# POTENTIALS ENERGY AND REDUCTION OF CARBON EMISSIONS FROM CRUDE PALM OIL PRODUCTION - CASE STUDY IN PT DENDY MARKER INDAH LESTARI SUMATERA SELATAN

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**Abstract.** Climate change has been a crucial issue in the world, it is believed as one of the cause of the agricultural disruption through extreme weather. Indonesia is an agrarian country which supports the *Paris Agreement COP21* in reducing greenhouse gases concentration in the atmosphere to prevent climate change, especially $CO_2$. Research about palm oil as a source of renewable energy have do to. Nowadays, Indonesia is the biggest exporter country of palm oil in the world, while palm oil is well known as one of the source of alternative energy which has high potential in reducing greenhouse gases concentration in atmosphere because has been carbon stock or utilization biomass as renewable energy.This study aimed to evaluate palm oil as a sustainable energy alternative and carbon emissions from CPO production. In this study carbon mobilization in palm oil was investigated from oil palm plantation process to the milling process. It was associated with carbon emission, carbon fixation, and carbon reduction. Survey results showed that the daily energy use in the mill start up averaged 5.6 kWh/ton of FFB. In addition, in the process of production CPO per ton achieved 52% that wastewater generated. Wastewater produces methane gas that could be converted biogas as a renewable energy. Based on the carbon balance approach, carbon emissions observed from the use of fossil energy in palm oil milling. The total of carbon emissions from palm oil milling can be calculated, resulting in a reduction of carbon in CPO production. The emission sources could be calculated from the use of fossil fuel, electricity. The total carbon emission from palm oil milling is very small (0.042%).While the emission reduction could be calculated from the utilization of waste either at the palm oil milling or palm oil plantation as a power generated or a soil fertility.

**Keywords:** biomass, carbon equivalence, palm oil milling

## I. INTRODUCTION

The issue of climate change is a serious problem in the world. Indonesia is one of country that has approved the reduction of greenhouse gases. The proof of of it sincerity that signed a Paris Agreement or COP21 Paris Agreement. Based on this case, there are many efforts in the reduction of greenhouse gas emissions (GHGs) is one of them by using energy that emit lower than the use of fossil energy such as biomass utilization.Several the effects of increasing GHG on climate change is that the Earth has warmer (global warming), drought, floods, higher sea levels and destruction plantations.

Indonesia is the biggest exporter country of palm oil in the world, while palm oil is well known as one of the source of alternative energy which has high potential in reducing greenhouse gases concentration in atmosphere because has been carbon stock or utilization biomass as renewable energy. The potential of palm oil production amounted 27.7 million tons in 2013 and with an estimated 30.9 million tons in 2015 [1]. Accordingly, the research utilization of palm oil biomass is shown to have a significantly high potential as a resources to be used for climate change mitigation to reduce cabon emissions, with the sum of potential C reduction 1.2 times greater than that of C emission in crude palm oil production can be increased up to 5.5 [2]. Others survey shows in carbon reduction used for electricity generation and soil conditioning in plantation are 649.3 and 13.5 kg CE/ha-y, respectively [3]. Based on the survey, the waste of oil palm production have a potential reduction of emission and a potential alternative energy. However, carbon is the main substance in the biosphere and its organic forms support the lives of almost all heterothophs [4].

Carbon reduction and emission in the CPO production were known by using the Carbon Balanced Model (CBM) [2]. This is achieved by comparing all resources used (or

carbon emission) within the utilization of biomassa residues (or carbon reductions) per functional unit (or carbon fixation). The following the concept of CBM [5], the aimed of this study to determine the carbon equivalence (CE) values and energy produced to control carbon emission and identify potential source of energy and carbon reduction in the milling process. The analysis is included from Fresh Fruit Bunches (FFB) as an input to the mill and output as a main products CPO and Palm Kernel Oil (PKO) co-products fiber, shell, Empty Fruit Bunch (EFB) and Palm Oil Milling Effluent (POME) which can be used to generate electricity in the power plant. Results from the *CE* analysis is a sustainability energy sector in reducing carbon emissions.

The carbon cycle of the earth modified by [2] from [5] is illustrated in Fig. 1, and it indicated the circulation of carbon and water, both of which are activated by radiated sun energy [2]. The schematic flow diagram of carbon transfer having three main paths carbon emission, fixation, and reduction. Details of there paths:

-Carbon emission comes from the anthropogenicuse of fossil energy and other fossil energyderived materials. As shown in Fig. 1, fossilmatter underneath the earth surface is dug up andused as energy to facilitate human activities. Afterthis, it remains in the atmosphere as the incremental$CO_2$.[3]

- Carbon fixation is the product of photosyntheticreaction in which atmospheric $CO_2$is combinedwith $H_2O$ to form organic carbon. It will be, then,mobilized horizontally to satisfy human need. Finally after being consumed by humans, it returns to the atmosphere, resulting in no emissions in this pathway.[3]

-Carbon reduction is the amount of carbon involved with any recovery, recycling, and reuse of waste. It is considered as a carbon reduction because it helps reduce the use of natural raw materials and fossil energy [10]

PT DMIL was located in the South of Sumatera. The areas about 18.000 hectare.

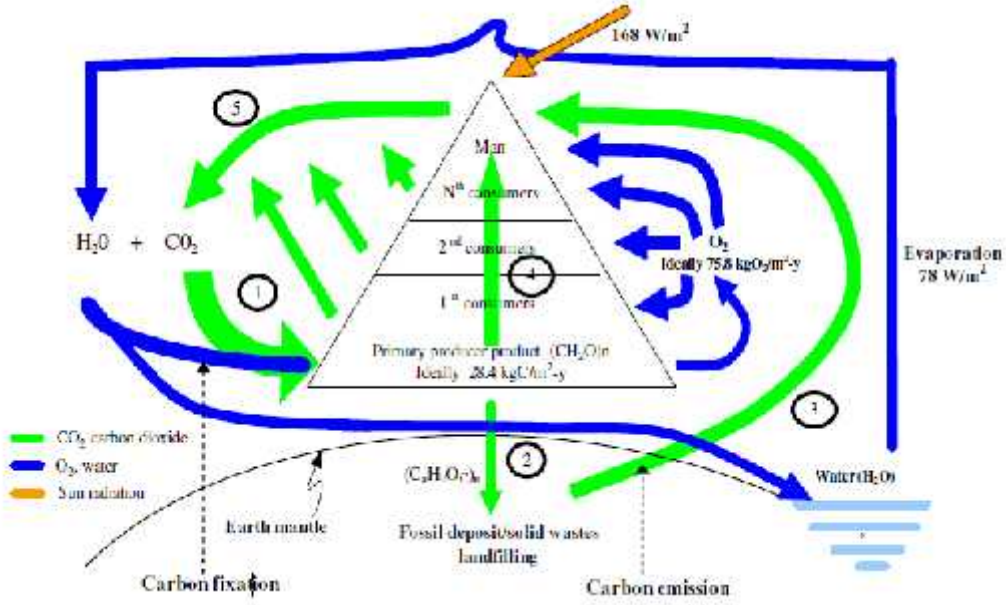


Fig. 1 Carbon cycle of the globe [3]

## II. METHODOLOGY

### *A. Goal and Scope of Research*

The goal of this study is to evaluate CE and energy produced related to palm oil milling in PT DMIL. The scope this study begins with FFB from palm oil plantations as an input material, but did not to evaluate the variable emission in plantations. The FFB as an input material will produce CPO and co-product in palm oil milling. Both energy consumption and energy generation will be evaluated. Energy coefficients reported from analysis laboratorium (kernel, fiber, shell, and EFB) and other from literature (CPO, diesel, electricity etc). CE estimations were made by using carbon equivalence conversion factors following the CBM concept. An approximate of carbon emission and carbon reduction is also calculated which the potential benefits of palm oil and co-products as renewable sources of energy. The unit of measurement used in this study for energy and carbon equivalence is MJ/ton FFB or kWh/ton FFB and kg CE/ton FFB or kg CE/ha-y, respectively. The first units are used to express the quantities of energy contained in product, and electricity generated from product. The second units are used for signify the quantities of carbon equivalence occurring per unit mass of raw material to the mill or plantations where carbon flow is emitted, fixed, or reduced.

### *B. Conversion Factor of Carbon Equivalence*

Conversion factors of equivalence from other studies were acquired from several databases such as IPCC [6]. This study formulates conversion factors of carbon equivalence by using the concept of CBM [2]. A major procces includes

photosynthesis, in which C from atmospheric $CO_2$ is fixed to become part of the organic molecules found in food, fuel, and fiber until decomposition when organic carbon is converted to inorganics and return to the atmosphere.

The mobilization process the fixed carbon can be categorized into three paths emission, fixation, and reduction. Emission carbon that would increase because manufacture, chemical fertilizer, and transportation shows in path 3 cycled, Fig. 1. Fossil fuel is non renewable energy, and increasing the atmospheric concentration of $CO_2$. So the caused of carbon emission are from the human use of fossil energy and other fossil from material. If the chemical formulas are known, the conversion factors for carbon equivalence of fossil energy compound can be calculated by dividing their molecular weights with the atomic weight of carbon (12 g/mol).

In this model equivalent carbon fixation is FFB which are the product of photosynthesis. As know that FFB are input of raw material. The reaction, including the enthalpy calculation, can be written as Equation 1[2].

$$CO_2(g) + H_2O(g) \leftrightarrow CH_2O(g) + O_2(g)$$
$$\Delta H_f^o;\ -393.5 \quad -241.8 \quad -116.0 \quad 0\ ;\mathrm{kJ/mol}$$
$$\Delta H^o = (-116.0 + 0) - (-393.5 - 241.8) = +519.3\ \mathrm{kJ/mol} \quad (1)$$

*CE* conversion factor of fossil fuels can be directly calculated from amount of carbon molecules present in the chemical formulas, such as diesel ($C_{12}H_{23}$). The equation for carbon equivalence estimation is shown in Equation 2[2].

$$CE_f = \frac{n \times C}{MW} \quad (2)$$

Where $CE_f$ is the conversion factor for fossil fuel (kg C/ kg fuel), *n* is the number of carbon atoms in the chemical formula (#), *C* is the atomic weight of carbon (12 g/mol), and *MW* is the molecular weight of the fuel (g/mol).Therefore, for biomass CE conversion factors are calculated, using the energy content for its production divided by the thermodynamic conversion factor (Equation 1, 43.3 kJ/g C) as shown in Equation 3.

$$CE_{fb} = E/43.3 \quad (3)$$

Where $CE_{fb}$ is the conversion factor, (kg C/kg fossil based material) and *E* is energy consumption for fossil-based material production (MJ/kg) [3].

In this study the *CE* conversion factor where calculated only in the palm oil milling. Energy consumption in the palm oil milling is diesel and electricity. As for the diesel consumption in this study that is assume data from two years latter 2014 times two is 1.948 liter per years equals to 0.21 liter per ton CPO. The energy of diesel is 0.86 [3]. Than be calculated, using Equation 3, as summarized in Table 2.

Biomassa is one of the renewable energy to reduce the use of fossil fuel.Burning of biomass resources no new carbon dioxide to the atmosphere because replanting harvested biomass ensures that $CO_2$ is absorbed and returned for a cycle of new growth [7]. The *CE* conversion factor can be calculated by known the value calorific of biomassa divided thermodynamic conversion factor from Equation 2.

The conversion factor of electricity was calculated, using the emission factor was calculated by Directorat General of Indonesia Electricity [8]. Where Sumatera have value of emissions factor equal to 0.79 kg $CO_2$/kWh with ratio of C to $CO_2$ with molecular weight of 0.27 [2]. Therefore, 0.21 kg CE/kWh was conversion factor used to determine the carbon equivalence from electricity consumption. In this study electricity from grid was considered as the equivalent carbon emission. The electricity from waste as biomass fuel was considered as the equivalent carbon reduction [9].

The authors consider the world's human population as a carbon mobilizer that causes carbon movement to statisfy their need. therefore, it is not included in the determination of carbon equivalences [3].

### *C. Field Data Collection*

Primary data were collected from a field survey of PT DMIL having a capacity of 20 tons FFB/h and wide 18,000 ha. the sample where PT DMIL located in the South Sumatera Province. Data collected include resources used, such as electricity consumption and fossil fuel required in the mills, which are used to evaluate the equivalent carbon emissions. In addition, data of product and co-products produced (such as FFB, CPO, shell, EFB, and POME) were as carbon fixation and reduction. Analysis of energy from fiber, shell, EFB and kernel was known from calorific evaluation by using bom calorimeter. The analysis conducted in Laboratorium Science and Technology of Feed, Bogor Agriculture University. The secondary data are partially the value conversion factor, factor emission of electricity, diesel and other can find in literature.

## III. Result and Discussion

### *A. Energy Consumption in Palm Oil Milling*

Process palm oil milling consist of six steps are sterilization, treshing, digestion, pressing, clarification and drying, nut cracking and kernel recovery. From that processes will produced CPO.

The primary product of palm oil milling is CPO. And the co product is fiber, shell, efb, kernel and POME. Kernel can be produced PKO. So kernel is one of the main product in palm oil milling beside CPO. In this company there produced CPO and kernel, 16% and 4.7%, respectively. Where the average FFB produced as an input about 66,848.76 ton FFB per years. CPO produced at amount 522.55 kg/ha-y. Kernel produced equal 149.88 kg/ha-y. kernel oil has the potential to be a PKO that has a price more expensive than a carbon reduction in this study. While waste from the crude palm oil production is fiber, shell, EFB and POME will be used as an alternative fuel as the reduction of carbon in the palm oil milling. The energy potential is the EFB, fiber, shell and biogas. The EFB potential for soil fertilizer and other for biofuel in the palm oil milling as shown in Table 1.

TABLE I
BIOMASS PRODUCTION AND POTENTIALENERGY
IN PALM OIL MILLING PT DMIL

| No | Type of Biomass | Massa (kg/ha-y) | Calorific Value (MJ/kg) | Energy Produced (MJ per ha-y) |
|---|---|---|---|---|
| 1 | CPO | 522.55 | 35.20[a] | 18,393.64 |
| 2 | Kernel | 149.88 | 24.07 | 3,607.09 |
| 3 | Empty Fruit Bunches | 854.18 | 21.43 | 18,301.85 |
| 4 | Shell | 297.11 | 18.49 | 5,493.21 |
| 5 | Fiber | 631.35 | 16.46 | 10,389.28 |
| 6 | Biogas ($m^3$) | 196.00 | 23.00[a] | 4,508.00 |
| **Total energy** | | | | 60,693.08 |

Derived from: [a] [2]

Mass (kg/ha-y) is the percentage of production in kilograms per unit area of oil palm plantations is 18,000 ha. Calorific value (MJ/kg) obtained from Equation 3. where for CPO and biogas researchers used literature data. While the kernel, EFB, shell, fiber get from laboratory analysis. One cubic meter POME contains 12-16 $m^3$ of biogas, of which 1 $m^3$ generally can generate 1.0-1.2 kWh of electricity. Here researchers used the average value is 14 $m^3$ of biogas [11]. In this study, the assumption of many pome generated in producing CPO is 0.7 $m^3$ per tonne of FFB [12]. The capacity of FFB is 20 ton FFB per hour. that the mass of biogas produced by PT DMIL is 196 $m^3$ per ton TBS or equal to 3,695.72 kg/ha-y.

*B. Energy and C-equivalences in The Palm Oil Milling*

Carbon equivalence conversion factor can be calculated is shown in Equation 3. Where the energy content or calorific value (MJ/kg) is shown in Table 1. After that, the *CE* conversion factor calculated by divided energy content (MJ/kg) with thermodynamic conversion factor. See Table 2.

TABLE II
CE-CONVERSION FACTOR IN CRUDE PALM OIL MILLING

| No | Variable | CE Conversion Factor (kg CE/kg) |
|---|---|---|
| 1 | Diesel | 0.86[a] |
| 2 | Electricity | 0.21[b] |
| 3 | CPO | 0.81[a] |
| 4 | Kernel | 0.56 |
| 5 | Empty Fruit Bunches | 0.49 |
| 6 | Palm Fiber | 0.38 |
| 7 | Palm Shell | 0.43 |
| 8 | Biogas | 0.53[c] |

Remark: [a] [2], [b] [8], [c] data express in kg CE/ $m^3$

From the Table 2.can calculated the carbon emission, carbon fixation and carbon reduction in oil palm milling. In this study are calculated carbon emission in the palm oil milling. The carbon equivalence was divided in to three categorizes. First carbon emission that comes from diesel consumption and electricity consumption.Second carbon fixation from CPO production and kernel production. Third carbon reduction from reuse waste from CPO production there are, electricity from fiber, shell as a fuel, EFB as a soil fertilizer, and electricity generation from biogas.

Using the carbon equivalence conversion factor 0.21 kg CE/kWh for electricity generation in Sumatera [8], the amount of electrical consumed 11.51 kg CE/ton CPO as summarized in Table III. The *CE* value of electricity in this study is consistent with those reported study [2].

In addition, fiber, shell as a fuel, EFB for soil conditioning resulting in a reduction of 23.37, 244.49, and 5.23 kg CE/ton CPO, respectively. Biogas, which can be produced anaerobically from POME resulting in a reduction of 5.26 kg CE/ton FFB.

The total carbon emission from palm oil milling is very small at amount 11.69 kg CE/ton CPO(0.042%). Based on the amount of carbon emission from palm oil plantation and oil palm milling is very small (2%) [2].

The total carbon reduction was estimated 274 kg CE/ton CPO) this study consistent from other research [3].While the total carbon fixation derived from CPO production and kernel production equal to 840 kg CE/ton CPO. This study consistent from other research [3]. Assumed that per kg biodiesel equal to 0.307 kWh. [12]. If all biomass are used as fuel for the boiler can substituting electricity from oil palm plantation. on RUPTL PT. PLN (Persero) year 2009-2018, Indonesia require 2,425 million liters of diesel fuel diesel to generate 8,115 GWh of electricity [13]. Assuming one kg biomass can produced biodiesel equal to 0.307 kWhof electricity. Then assumed the quality of diesel and 100% biodiesel (B100) is equal to the weight of fuel for the production of 1 kWh of electricity each, 0.25 kg equal to 4 kWh per kg[14]. From this study the production of FFB about 66,8 ton FFB. The calculated of biodiesel production from this palm oil milling can achive about 141 MWh.

TABLE III
UNIT MEASUREMENT AND CARBON EQUIVALENCE IN OIL PALM MILLING

| No | Process | Unit Measurement | | Carbon Equivalent (kg CE/ ton CPO) |
|---|---|---|---|---|
| | | Value | Unit per ton CPO | |
| *Carbon Emission* | | | | |
| 1 | Diesel Consumption | 0.21 | L | 0.18 |
| 2 | Electricity from grid | 54.80 | kWh | 11.51 |
| Total Emission | | | | **11.69** |
| *Carbon Fixation* | | | | |
| 3 | CPO production | 1,000 | kg | 812.93 |
| 4 | Kernel Production | 49 | kg | 27.23 |
| Total Fixation | | | | **840** |
| *Carbon Reduction* | | | | |
| 5 | EFB Production (for soil fertilizer) | 1,634.65 | kg | 5.23 |
| 6 | Electricity from fiber | 111.27 | kWh | 23.37 |
| 7 | Shell as a fuel | 568.57 | kg | 244.49 |
| 8 | Electricity generation from biogas | 25.03 | kWh | 5.26 |
| Total Reduction | | | | **278** |

### *C. Scenarios*

Reduction potential scenario consists of a baseline scenario, scenario 1, scenario 2, scenario 3. As is the baseline scenario, which consists of the use of fiber alone in the factory. Scenario 1 is the use of fiber and shell. Scenario 2 is the use of fiber, shell, and EFB. While all three scenarios is the use of fiber, shell, EFB, and Biogas. Calculations by per kg biomass equal to 0.307 kWh electricity. The value baseline scenario to scenario 3 there are 307.92, 545.47, 1,047.31 and 1,072.34, kWh/ton CPO, respectively.

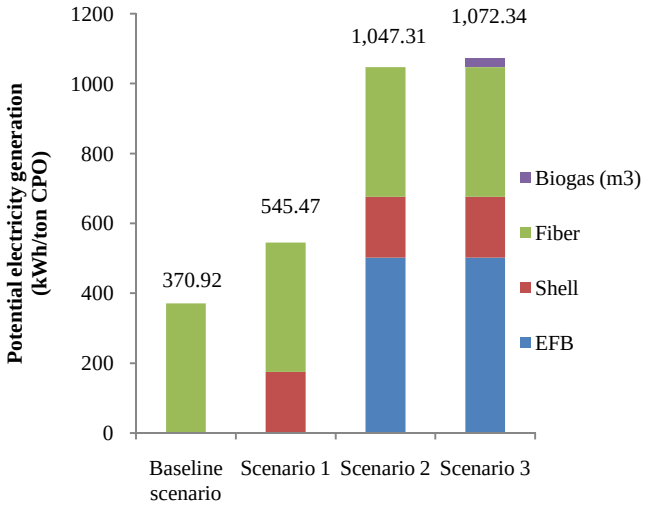


Fig. 2 Scenarios of potential electricity generation (kWh/ton CPO)

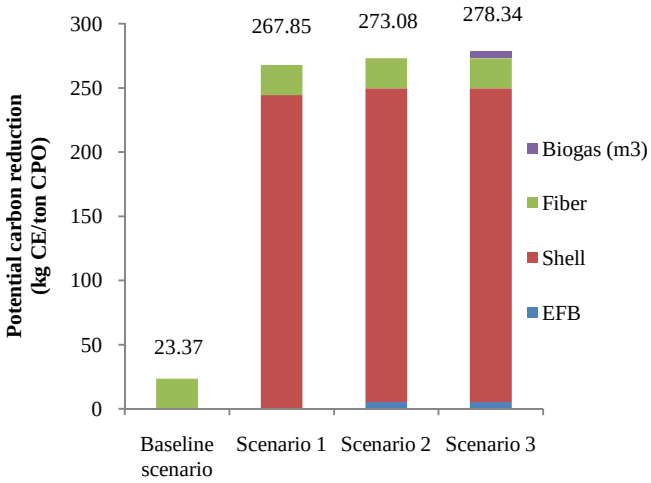


Fig. 3 Scenarios of potential carbon reduction (kg CE/ton CPO)

Potential carbon reduction is the result of multiplying the emission factor and the mass of each co-product. The highest potential carbon reduction is scenario 3 at amount 278.34 kg CE/ton CPO)

## IV. CONCLUSION

Oil palm plantations can be an energy source that is sustainable biomass energy. The potential of electricity achieve 141 MWh. The potential carbon reduction 278 kg CE/ton CPO by using all biomass. The carbon fixation derived CPO production 840 kg CE/ton CPO. The total carbon emission from palm oil milling is very small (0.042%).

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