil in their cell debris, while the inner nut consists of the endocarp and edible kernel, which contain palm kernel oil. These two separates, non-toxic, edible oils derived from oil palm fruits are both important in international trade.

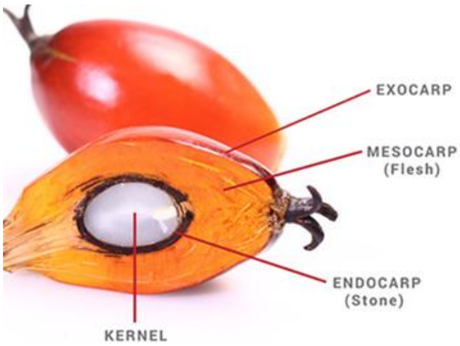

Figure 2.1: Palm Oil Fruit Diagram [8]

From the research study [8], employing remote sensing data to estimate the above-ground biomass (AGB) and stem volume of oil palm. Oil palm agricultural tree crops have been the focus of extensive botanical and agricultural study because to their societal and commercial value. With over 4.69 million hectares of plants, The world's largest producer of palm oil is Malaysia. Malaysia possesses a wealth of biomass and renewable energy resource possibilities, particularly oil palm. About 2400 megawatts of power might be generated mostly from oil palm by-products. Given the exponential growth of the world's population and the effects of climate change, it has been accepted that renewable energy may be crucial in preserving the equilibrium of economic development. Despite the importance of oil palm to the nation, there is no precise or reliable way to predict the availability of resources. This study used well-known allometric equations to carry out a ground survey in order to get an up-to-date inventory of oil palm biomass and stand volume. In this exploratory study, stem volume and AGB of oil palm plantations of various ages will be measured, and correlations between farm age and stem volume and oil palm biomass will be examined. A non-destructive method was used to calculate the stem volume and above-ground biomass (AGB). According to this study, the oil palm biomass, which is made up of 86 to 95% of the trunk, has an AGB of about 94.28 tonnes ha-1. However, between 5 and 14% of the total AGB was made up of frond biomass. According to calculations, there are 2.64 m3 of stems per tree and 382.68 m3 of stems per hectare. This study shows a strong relationship between age and above-ground biomass, demonstrating that as age rises, above-ground biomass climbs as well.

2.2.2 Palm Oil Residues for Energy Utilisation

From the research [9], the authors highlight how Nigeria creates a substantial quantity of trash from the oil palm sector, which may be used as an alternative energy source. Laboratory tests of oil palm waste, including palm kernel fibre, empty fruit bunch, and palm kernel shell (PKF). Calculated the moisture content and caloric value of the trash for energy use. The palm kernel shell contains 29% empty fruit bunch, 14% fibre, and 6% moisture with a calorific value of 23,604.71 kJ/kg. In comparison to the Empty Fruit Bunch, which has a value of 17,854.807 kJ/kg, fibre has a value of 14,511.96 kJ/kg. As a result, Nigeria's energy mix may be dramatically and sustainably improved by using these oil palm wastes as a substitute energy source.

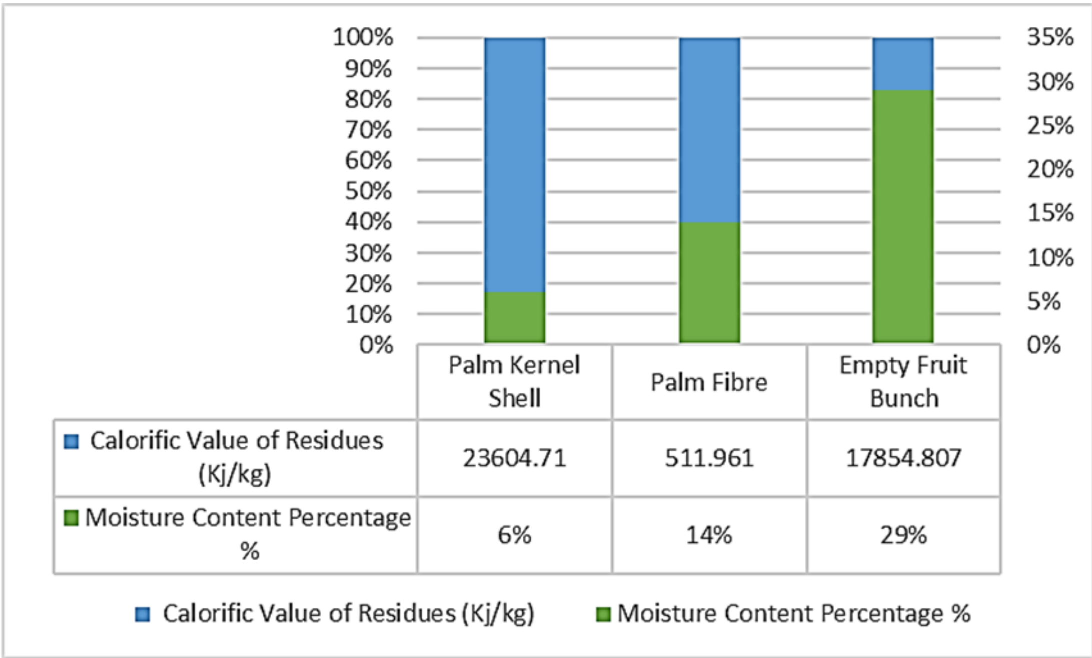

Figure 2.2: Moisture Content and Calorific Value of Residues of Palm Fruit [9]

2.2.3 Biomass Energy in Malaysia

From the research [10], the researcher states that energy consumption in Malaysia has increased significantly in recent years, with natural gas and coal being the primary sources. However, due to declining fossil fuel supplies and negative environmental effects, transitioning to sustainable renewable energy to meet future energy demands is suggested. As Malaysia is rich in natural resources, using biomass energy as an alternative energy source is worth further study. The aim of this research is to examine the current status of various forms of biomass energy in Malaysia and the recent local biomass energy-related environmental regulations (from 2016 onwards). Additionally, the barriers and limitations to large-scale biomass energy deployment in Malaysia will be highlighted. This review article is significant because it can help to promote the use of biomass as an energy source, secure the future growth of the biomass energy market in the country, and ensure its successful implementation while addressing the problem of waste disposal and creating job opportunities. Furthermore, it is important to emphasize the need for collaboration to increase viable biomass feedstocks other than oil palm to support the country's diversification of renewable energy production [10].

2.2.4 Tesla inspired pump and microfluidic gradient realized with lithography based additive manufacturing.

Nikola Tesla invented the Tesla turbine in 1909 and this type of turbine is unique in that it does not have blades. Unlike Kaplan and other turbines, the Tesla turbine has limited and specific uses, mainly in power plant operations, but it can also be used for pumps and other general purposes [18]. According to research [19], although the challenge of maintaining laminar flow between rotor discs and the limited use of smooth flow output, Nikola Tesla still demonstrated the bladeless turbine in 1913. However, by reducing the size to the microfluidic flow regime, these limitations can be overcome. This article details the creation of a microscale Tesla pump using a 3D printer powered by Digital Light Processing (DLP). The small pump produces 53 W of pump power, has a Reynolds number of 1000, and can move 12.6 mL/min at its maximum rate of 1200 revolutions per minute. When combined with a mixer network based on Tesla valves, it forms an entirely Tesla-inspired microfluidics system.