Utilization of Renewable and Conventional Energy in Palm Oil Industry in Indonesia

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Abstract. In this study, the utilization of renewable energy and conventional energy in the palm oil industry of Indonesia is explored. The objectives are to examine the characteristics of energy utilization in the palm oil industry and to estimate the potency of renewable energy from the waste of palm oil mill. The literatures of Indonesia’s palm oil industry are reviewed. Then, validate the data with site visits to six palm oil mills, continue with an interview with national consultants. The results show that the total area of palm planted area and produced CPO in Indonesia in the year 2020 are estimated as 14,996,010 Ha and 49,117,260 tons CPO, respectively. The palm oil industry has abundant renewable energy potency, and some of them are used as a fuel of the boiler for CPO production in the mill, and there is 605,523 ToE of the mill has not used. Even though there is a great potency of renewable energy, the palm oil industry still consumes conventional energy, mainly for FFB transportation. Conventional energy used in the palm oil industry estimates about 602,540 ToE in 2020. The palm oil industry should replace fossil fuel consumption by utilizing its renewable energy resources.

1. Introduction
Indonesia has released two targets related to renewable energy utilization. The first target is the first Nationally Determined Contribution (NDC) [1], and the second one is National Energy Policy (in Bahasa KEN) [2]. In the NDC submitted to UNFCC, Indonesia’s target is to reduce emissions by 29% on its efforts and up to 41% with international support, against the business as usual scenario by 2030. In the energy sector, the 29% and 41% emissions reductions mean 314 MTon CO$_2$e and 398 MTon CO$_2$e, respectively. The solution to achieve this energy target is promoting energy-efficient technologies and the utilization of renewable energy resources. In line with the energy sector, in Government Regulation No. 79/2014 on National Energy Policy [2], Indonesia set out to transform the primary energy supply mix with a share of new and renewable energy at least 23% in 2025 and at least 31% in 2050. These targets and policy have forced all of the related stakeholders to formulate suitable solutions to meet the target. Indonesia has several renewable energy resources such as solar energy [3-8], bioenergy [9-12], geothermal, hydropower, etc. These energy resources shall utilize optimally to meet the target.

One of the potential solutions to meet the twofold targets, reduce the emissions and reach the renewable energy share, is to utilize the wastes of Palm Oil Industry and covert those into energy. The waste to energy strategy has a significant potency to be implemented in the Palm Oil Industry. Studies
on the utilization of renewable energy and emission of palm oil industry stated in literatures. Jekayinfa and Bamboye [13] reported on the energy use study of 40 Palm Oil Mills in Nigeria. The utilization of energy from each source varies from one mill to others and depends on the capacity of the mill, reported. Even though the energy use in the range of efficient, however, there was still room for improvement. Chiew and Shimada [14] compared the environmental impact of utilizing oil palm empty fruit bunches for fuel, fiber and fertilizer. The study was particular for Malaysia’s case. To examine the environmental impacts of available technologies, using the life cycle assessment (LCA) method. For energy production, Combine Heat and Power (CHP) plants show the best performance if the electricity generated is connected to the national grid. However, methane recovery and composting are more environmentally friendly than the other technologies. Wicke et al. [15] analyzed the greenhouse gas emissions of crude palm oil (CPO) production and fatty acid distillate (PFAD) production in Borneo (Malaysia), their transport to the Netherlands and their co-firing with natural gas for electricity production. It suggested that bioelectricity and biodiesel production from Palm Oil industry categorized as sustainable when only use in degraded land. Besides, plantation management needs to be improved. The Feed-in Tariff (FiT) policy framework has used by Umar et al. [16] to examine renewable energy generation from oil palm biomass in Malaysia. The study concluded that appropriate policy support and sustainable solution are needed to bridge any gaps that exist. The FiT framework in Malaysia needs to be improved. De Souza et al. [17] identified and evaluated the net GHG emissions and the energy balance of palm oil biodiesel in Brazil and compared the results with studies carried out in other countries. The industrial phase of biodiesel production is the highest energy input, and nitrogen causes a considerable influence on the greenhouse gas emission of the process. Also, fuel consumption responsible for 18% of the greenhouse gas emissions in the palm biodiesel life cycle.

As the worst-case scenario, if the empty fruit bunches dumped and mill effluent stored in the pond, every ton of fresh fruit bunches emits 460 kg CO₂e. On the other hand, if the best scenario implemented on processing one-ton fresh fruit bunches will emit only 110 kg CO₂e [18]. This fact motivates mail palm oil producers to develop a more sustainable palm oil industry. It includes explore the possibility to producing biofuel and also to exploring renewable energy utilization from the waste. In Thailand’s case, Papong et al. [19] estimate the energy potential of biodiesel from palm oil industry. Some related studies of renewable potency and utilization of palm oil waste for Malaysia case are also reported in literature [20, 21 and 22].

In particular, several studies in energy and potential renewable energy in the palm oil industry in Indonesia have been found in the literature. Nasution et al. [23] analyzed 83 palm oil mills in Sumatera Utara province of Indonesia. The potency of reusing the empty fruit bunches in the mill to produce electricity as an excess power and send the electricity to the grid examined. By using the existing technology, if all of the fiber and shell are used, the mill can produce excess electricity of 35 MJ for every ton of fresh fruit bunches. Besides, if all of the empty fresh bunches used, the excess electricity produced is 1885 MJ for every ton of fresh fruit bunches. Harsono et al. [24, 25] assess the potential biodiesel production from palm oil by considering the contribution of anaerobic treatment of POME in digestion plants to reduce fossil fuel consumption and lower greenhouse gas emissions. Recently, Harahap et al. [26] investigated the optimal development palm oil-based bio-refineries on two major islands of Indonesia: Sumatera and Kalimantan. The palm oil potential report to meet national bioenergy targets from 2020-2030 available. The result shows that palm-oil based biorefineries in Sumatera and Kalimantan can produce 1 – 1.25 GW of electricity, 4.6 – 12.5 bL of biodiesel, and 2.8 – 4.8 bL of ethanol in 2030.

The above literatures show that several studies related to the emission and renewable energy utilization in the palm oil industry reported from different point of view. The present study will focus on exploring the utilization of conventional energy and renewable energy in the palm oil industry. The objectives are to analyze the characteristics of energy utilization in the palm oil industry and to estimate the potency of renewable energy from the waste of palm oil mill. The results expect to supply the necessary information that can use to develop an appropriate technology and strategy to meet the national targets on emission reduction and renewable energy share.
2. Method
In this study, data collection, site visits and interviews are conducted. Collect data used desk evaluation. Several technical reports and statistical data are collected and reviewed. The data are verified using a peer review research paper. The verified data related to the palm oil industry validated by visiting 6 palm oil mills in Sumatera Utara province. An interview with two national consultants on the palm oil mill has conducted.

3. Results and discussions
Indonesia is facing several energy problems that must be solved. The energy resources of Indonesia are treated as an economy object. The fossil energy is explored to be exported, not as an asset for development. On the other hand, the national production of oil and gas is depleting. Since 2004, Indonesia becomes a net oil importer. Also, the price of renewable energy is not competitive, the effectiveness of energy subsidy is still low, and the energy utilization is far from efficient. The main problems of Indonesia’s energy that motivate this work are the utilization of renewable energy is low, and research and development of technology of renewable energy limited. The palm oil industry is expected to play a significant role in solving this problem. Since, Indonesia is the biggest producer of oil palm in the world.

3.1. Palm oil industry
The world demand for vegetable oil is rapidly increasing along with economic and population growth in developing countries. It is also affected by urbanization trends. In the year 2008, the oil palm accounts for 41.31 million tons of the world consumption of significant vegetable oils, overtaking soybeans, rapeseed, and sunflower seed oil with 41.28 million ton, 18.24 million ton and 9.91 million ton, respectively [27]. In the year 2020, the world production of oil palm 75 million tons expected. This production will increase and predicted to be 256 million per year in the year 2050.

![Figure 1 Planted area and CPO productivity of Indonesia](image)
CPO and PKO productivities in the year 2011 are 2.57 ton CPO/ha/year and 0.51 ton PKO/ha/year, respectively. In the year 2020, the CPO and PKO productivities are 3.28 CPO/ha/year and 0.66 ton PKO/ha/year, respectively. The CPO and PKO productivities increase by 27.62% and 29.41%, respectively. Based on this data, it is predicted that the CPO production of Indonesia in the year 2030 will be 98 million ton per year.

3.2. Palm oil mill process
The production process of Palm Fresh Fruit Bunches (FFB) into CPO and PKO in the Palm Oil Mill (POM) depict in Figure 2. The process can be explained in brief as follows: Palm FFB are transported from the plantation field into Palm Oil Mill (POM) by using trucks. Every truck weight at the weight station, the FFB unloads in the unloading ramp. The FFB fed into the lorry by dropping the FFB through the unloading ramp window. The lorry will be transport into sterilizer tank. The FFB and lorry sterilize in the vessel.

![Figure 2 Typical CPO Processing in the Palm Oil Mill](image)

The steam from turbine exhaust injects into the vessel. The steam’s pressure and temperature in the vessel are 2.5 – 3 kg/cm² and 120 – 130°C, respectively. The sterilization process will take about 110 to 120 minutes. After the sterilization process, the vessel will unload, and the lorry with the Fruit Bunches (FB) will be drawn. Every lorry picked up by the hosting crane and fed into stripper. In the Stripper, the fruit will separate from the bunch. There are two outputs of the stripper, they are empty fruit bunches (EFB) and fruit. The EFB will transport into EFB hopper using EFB conveyor. The fruits will be transported into the digester using fruit elevator. In the digester, the fruit will be heated up to 80 – 90°C and then stirred using blade mixer. Here, the kernel separates from mesocarp. The objectives of
extraction in digesters are to smash the mesocarp, to separate kernel from waste, and to break into oil cell. From the digester, the fruit will send to a screw press with a standard pressure of 30 – 50 bar. Here, hot water with 90 – 95°C temperature adds to the fruit. The amount of water is 15 – 20% of the raw material (FFB). The fruit will separate into sludge and press waste (contain kernel and fibre).

The sludge sends to Crude Oil Gutter. Here, the Crude Oil gets hot water at 100°C. The Crude oil mixed with the hot water then filtered in the Energy Separator of Vibrating Screen that has two level of filter. The top filter with dimension two different meshes. The oil will be sent directly to heated injection tank to maintain the temperature. The oil sends to purifier and vacuum drier, the sludge is the filtered again, and the effluent sent to wastewater treatment. The clean crude oil from vacuum drier sends to storage tank by using a pump. It is the final product of CPO. The kernel sends to ripple mill. Here there are three steps of drying performed. They are at 60°C, 70°C, and 80°C. The kernel then cracked and separated into shell and nut. All of the mechanical power and electricity in the POM area have resulted from a steam power plant. The steam has resulted from a boiler. The solid wastes of the process (fibre and shell) use as a fuel for the boiler. The photograph in several processing points showed in Figure 3.

![Figure 3 Fresh Fruit Bunches Processing in Palm Oil Mill](image)

### 3.3. Renewable energy potency

As mentioned above, the main products of the POM are CPO and PKO. The waste of by-products are EFB, Shell, Fiber, and POME. In the present technology, some of shell and fiber are used as fuel for POM. On the other hand, EFB and POME are remaining as wastes. Based on a survey in several POM and discussions with national consultants, the distribution of every ton of FFB in POM showed in Table 1.

| Main Products          | Produce | Reuse | Net  |
|------------------------|---------|-------|------|
| Crude Palm Oil (kg)    | 223     | 0     | 223  |
| Palm Kernel Oil (kg)   | 46      | 0     | 46   |
| Empty Fruit Bunches (kg) | 226  | 0     | 226  |
| Palm Nut Shell (kg)    | 55      | 27.5  | 27.5 |
| Mesocarp Fiber (kg)    | 140     | 140   | 0    |
| POME (kg)              | 650     | 0     | 650  |
About 50% of the Shell and 100% of the fiber, reused as fuel. Even though some POMs in Indonesia are sometimes use EFB as fuel but the number is only few. Thus, it is neglected in this study. The solid and liquid wastes shown in Table 1 still contain energy. The High Heating Value (HHV) and proximate analysis of the solid palm oil biomass showed in Table 2. As a comparison, the HHV of coal (Bituminous and Lignite) also show in the table. The HHV of EFB is way higher than Lignite, and it is about 66.71% of Bituminous HHV. The Palm kernel shell is even better because it has 70.99% Bituminous. These wastes have a significant energy value.

### Table 2 HHV and proximate analysis of Palm oil biomass waste in comparison with Coal

| Sample            | HHV (MJ/kg) | Moisture content (wt%) | Ash content (wt%) | Volatile matter content (wt%) |
|-------------------|-------------|------------------------|------------------|-------------------------------|
| Palm Oil Waste    |             |                        |                  |                               |
| EFB               | 18.8        | 67.00                  | 4.60             | 87.04                         |
| Mesocarp Fibre    | 19.06       | 37.09                  | 6.10             | 84.91                         |
| Kernel Shell      | 20.09       | 12.00                  | 3.00             | 83.45                         |
| Palm tree fronds  | 15.72       | 70.60                  | 3.37             | 85.10                         |
| Palm tree trunks  | 17.47       | 75.60                  | 3.35             | 86.70                         |
| Coal              |             |                        |                  |                               |
| Bituminous        | 28.30       | 11.00                  | 8.70             | 46                            |
| Lignite           | 2.80        | 39.00                  | 10.70            | 29                            |

POME also has an immense potency of energy values. In general, POME always regards as highly polluting wastewater generated from POM as a by-product of CPO production. It is brownish liquid composed of biomass, BOD and COD. It will produce significant CO2 and CH4 emissions if it sends to the lagoon. However, several proven technologies can implement to convert POME into Methane, to use as fuel. Every 1 ton of POME can convert into 28 m³ of biogas, which has a methane potential of about 15 m³. This value will use for estimating the potency of renewable energy from POME. Based on this data, the estimated potential of renewable energy from the wastes of the Palm oil industry in Indonesia in 2020 and 2030 showed in Table 3. This table showed that in 2020, 605,523 Ton of Oil Equivalent can generate from a waste of POM in Indonesia. If the CPO production increases as expected, the fuel energy saving can reach a value of 1,208,154 ToE.

### Table 3 The potency of Fuel saving from POM in Indonesia

| Material | Heat to Electricity (kWh/ton) | Year 2020 | Year 2030 |
|----------|-------------------------------|-----------|-----------|
|          |                               | Ton       | Fuel Saving Potential (ToE) | Ton       | Fuel Saving Potential (ToE) |
| CPO      | -                             | 49,117,260| -         | 98,000,000| -                         |
| FFB      | -                             | 223,260,273| -         | 445,454,545| -                         |
| EFB      | 60.61                         | 50,456,822| 524,658    | 524,658    | 524,658                  |
| Shell    | 35.00                         | 6,028,027 | 36,195     | 36,195     | 36,195                   |
| POME     | 26.00                         | 145,119,177| 647,301   | 647,301    | 647,301                  |
| Total    |                               | 605,523   | 1,208,154  |           |

3.4. Fossil fuel

Although there is a significant potency of fossil fuel can generate from the palm oil industry, however, the Palm Oil industry in Indonesia still consumes significant fossil fuel. Based on the interview, fossil fuel consumption in the Palm oil industry for every 1000 hectare planted area per year showed in Table 4. Fossil fuel consumption counted in a liter of diesel oil. As a note, one palm oil mill design for 12,000 hectare planted area. Trucks transport the FFB to the mill. The trucks’s fuel is diesel oil. As shown in the table, the fuel consumption to transport the FFB from the plantation to the mill is the highest fossil fuel consumption. The second is fossil fuel for POM. It includes to start-up the mill, to supply the power when idle time, and additional engine in the mill. The total fossil fuel consumption for 12,000 Ha of
planted area is 492,000 Liter. In the year of 2020, the total planted area is 14,996,010 Ha. Thus, the total fossil fuel consumption in the palm oil industry in Indonesia in the year 2020 is 615 million liter of diesel fuel, equal to 602,540 ToE.

**Table 4** Fossil fuel consumption for 12000 Ha Planted Palm Oil

| Process                        | Type of Fuel | Consumption per Year | Note                                                                 |
|--------------------------------|--------------|----------------------|----------------------------------------------------------------------|
| Office and Housing             | Diesel       | 36,000 Liter         | To power Generator for stand by and when the electricity from the mill is absence |
| Transport FFB to the mill      | Diesel       | 300,000 Liter        | To fuel the truck to transport the FFB from the field to the Mill     |
| Tractor and Heavy Machines     | Diesel       | 36,000 Liter         |                                                                      |
| Palm Oil Mill                  | Diesel       | 120,000 Liter        | For Start Up, idle time, and additional need                          |
| **Total**                      |              | 492,000 Liter        |                                                                      |

4. Conclusion

In this present study, the utilization of conventional and renewable energy in the palm oil industry in Indonesia are analysed. The conclusion of this study is as follows. Based on the statistics, the total area of palm planted area and produced CPO in Indonesia in the year of 2020 are 14,996,010 Ha and 49,117,260 ton CPO, respectively. The palm oil industry has abundant renewable energy potency, and some of them has used to fuel the boiler for CPO production in the mill. On the other hand, there is 605,523 ToE of the potential has not been used. Since the production of CPO still increasing, the potency will rise up to 1,208,154 ToE. Even though there is a significant potency of renewable energy, conventional energy is still used in the palm oil industry. In the year 2020, it is estimated the conventional energy used in the palm oil industry is about 602,540 ToE. It is suggested that palm oil industry replaces the fossil fuel consumption and replace it with renewable energy.

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