RENEWABLE ENERGY PRODUCTION FROM PALM BIOMASS BY PYROLYSIS: A PATH TO ACHIEVE ECONOMIC AND ENVIRONMENTAL SUSTAINABILITY

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ABSTRACT: *This study aims to unlock the information on the renewable energy production performance from carbon emission potential waste palm biomass. The specific objective of this paper is to reveal the current advancement in the pyrolysis process and its ability to replace fossil fuel with palm biomass. This study also addresses the problem relating to carbon emissions from waste palm biomass for contributing to achieving economic and environmental sustainability in Southeast Asian countries. The research methodology used for this study is reviewing the published research papers. The number of reviewed journals was 75 and published between 2010 to 2022 on research findings relating to the aims of this study. The study revealed that advancements in the pyrolysis process have significantly contributed to producing renewable energy from palm biomass. The temperature range of palm biomass pyrolysis is from 300OC to 9000 C. Energy products of this process are bio-oil, syngas, hydrogen, and bio-char. The energy output of this process is about 17.5MJ per kg of palm biomass. Combined heat and power cycle installed in series with palm biomass pyrolysis for achieving energy production efficiency up to 95%. Palm biomass pyrolysis offers a few benefits. It contributes to substituting fossil fuels with renewable energy and reducing 0.75kg* CO_2*eq emission. The research outcomes listed in this paper would be a guideline for investors, policymakers, researchers, government agencies, and industries for making a strategic plan to implement palm biomass-based renewable energy production plants. The novelty of this study is a presentation of ways to convert waste palm biomass into renewable energy with advanced technology.*

Keywords: Palm Biomass, Advanced Technology, Clean Energy, Production Performance, Optimization, Economic Sustainability, Environmental Sustainability, Climate Change.

1.0 BACKGROUND OF THE STUDY

In 2020, the global Fresh Fruit Bunches (FFB) production was about 220 million tons [1, 2]. The average rate of crude palm oil (CPO) outputs from FEB was 22%, and the other 78% was waste [3–5]. The waste part is known as Empty Fruit Bunch (EFB); and it is a biomass. EFB has traditionally been dumped into the environment. A small part of this biomass is also used for producing steam and energy.

When EFB degrades in the atmosphere, this biomass emits The carbon [CO_2eq(methane-CH_4) and carbon dioxide-CO_2)] [6]. and carbon emission potential is about $60kgCO_2eq.(ton)^{-1}$ [7]. When EFB burns for steam and energy, the emission rate is about $29CO_2eq.(kWh)^{-1}$. In both ways, EFB is environmentally hazardous biomass. On the other hand, dry EFB contains Carbon (45.53 wt. %) and hydrogen(5.46 wt.%), which represent energy[8]. his energy is environmentally friendly and renewable [9, 10].

With this background, the current study has undertaken to answer whether "***is waste palm biomass a renewable green energy source****?"* This study conducts to find the answer to this question. Total 75 journal papers studied published between 2010 and 2022 related to this question.

This paper divides into 5 sections. Energy contents of palm biomass describe in section 2. Section 3 gives an overview of advancements in technology relating to energy production from waste palm biomass. Section 4 describes the economic and environmental benefits of producing renewable energy from waste palm biomass. Section 5 is for conclusion and recommendation.

2.0 ENERGY POTENTIAL OF PALM BIOMASS

The earth receives around 1000 $W.(m)^{-2}$ of power from the Sun and only a fraction of this solar energy can convert into biomass (chemical energy) via the process of photosynthesis with water, and carbon dioxide. Palm biomass is also growing by absorbing solar energy, water and carbon dioxide. Equation 1.0 presents the formation of biomass.

$$Es + CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 \qquad \text{Eq (1)}$$

Here, Es is the solar energy, and $C_6H_{12}O_6$ is biomass, and a renewable organic material [11, 12]. Table 1 presents the specific heat capacity of Palm biomass.

Table 1: Specific Heat Capacity of Palm Biomass

Type of Biomass	Cpi (kJ/kg·K)	Type of Biomass	Cpi (kJ/kg·K)
FFB	3.231 [13]	MF	2.816 [13]
EFB	1.483 [14]	PKS	2.083 [15]
Nuts and Shells	2.291 [13]	OPT	2.567 [13]

The calorific value of FFB is comparable to the low-rank coal. The energy contents of EFB depend on moisture level. Palm biomass is highly volatile, and suitable for liquid fuel production. The calorific value of palm residues varies between 18 to 21 $MJ. (kg)^{-1}$. Palm kernel shell (PKS) and Mesocarp fiber (MF) have used in the boilers to generate steam [8], [16]. The Table 2 presents the energy contents of EFB.

Table 2: Energy Content in EFB [17], [18]

Type of Biomass	Energy and Physical Properties			
	Gross Calorific Value ($MJ kg^{-1}$)	Moisture Content (wt.%)	Ash Content (wt.%)	Volatile Matter Content (wt.%)
EFB	38.3	35.3	22.1	2.7
MF	33.9	26.1	27.7	6.9
PKS	20.8	22.7	50.7	4.8
OPF	30.4	40.4	21.7	1.7
OPT	34.5	31.8	25.7	3.7

The energy value per kg of EFB increases with the moisture reduction rate. For example, the calorific value or low heating value (LHV) of palm biomass is about 15.0 $MJ. (kg)^{-1}$ at moisture level 50%. The HHV is 17.17$MJ. (kg)^{-1}$