# Update on Renewable Energy Potential from Palm Oil Mills

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## INTRODUCTION

The Malaysian palm oil industry has progressed over the past 100 years since its commercial inception in the country in 1917. Currently, oil palm is the country's largest planted commodity crop with planted areas amounting to 5.67 million hectare nationwide. The primary economic-commodity products of the oil palm industry that are established are crude palm oil (CPO), crude palm kernel oil (CPKO) and palm kernel cake (PKC). The production of CPO, CPKO and PKC were 18.45, 2.10 and 2.36 million tonnes respectively, from the processing of 93.65 million tonnes of fresh fruit bunches (FFB) and 4.55 million tonnes of palm kernel in 2022 (Parveez *et al.,* 2023). Globally, Malaysia is the world's second largest producer and exporter of palm oil after Indonesia, contributing about 21% and 34% of the world's palm oil production and export, respectively, in 2022 (Parveez, 2023).

The huge success of the palm oil industry is often related to sustainable considerations, including the impacts of the milling process and its by-product generation on the environment. This perception overshadows the industry's contribution and commitment towards achieving sustainable palm oil production, particularly in greenhouse gas (GHG) mitigation action via palm-based renewable energy (RE). It is important to note that the use of RE resources is one of the global initiatives aimed at combating climate change, addressing global warming and ensuring energy security. RE contributes about 14% to the total primary energy supply worldwide (Gielen *et al.,* 2019). Biomass is the largest RE used, with a 70% share of the total RE resources globally. From Malaysia's perspective, the oil palm industry is the single largest contributor to biomass resources, amounting to 90% of the country's total lignocellulosic biomass (Loh, 2017). An emerging use of palm-based biomass is for RE. This paper discusses and highlights the potential and roles of the oil palm biomass generated from the palm oil milling sector for RE generation and utilisation.

## RENEWABLE ENERGY FROM PALM OIL MILLS – BUSINESS AS USUAL SCENARIO

The oil palm industry generates an abundance of biomass resources in the form of solid and liquid by-products that can contribute to the country's RE energy mix target. These non-oil biomass resources, which are mainly from plantations and milling sectors, represent about 90% of the total mass balance of the palms, in addition to 10% CPO and CPKO. At the palm oil mills where the FFB are processed, other biomass residues comprising mesocarp fibres (MS), palm kernel shells (PKS), empty fruit bunches (EFB) and palm oil mill effluent (POME) are produced. *Table 1* summarises the estimated amounts and major characteristics of oil palm biomass generated from palm oil mills nationwide in 2022. Based on the mean weight ratio of MF, PKS, EFB and POME to FFB, approximately 100 million tonnes (wet basis) of oil palm biomass in both solid and liquid forms were produced annually from palm oil mills alone in 2022.

**TABLE 1. OIL PALM BIOMASS GENERATED FROM PALM OIL MILLS IN 2022**

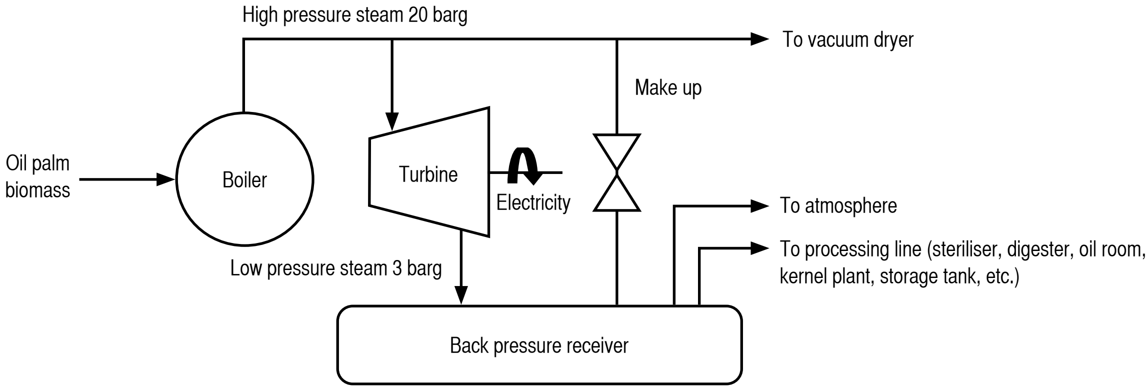
| Biomass | Weight ratio to tonne FFB, wt. $wt.^{-1}$% | Quantity, million tonnes | *[1]Moisture content, % | *[2]Calorific value, kJ $kg^{-1}$ |
|---|---|---|---|---|
| MF | 13 | 12.17 | 37.00 | 19 068 |
| PKS | 6 | 5.62 | 12.00 | 20 108 |
| EFB | 23 | 21.54 | 67.00 | 18 838 |
| POME (biogas) | 65 | 60.87 (1 704 million $m^3$) | - | 20 000 kJ $m^{-3}$ |

*Source: Subramaniam *et al*., (2004)
Note: [1]wet basis; [2]dry basis.

An immediate and direct use of these resources is as renewable fuel. The palm oil industry, in particular the milling sector, is one of the pioneers and self-sufficient industries in RE generation and utilisation in the country. Conventionally, the mixture of MF and PKS is used by the palm oil mills as the main fuel to produce steam and generate electricity for the milling process via a combined heat and power (CHP) plant (*Figure 1*). Mills are now gradually increasing their utilisation of EFB fibres and, to a limited extent, biogas in their boilers, thus displacing the PKS and MF, if any, which can be sold for various downstream processing and applications. EFB fibres are produced via a typical pretreatment process, either using a single machine consisting of a press and cutter or a 2-stage process using a shredder machine followed by a pressing process. It can be said that the CHP, or cogeneration plant operated in mills, also serves as waste disposal, particularly for solid biomass.

Typically, mills were designed to consume about 20 kWhr of electricity and 600 kg of steam to process 1 t of FFB (Nasrin *et al.,* 2004; 2011). Thus, the total off-grid electricity and steam that were mainly generated and consumed from the MF and PKS used in 450 mills in 2022 was 1873 million kWhr (or 1873 GWhr) of electricity and 56.2 million tonnes of steam. This is equivalent to the total installed electrical and steaming capacities of 390 MW and 11.71 kilo tonnes $hr^{-1}$, respectively, calculated based on the average monthly milling hours of 400 hr by the mills. It is estimated that an average of 0.34 L of diesel is required for every kWhr which emits approximately 0.47 kg $CO_2$eq $kWhr^{-1}$ (Ngan, 2002). Therefore, the industry had saved about 637 million litre of diesel, with potential GHG savings of 0.9 million tonnes of $CO_2$eq in 2022. Assuming that the diesel cost for the industry sector is RM3.00 $L^{-1}$ about RM1.9 billion of fuel costs have been further saved by the millers annually from the use of oil palm biomass as fuel.

Oil palm biomass used as fuel in palm oil mills is a well-accepted process from economic, environment and social perspectives. It is justified by the operation cost savings of the mills, carbon footprint and GHG reduction of the CPO supply chain and the fact that it does not create the 'food vs fuel' issue. It must be mentioned that the full potential of oil palm biomass, particularly EFB and biogas from POME is not fully exploited, due to the limitations of onsite energy uses and CHP plant design in a typical palm oil mill. The CHP operated in mills generates more than sufficient energy from the MF and PKS for the milling process. Many studies reported that the efficiencies of boilers, electrical and cogeneration plants operated in palm oil mills vary from 65%-87%, 3%-4% and 58%-66%, respectively (Loh *et al.,* 2022). These show that the CHP plant was operated at low efficiencies and designed to have such a low energy conversion rate just to cater to the energy required in the milling process. Thus, the RE generation process deployed in mills has been more of a waste disposal solution rather than a way to optimally utilise the biomass for energy. Therefore, there are many potentials and opportunities still available for exploiting the RE from oil palm biomass, particularly for RE generation and utilisation beyond palm oil mills.




Source: Nasrin *et al*., (2011); Basiron *et al*., (1997).

*Figure 1. Combined heat and power (CHP) plant used in palm oil mills.*

## TECHNICAL POTENTIAL OF RENEWABLE ENERGY FROM OIL PALM BIOMASS IN PALM OIL MILLS

The potential for renewable energies from oil palm biomass and biogas from POME is mainly in the form of heat (steam) and power (electricity) via a direct combustion process. The oil palm biomass can also be used as a feedstock for the production of second-generation biofuel in solid, liquified and gaseous fuels via physical/mechanical treatment, thermochemical and biochemical routes. Besides solid biofuel, most of the R&D on these palm-based second-generation biofuels are technically established or in an advanced stage of development, but its full commercial development may need more time. Onsite energy use from EFB and biogas from POME in a typical mill is limited, except in mills with downstream processing activities or those that are integrated with palm oil complexes. EFB and biogas have huge potential for off-site use of electricity, particularly for grid connections or rural electrification. *Table 2* shows the estimated technical potential of RE in heat and electricity forms generated from oil palm biomass and biogas.

Based on calorific value, the total energy potential from EFB, MS, PKS and biogas was estimated at about 330 072 million MJ in 2022. This value is equivalent to 11 630 million litre of diesel annually. The EFB and biogas produced by all palm oil mills could have a total installed electricity capacity of 1374 and 526 MW, respectively, in 2022. The total potential installed capacity from both of these resources only was 1900 MW, which contributes about 5.25% to the country's total installed capacity in 2019, amounting to 36 182.8 MW (Suruhanjaya Tenaga, 2021). This estimated potential RE can only materialise if all 450 mills in 2022 are integrated with an EFB-based power plant and biogas capturing facilities. As of December 2022, there were five EFB-based grid-connected biomass power plants operated and connected to the national grid, and 140 mills have installed and captured biogas from POME for various energy applications, including more than 43 plants connected to the grid (Nasrin *et al.,* 2023). All these potentials show that oil palm biomass produced from palm oil mills has significant roles and contributions to support the country's RE targets, including GHG reductions. The major obstacles to materialising this palm-based RE potential are technology adoption, consistent operation, infrastructure and interconnection issues. To address these, various RE policies, technical support and financial incentives have been introduced to improve the economic viability of the palm-based RE projects in Malaysia.

**TABLE 2. ESTIMATED RENEWABLE ENERGY POTENTIAL FROM OIL PALM BIOMASS GENERATED FROM PALM OIL MILLS IN 2022**

| | EFB | POME (Biogas)[a] | Mesocarp fibres | Palm kernel shells | Total |
|---|---|---|---|---|---|
| Production, million tonnes | 21.54 | 60.87 (1 704 million $m^3$) | 12.17 | 5.62 | 100.2 |
| [(1)]Energy potential, million MJ | 142 487 | 34 080 | 144 093 | 99 412 | 330 072 |
| [(2)]Diesel equivalent, million litre | 3 945 | 944 | 3 989 | 2 752 | 11 630 |
| [(3)]Electricity generation, million MWhr | 9.9 | 3.8[(4)] | 10.0 | 6.9 | 30.6 |
| [(5)]Electricity (Installed capacity), MW | 1 374 | 526 | 1 390 | 960 | 4 250 |

Note: [a]POME volume × 28 $m^3$ biogas $m^{-3}$ POME
[(1)] Production rate × calorific value of biomass or biogas @wet basis
[(2)] Energy potential ÷ CV diesel @ CVdiesel = 36.12 MJ $L^{-1}$
[(3)] based on CV of biomass (wet basis) at 25% thermal efficiency running at 7200 hr $yr^{-1}$
[(4)] based on 20 MJ $m^{-3}$ biogas CV at 40% gas engine efficiency running at 7200 hr $yr^{-1}$
[(5)] Electricity generation ÷ 7200 hr

## CONCLUSION

RE generation and utilisation from oil palm biomass produced in palm oil mills is one of the cleaner production strategies for the betterment of environmental sustainability and profitability in the industry. Palm oil milling is a green process which uses RE extensively and produces RE for other industries. The millers should make the biomass and biogas power plant, particularly for grid connection or offsite uses, as an integral part of the milling process. This approach would benefit the millers by providing additional revenue from the power generated, including savings on operational costs and other biomass for value-added products. The use of oil palm biomass will contribute greatly to the lower carbon footprint, which leads to better access to competitive markets. Appropriate business models need to be strategized and more proactive-synergised efforts are required both from industry players and the government in order to further exploit the huge untapped potential of RE from palm oil mills.

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