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Abstract. The palm oil industry contributes to produce Green House Gases (GHG) from the land conversion sector, energy use, industrial processes and residual waste from palm oil production. Energy is one of the important sectors in the inventory of GHG emissions. In energy consumption, GHGs are generated from the use of diesel fuel, burning shells and fiber. In addition to the use of diesel as its main fuel, shells and fiber are utilized for fuel. In this study, the calculation of the amount of emissions produced from palm oil mills in the energy sector was calculated according to the 2006 IPCC Guidelines Volume 2 Chapter 2 concerning the Stationary Combustion. The calculation results obtained by the average emissions produced in observed palm oil mill for the energy sector is 1,570,883 kg CO_2/year or 1.5 Gg CO_2/year.

Keywords: GHG in palm oil mill, methane capture, IPCC emission guidelines, stationary combustion, allocation factor.

1. Introduction

Indonesia is the largest palm oil exporter in the world, with the total export of palm oil reaching 26467.6 thousand tons [1]. The rapid development of the world oil palm industry has a positive and negative impact on the environment. One of the adverse effects of the existence of palm oil mills is the emission of Green House Gases (GHG) generated in the production process, energy consumption, and the process of degradation of residual waste production. The accumulation of GHG in the atmosphere increases the global-mean temperature. Climate change and variability can lead to disaster [2], lead to loss of property, infrastructure damage [5], and affecting people livelihood [3], [4]. Efforts are conducted all over the world trying to limit the rise of global-mean temperature to 1.5^{o}C [6], including developing climate modelling and pathways [7], reduced energy use, and carbon-dioxide removal [6]. Calculation of GHG emission in industry sector become necessary to be able to set the target of emission reduction. This paper analyses the carbon emission in one of Palm Oil Mill in Belitung Island, Indonesia.

Observed palm oil mill in Belitung Island produces Crude Palm Oil (CPO) and Palm Kernel Oil (PKO) from Palm Fresh Fruit Bunches (FFB). The mill has been operating since 2000. Fresh Fruit Bunches (FFB) come from 3 nucleus estates and 5 outer estates. FFB from the outer estates will then be transported by truck to the Palm Oil Mill (POM). FFB sent to POM was weighed before and separated into Black Bunch, Unripe Bunch, Rotten Bunch, Ripe Bunch, Long Shaft, and Pest Damage. FFB will then go through a refinery process which is a process of CPO oil preparation to eliminate Free Fatty Acid (FFA), odor, and reduce color so that it meets quality standards.

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CPO will be processed in a refinery and produce Refined Bleached Deodorized Palm Oil (RBDPO), Palm Fatty Acid Distillate (PFAD), and Stearin, and olein. This olein can be used as cooking oil. While the Kernel Palm is processed into the Crude Palm Kernel Oil (CPKO).

Based on the 2006 IPCC Guideline, GHG emission sources from the energy sector classified into three main categories, namely: The emissions from fuel combustion; The fugitive emissions in fuel production and supply activities; and The emissions from CO_2 transport and injection in CO_2 storage activities in geological formations. [8]

The main type of GHG from the fuel combustion process is carbon dioxide (CO_2). Other types of GHG released from fuel combustion are carbon monoxide (CO), methane (CH_4), N_2O and non-methane volatile organic compounds (NMVOCs). The main type of GHG from fugitive emissions is methane [9].

2. Purpose of Study

The purpose of this study is to determine the amount of emissions produced from palm oil mills in the process of energy consumption.

3. Research Methodology

The research framework describes the stages carried out during this research. Figure 1. Shows the research framework.

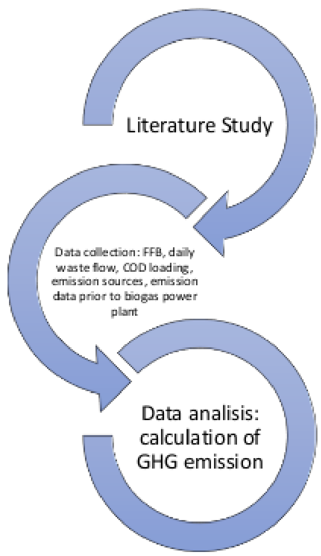

Figure 1 Research Framework
Source: Author, 2018

Based on the research framework above, the initial stage of this research begins by looking for literature that are related to the research. Furthermore, secondary data collection is in the form of daily raw material used, diesel consumption data, and consumption of shells and fiber. The research method used in this study is the evaluation of GHG emissions in the energy sector following the IPCC 2006 Volume 2 Chapter 2 for GHG emission from stationary combustion [2].

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GHG Emission from Stationary Combustion

GHG emissions, fuel = *Fuel Consumption, fuel • Emission Factor, fuel* ………………..(1)

Where:
Emissions GHG, fuel = GHG emissions based on fuel type (kg GHG)
Fuel Consumption, fuel = Fuel burning (TJ)
Emission Factor, fuel = Emission factor based on fuel (kg gas/TJ). For CO_2, including carbon dioxide factors, it is assumed to be 1.

In table 1 attached the fuel heating value in Indonesia is used as a conversion factor to find consumption in Terra Joule (TJ).

Table 1 Indonesian Fuel Value

Fuel	Calorific Value	Usage
Premium*	33×10^{-6} TJ/liter	Motor Vehicle
Solar (HSD, ADO)	36×10^{-6} TJ/liter	Motor Vehicle Power plants
Diesel Oil (IDO)	38×10^{-6} TJ/liter	Industrial Boiler, power plant
Marine Fuel Oil (MFO)	40×10^{-6} TJ/liter 4.04×10^{-2} TJ/liter	Power Pants
Natural Gas	1.055×10^{-6} TJ/liter 38.5×10^{-6} TJ/liter	Industry, household, restaurant
LPG	47×10^{-6} TJ/liter	Household, Restaurant
Coal	18.9×10^{-6} TJ/liter	Power plant, industry

Note: *) including Pertamax, Pertamax Plus
HSD: *High Speed Diesel*
ADO: *Automotive Diesel Oil*
IDO: *Industrial Diesel Oil*

Source : [9]

The emission factors are needed for calculating the level of immovable and moving sources of greenhouse gas emissions that can be seen in table 2.

Table 2 Stationary and Moving Source of Green House Gas Emission Factors (FE)

Fuel Type	**Stationary FE *Default* IPCC 2006, Ton/GJ**			**Moving FE *Default* IPCC 2006, Ton/GJ**		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Natural gas/BBG	56100	1	0.1	56100	92	3
Premium (without catalyst)	-	-	-	69300	33	3.2
Diesel (IDO/ADO)	74100	3	0.6	74100	3.9	3.9
Industrial/Residual Fuel Oil	77400	3	0.6	-	-	-
Marine Fuel Oil (MFO)	-	-	-	77400	7±50%	2
Coal (sub-bituminous)	96100	10	1.5	-	-	-

Description: 1 ton/Gj = 1 kg/Tj
Source:[8]

PKO extraction is outside the system boundary of this calculation, so that a portion of the emissions and releases of oil palm cultivation and the production of crude palm oil must be allocated to the palm kernel which leaves the system. The Allocation with mass or energy is recommended by the ISO 14040 standard. The Mass allocation results are converted to energy allocation using LVH for CPO (39.3 MJ/kg) and PK (21.1 MJ/kg). The calculation for allocation factors:

$$\text{Allocation Factor} = \frac{\text{CPO x 1000 x39.3}}{\text{CPO x 1000 x 39.3+ kernel 1000 x 21.1}} \qquad \text{...(2)}$$

4. Result and Discussion

Data of oil palm fresh fruit bunches (FFB) produced from 3 nucleus estates and 5 outer estates were obtained annually from observed POM. The increase and decrease in the amount of FFB processed is affected by the climate and weather. If the rainy season, the amount of FFB processed tends to be less because fruits are damaged. In Table 3, there are data on FFB per year calculated from October and end in September.

Table 3 Total FFB per Year

Time	Product Total (ton FFB/year)
oct 10 - sep 11	277,881.04
oct 11 - sep 12	341,870.80
oct 12 - sep 13	426,975.42
oct 13 - sep 14	440,356.10
oct 14 - sep 15	439,372.94
oct 15 - sep 16	371,191.42
oct 16 - sep 17	372,864.51

Source: observed POM

The data on annual solar usage is obtained from POM and Bulking Installation. The calculation of solar consumption per year is calculated starting in October and end in September. From the available data, it can be seen that there was an increase in diesel usage from October 2010 to September 2012, then decreased from October 2013 to September 2017.

The increase and decrease in diesel consumption are affected by the amount of FFB processed in a year. The more FFB processed, the greater the consumption of diesel fuel used to drive the turbine. In this data the decline is also influenced by the use of diesel in bulking installations. In September 2012 to September 2013 there was a decrease in the use of diesel fuel because in that year there was no diesel consumption for bulking installation.

In Table 4, there is data on diesel consumption in POM and Bulking Installation per year, calculation were start in October and end in September.

Table 4 Solar Consumption Data in POM

Year	Solar in POM	Solar in Bulking Installation	Total (liter)
Oct 10 - Sep 11	417,384	455,738	873,122
Oct 11 - Sep 12	532,596	517,698	1,050,294

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Year	Solar in POM	Solar in Bulking Installation	Total (liter)
Oct 12 - Sep 13	613,099	0	613,099
Oct 13 - Sep 14	680,556	0	680,556
Oct 14 - Sep 15	428,421	0	428,421
Oct 15 - Sep 16	373,618	0	373,618
Oct 16 - Sep 17	103,017	0	103,017

Source: Observed POM

In table 5, there are the results of the calculation of emissions produced by observed POM in the energy sector which is calculated using equation 1. The calculation uses the fuel consumption data in table 4 which is then converted with the conversion factor attached to table 1. Data on diesel fuel consumption that has been converted then multiplied by the emission factor attached to table 2.

Table 5 Table Fuel Consumption, Conversion Factor, Emission Factor and Emission Solar

Year	Time	Fuel Consumption (Litre)	Conversion Factor	Emission Factor (Kg/Tj)	Emission (Kg CO2eq)
1	Oct 10 - Sep 11	873,122	36 x 10^{-6} TJ/liter	74100	2,329,139.18
2	Octv11 - Sep 12	1,050,294	36 x 10^{-6} TJ/liter	74100	2,801,764.81
3	Oct 12 - Sep 13	613,099	36 x 10^{-6} TJ/liter	74100	1,635,502.89
4	Oct 13 - Sep 14	680,556	36 x 10^{-6} TJ/liter	74100	1,815,451.19
5	Oct 14 - Sep 15	428,421	36 x 10^{-6} TJ/liter	74100	1,142,855.86
6	Oct 15 - Sep 16	373,618	36 x 10^{-6} TJ/liter	74100	996,663.38
7	Oct 16 - Sep 17	103,017	36 x 10^{-6} TJ/liter	74100	274,808.15

Based on the calculations using the 2006 IPCC method on National Greenhouse Gas Inventories Volume 2 Chapter 2 for stationary combustion with Tier 1 applications, the GHG produced by observed POM in the energy sector from October 2010 to September 2017 shown in table 6.

Table 6 Energy Sector Emission Calculation Results

Time	Emission Gg CO2eq	Emission Kg CO2eq
Oct 10 - Sep 11	2.33	2,329,139.18
Oct 11 - Sep 12	2.80	2,801,764.81
Oct 12 - Sep 13	1.64	1,635,502.89
Oct 13 - Sep 14	1.82	1,815,451.19
Oct 14 - Sep 15	1.14	1,142,855.86
Oct 15 - Sep 16	1.00	996,663.38
Oct 16 - Sep 17	0.28	274,808.15

Source: Author, 2018

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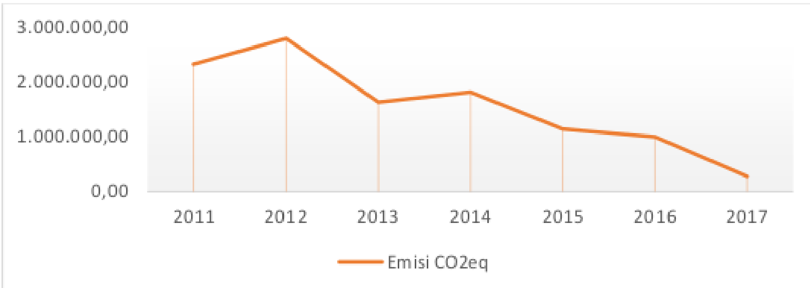
Based on graph 4.1, CO2eq emissions from the energy sector are directly proportional to the graph of diesel fuel consumption in POM and bulking installations. This shows that the more diesel consumed, the higher CO2eq gas emissions will be produced

Graph 1 Energy Sector Emission Calculation Results



Source: Author, 2018

Based on the calculations made by observed POM from the consumption of diesel fuel, CO_2 produced in the energy sector from October 2010 to September 2017, the results is shown in table 7

Table 7 Energy Sector GHG Emission Calculation Results from Solar Consumption

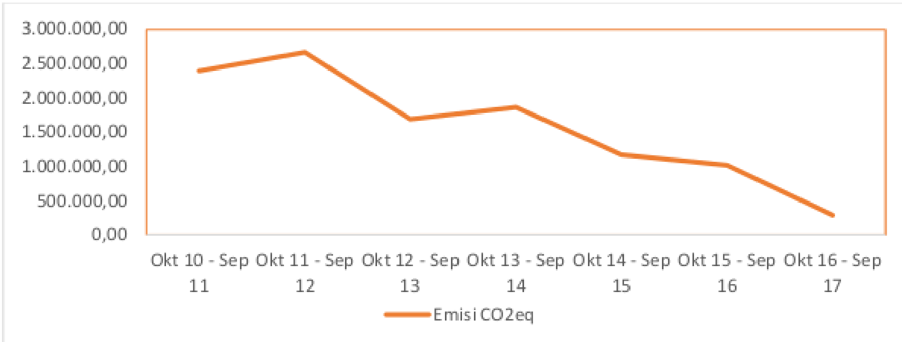
Year	Solar (litre)	*Co-efficient factor*	Allocation Factor	Emission Kg CO_2eq from solar consumption
Oct 10 - Sep 11	873,122	3.1	0.88	2,393,938.67
Oct 11 - Sep 12	1,050,294	3.1	0.88	2,663,199.74
Oct 12 - Sep 13	613,099	3.1	0.88	1,688,897.39
Oct 13 - Sep 14	680,556	3.1	0.88	1,863,939.36
Oct 14 - Sep 15	428,421	3.1	0.88	1,171,854.73
Oct 15 - Sep 16	373,618	3.1	0.88	1,017,510.21
Oct 16 - Sep 17	103,017	3.1	0.88	290,059.13
			Average	1,584,199.89

Source: observed POM

GHG emissions are calculated by multiplying the total use of diesel (litre) by the co-efficient factor (3.1) [kgCO2e/liter]. This coefficient factor is used by the observed POM from the Renewable Transport Fuel Obligation (RTFO). Whereas for the value of the allocation factor obtained from the calculation using equation 2.

Based on graph 2, CO_2eq emissions from the energy sector from solar consumption decreased from October 2014 - September 2017, because, after the installation of biogas power plant, the amount of diesel consumed was reduced. The electricity from the biogas power plant is used for electricity in housing and mill.

Graph 2 Energy Sector Emission Calculation Results using Data from Observed POM



Source: Author, using secondary data from observed POM, 2018

5. Conclusion

The conclusion obtained from this study is that the amount of CO_2 emissions in the energy sector depends on the amount of diesel consumed annually and the average emission produced by observed POM in the energy sector annually is 1,570,883.64 kg CO_2/year or 1.5 Gg CO_2/year.

Acknowledgement

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