IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Mitigation of Carbon Dioxide Emissions from Crude Palm Oil Industry in Kampar Regency of Riau Province

Mitigation of Carbon Dioxide Emissions from Crude Palm Oil Industry in Kampar Regency of Riau Province

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Abstract. Riau is one of the provinces that has the most palm oil mill in Indonesia. The palm oil mill activities produce carbon dioxide emissions from it processes. This study aims to calculate carbon dioxide emissions from the palm oil mill and plan it mitigation efforts. This research was conducted at one of the palm oil processing plants in Kampar district, Riau Province. Palm oil mill utilizes biomass in the form of fibers and shells of palm fruit as boiler fuel to generate electricity, in addition from the use of generator sets. The palm oil mill produces liquid waste. In the process of transporting palm fruit from the garden to the factory, it also produces emissions from transportation. The results of this study showed that carbon dioxide emissions from palm oil mill amounted to 709,436.87 ton CO_2 eq/year. The mitigation efforts that can be carried out are by catching methane gas produced from the process of treating liquid waste and turning it into electricity. The electricity generated would meet the energy needs of the plant so that it could eliminate the use of boilers and generator set, eventually the carbon dioxide emissions produced from palm oil mill can be reduced by 99.23%.

1. Introduction

Climate change is a challenge for the sustainability of human life. Efforts have been made to more accurately evaluate the amount of human-induced carbon emissions. As industry is one of the major users of energy, carbon emissions caused by combustion from industrial sectors have also been widely studied and estimated. Compared to studies on carbon emissions from combustion, fewer studies focused on the emissions from industrial processes and waste management, especially in the context of developing countries [1]. One of those industry is palm oil industry. The palm oil tree is considered as the most promising biomass plant. It has the highest yield among oil yielding plants and its long rotation period provides a long-term supply of products and residues [2].

Indonesia is a country with the world's largest oil palm plantation land. According to [3] Indonesia's palm oil plantation land is recorded at 12.3 million hectares in 2017. Riau Province is the largest producer of palm oil fruits in Indonesia which amounted to 7.33 million tons with the number of Palm Oil Mill as many as 146 units.

Indonesia's palm oil potential shows that palm oil agribusiness plays a role in the economy, society, national and global. In addition, the future development of palm agribusiness is also promising, as it is predicted that the demand for palm oil and its derivatives will increase. But on the other hand, palm oil agribusiness invites national and global attention related to environmental issues. Environmental issues are closely linked to palm oil agribusiness as one of the major contributors to greenhouse gas (GHG) emissions. In 2011, the issue of Indonesia's environmentally unfriendly Crude Palm Oil (CPO) product since EPA (Environmental Protection Agency) issued a NoDA (Notice of Data Availability) policy that Indonesia only reduces its GHG emissions about 11-17% [4]. While the GHG emission reduction standard is at least 20% in accordance with Renewable Fuel Standards (RFS) standards.

The Government of Indonesia is paying a great attention to this issue by committing to reduce greenhouse gas emissions. Indonesia's commitment to reducing greenhouse gas emissions by 29% by self-employment and 41% international assistance until 2030. This is an affirmation from the overall national action plan to reduce greenhouse gas emissions contained in the Presidential Regulation of the Republic of Indonesia no. 61 of 2011 on the national action plan of greenhouse gas emission reduction and Presidential Regulation No. 71 of 2011 on the implementation of national greenhouse gas inventories [5,6].

2. Methodology

2.1. Research sites
The research was conducted on one of Palm Oil Mill in Sungai Jernih Village, Kampar Regency, Riau Province, Indonesia.

2.2. Research Boundary
This are the Research Boundary for this research

Table 1. Research boundary from process to count CO_2 Equivalent Emission

No	Emission Source	Process	Result
1	Palm Oil Mill Liquid Waste	Processing of Palm Oil Liquid Waste	CO_2 Equivalent Emission
2	Fibers and Shells	Boiler	
		Generator	
3	Diesel fuel	Transportation of fresh fruit bunches and empty bunches	

2.3. Types and Data Sources
Data types used include primary and secondary data. Primary data was obtained by way of direct retrieval in the field. Primary data was obtained through field observation and interview with company side. Secondary data is obtained from corporate documented data and relevant literature. The description of the type and source of the complete data can be seen in Table 2.

Table 2. Types and Sources of Data from Emissions of Palm Oil Mill

Data Description	Data Type	Data source
Fuel consumption of diesel (ton /year)	Secondary data	Company annual report
Electricity requirements (MWh/year)	Secondary data	Company annual report
Total CPO production (ton / year)	Secondary data	Company annual report
fresh fruit bunches (ton/year)	Secondary data	Company annual report
Operation time (day / year)	Secondary data	Company annual report
Fuel composition (% carbon)	Secondary data	Company annual report
fuel calorific value (kJ / Kg)	Secondary data	Company annual report
Consumption of fiber and shell (ton / year)	Secondary data	Company annual report
Wastewater discharge m^3 / hour	Secondary data	Company annual report
COD_{in} and COD_{out}	Secondary data	Company annual report
Waste water treatment of POME	Primary Data	Field observations
Number of trucks and its trip	Secondary data	Company annual report
Emission factor for transportation	Secondary data	Literature

IOP Conf. Series: Materials Science and Engineering **546** (2019) 022022 doi:10.1088/1757-899X/546/2/022022

2.4. Calculation of emissions

Data processing was done to obtain total CO_2 emissions equivalent that produced by palm oil mills. The GHG emission unit produced in ton CO_2 equivalent.

2.4.1. Use of generator set in palm oil mill. The electricity used by palm oil mill is not from the National Electricity Company but rather from the utilization of the work process of boilers and diesel-powered generators. Diesel-powered generators are used when the boiler does not work. Calculation of palm oil generator emissions using [7]

E = A x NCV x EF x GWP (1)

E = Emissions (ton CO_2 eq/year)
A = Amount of fuel (liter)
NCV = *Net Caloric Value* (TJ)/Liter
EF = emission factor (kg/TJ)
GWP = Global Warming Potential

2.4.2. Use of boilers in palm oil mill. The utilization of the work process from the boiler is one of the producers of electricity in Palm Oil Mill because the electricity used in palm oil mill does not come from the State Electricity Company. The fuel used for the boiler is palm oil fiber and shells. Calculation of palm oil generator emissions using [7]

E = B x NCV x EF x GWP (2)

E = Emissions (ton CO_2 eq/year)
B = Amount of Biomass (Kg/year)
NCV = Net Caloric Value (TJ)/Kg
EF = emission factor (kg/TJ)
GWP = Global Warming Potential

2.4.3. Waste water treatment of POME (palm oil mill effluent). Emissions are sourced from biogas production in palm oil mill effluent. Emissions generated from palm oil mill effluent in the form of methane emissions (CH_4) so that it is converted into CO_2 emissions, which is multiplied by GWP. Methane emissions are calculated based on CPO production data, POME production, and COD values. Calculation of palm oil liquid waste emissions using [8].

2.4.4. Transportation of fresh fruit bunches and empty bunches. Operational vehicles use truck type vehicle with diesel fuel. This vehicle is used to carry fresh fruit bunches (FFB) from the garden towards Palm Oil Mill. Calculation of palm oil transportation emissions using [7].

E = n x EF x K (3)

E = Emissions (ton CO_2 eq/year)
n = number of vehicles
EF = emission factor (kg CO_2/liter)
K = fuel consumption (liter/100 km)

2.5. Energy generation

POME is a prospective commodity which could be used as new source of energy (fuel).
Energy potential that can be generated [9, 10, 11]:

PE = PME x HEP (4)

PE = Energy potential (in 1 year)
PME = potential of methane gas
HEP = heat energy potential

Electricity potential that can be generated

EG = PE x EC (5)

EG = Electricity potential
PE = Energy potential (in 1 year)
EC = energy conversion to electricity (0,00028 MWh / MJ)

3. Results and Discussion

3.1. Emissions of CO_2 Equivalent

Sources of emissions from palm oil mill is activities divided into four sources, namely from the use of generator sets, the use of boilers, liquid waste treatment and the use of transportation.

3.1.1. Use of generator set in Palm Oil Mill. The amount of diesel fuel used by palm oil mill in 2018 is 42,971 liters / year. The heating value of diesel fuel is 36 x 10^{-6} TJ/L. Emission factors for CO_2 are 74,100 Ton / TJ, CH_4 is 3 Ton / TJ and N_2O is 0.6 ton/TJ. The value of global warming potential (GWP) for CO_2 is 1, CH_4 is 21 and N_2O is 310. To calculate the amount of emissions generated from the use of generator sets in palm oil mill, equation II.1 is used which contained in the research methodology. The value of CO_2 equivalent emissions from use generator set is shown at Table 3.

Table 3. Amount of Emissions sourced from the Use of Generators

Greenhouse Gas	Emissions Rate	Emissions on ton CO_2 eq/year
CO_2	114,629.44 tons CO_2 eq/year	114,629.44
CH_4	4.64 tons CH_4 eq/ year	97.44
N_2O	0.93 tons N_2O eq/ year	288.30
	Total emissions	115,015.18

3.1.2. Use of boilers in palm oil mill. To calculate the amount of emissions generated from the use of boilers in palm oil mill, equation II.2 is used, from the research methodology. The fuel used by the boiler is fibers and shells. The use of fibers and shells in 2018 was 25,964.5 tons/year and 11,153.7 tons/year respectively. The calorific values of fibers and shells are 11 x 10^{-6} TJ / kg and 15 x 10^{-6} TJ / kg respectively. The emission factor for N_2O is 0.6 Ton / TJ. The GWP value for N_2O is 310.

Table 4. Amount of Emissions Sourced from the Use of Boilers

Fuel Used	Emissions Rate	Emissions on ton CO_2 eq/year
Fibers	1142.44 tons N_2O eq/year	354,156.4
Shells	669.22 tons N_2O eq/year	207,458.2
	Total emissions	561,914.6

3.1.3. Waste Water Treatment at Palm Oil Mill. The amount of waste water in 2018 was 96,944 m^3/year. To calculate the amount of methane gas produced, the value of inlet COD contained in liquid waste is needed. The value of the inlet COD is 94,800 mg/L. The value of the formation capacity of methane gas from treated liquid waste is 0.21 kg CH_4/kg COD and the value of the methane gas correction factor is 0.8. From the calculation results obtained by total emissions from waste water treatment is 32,423.37 tons of CO_2.

3.1.4. Transportation of fresh fruit bunches and empty bunches. To calculate the amount of emissions generated from the use of transportation in palm oil mill, equation II.3 is used. The number of vehicles to transport Fresh Fruit Bunches and empty bunches is 7 units and 5 units respectively. The number of truck trips carrying Fresh Fruit Bunches and empty bunches are 7 trips/unit and 5 trips/unit, respectively, thus, the number of trips for each transportation is 35 times and 35 times. The distance of from Palm oil mill to the garden is ± 7 km, so the distance traveled is 14 km/trip. The fuel used is diesel fuel, so the emission factor is 2.2 kg CO_2/L. The vehicle used is a type of small truck (colt diesel) with diesel fuel so that the specific energy consumption is 10.64 L/100 km. The results of the calculation of emissions originating from the use of transportation in palm oil mill can be seen in Table 5.

Table 5. Amount of emissions originating from transportation use

Transportation of	Emissions rate ton CO_2 eq/year
Fresh Fruit Bunches	41.86
Empty Bunches	41.86
Total	83.72

3.1.5. Total CO_2 emissions equivalent in Palm Oil Mill. After calculating the value of GHG emissions from each source, the total GHG value from the Palm Oil Mill can be summed.

Table 6. Total Emissions sourced from palm oil mill

No.	Emissions Source	Emissions (ton CO_2 eq/year)	Percentage %
1.	Use of Generator set	115,015.18	16.212
2.	Use of boiler	561,914.60	79.206
3.	Waste water Treatment	32,423.37	4.570
4.	Transportation use	83.72	0.012
	Total Emissions	709,436.87	100.000

The use of shell-fired boilers produced the largest emissions (79.206%), which amounted to 561,914.60 because the boiler was the first source of energy for the plant. In addition to producing electricity for factories, steam boilers are also used for boiling fresh fruit bunches (FFB). Although CO_2 from biomass combustion does not include emissions, N_2O emissions from biomass combustion are included in the calculation, because these gases do not participate in the process of recirculating CO_2 in the atmosphere.

Emissions from electricity use from diesel-fueled generators accounted for the second largest emission of 115,015.18 tons CO_2 eq/year (16.212%). Diesel fuel generators are used when the boiler does not work. So that the emissions generated from the use of diesel-fueled generators are not so great. Waste water treatment emissions at palm oil mill that is equal to 32,423.37 tons CO_2 eq / year (4.570%). While the smallest emission value comes from the use of transport transportation at palm oil mill which is equal to 83.72 tons of CO_2 eq / year (0.012%).

3.2. Mitigation Efforts to Reduce CO_2 Equivalent Emissions in Palm Oil Mill

To reduce CO_2 emissions, efforts are made. One method used to reduce GHG emissions is by capturing methane gas into biogas. Besides being able to reduce GHG emissions, catching methane gas into biogas is a renewable energy that can replace fossil energy. The government has also targeted 60% of Indonesia's palm oil mills to have methane gas capture facilities into biogas by 2020 [12], therefore, the right strategy needed to accelerate the implementation of palm oil mill effluent utilization into electricity.

3.2.1. Waste Water Treatment at Palm Oil Mill. Processing of palm oil mill effluent produced greenhouse gas emissions in the form of methane (CH_4). One method used in processing wastewater is anaerobic treatment. Where in anaerobic treatment produced methane gas as the final product of the reaction. One way to use methane gas that is formed is to make it as biogas. The amount of liquid waste in palm oil mill in 2018 was 96,944 m^3 / year. To calculate the amount of methane gas produced, the COD outlet value contained in liquid waste is needed. The outlet COD value is 1526.25

mg/L. For each kilogram of COD it will produce 12.36 kg of methane/ton from processing liquid waste. Based on [9-11] the value of methane gas formation capacity from treated liquid waste is 0.21 kg CH_4/kg COD and the value of the methane gas correction factor for anaerobic process is 0.1. The total emissions obtained in the condition after the method of capturing and burning methane gas is equal to 5,342,747 tons CO_2 eq/year. The results of the calculation of emissions reductions from wastewater treatment at palm oil mill before and after the capture of methane gas into biogas can be seen in Table 7.

Table 7. Amount of Reduced Emissions from Palm Oil Mill Waste Water Treatment Before and After the Capture of Methane Gas into Biogas

CH_4 emission	**Emissions rate ton CO_2 eq/year**
Before Captured	32,423.370
After Captured	5,342,747
Total Emissions reduced	27,080.623

When viewed from the total palm oil mill emissions of 709,406,244 tons CO_2 eq/year, the reduction resulting from the capture of methane gas into biogas in wastewater treatment is only 27,080.623 tons CO_2 eq/year. This happens because the emissions generated from processing wastewater in palm oil mill are smaller than the emissions generated from the use of generators and boiler use in palm oil mill. However, if methane gas emissions from processing liquid waste in palm oil mill are captured, it can reduce emissions from generator and boiler use. This is because energy from biogas can be used as electrical energy which can supply electricity in palm oil mill. The potential for biogas production from all liquid waste is approximately 1075 million m^3. The average heating value of biogas ranges from 4700–6000 kcal/m^3 (20-24 MJ/m^3). With the calorific value of 1075 million m^3 of biogas, it will be equivalent to 516,000 tons of LPG gas, 559 million liters of diesel fuel, 666.5 million liters of kerosene and 5052.5 MWh of electricity [9-11]. If every ton of CH_4 produces a potential energy of 50000 MJ, then the energy potential can be generated:

Energy Potentials = Methane Gas Potentials / year x 50000 MJ
= 27,080.623 tons CH_4/year x 50000 MJ
= 1,354,031,150 MJ/year

If every 1 MJ of heat energy is equal to 0,00028 MWh, then the maximum electrical energy estimate can be generated:

Electricity potential = 1,354,031,150 MJ x 0.00028 MWh
= 379,128,722 MWh

3.2.2. Eliminating Electricity produce by Generator set and boiler. Electricity used by Palm Oil Mill study location in 2018 is 12,544 kWh. While electricity generated from the capture of methane gas can amount to 379,128,722 kWh. It can be seen in that electricity generated from boilers and generators is smaller than electricity generated from catching methane gas into biogas. So that the utilization of the boiler work process to produce electrical energy can be eliminated. But the boiler is still working only to produce steam for boiling fresh fruit bunches, so that the use of biomass fuel for boilers can be reduced. If this is applied, the emissions from the use of boilers as electricity generators become non-existent, because the emissions produced from boilers fall into emissions from the process sector.

Emissions from the use of generators can also be eliminated if this method is applied. This is because the electricity supply from the use of biogas is still left after being reduced by electricity that can be generated from the boiler, so that if the boiler does not work, the electricity supply does not use diesel generators anymore. GHG emission reduction in palm oil mill can be seen in Table 9.

Table 8. GHG Emission Reduction Results from Each Source in Palm Oil Mill

No	Emissions Source	Emissions Before Reduction (ton CO_2 eq/year)	Emissions After Reduction (ton CO_2 eq/year)
1	Use of Generator set	115,015.18	0.00
2	Use of boiler	561,914.60	0.00
3	Waste water Treatment	32,423.37	5342.75
4	Transportation use	83.72	83.72
	Total	**709,436.87**	**5426.47**

From table 9, it can be seen that the capture of methane gas into biogas can negate emissions resulted from the use of diesel-fueled generators and boilers for electricity supply in palm oil mill. In this way, the emissions can be reduced to 99.23%.

4. Conclusion

Based on the results of the study, total emissions generated from palm oil mill is 709,406,244 CO_2 eq/year. The biggest emissions came from boiler use which accounted for 79.206 % of total emissions, which amounted to 561,914.6 CO_2 eq/year. Then emissions originating from diesel use accounted for 16.212% of total emissions, amounting to 115,015.18 CO_2 eq/year and emissions from wastewater treatment accounted for 4.570% of total emissions, amounting to 32,423.37 CO_2 eq/year. While the smallest emission value derived from the use of transportation contributed 0.012 % to 83.72 tons of CO_2 eq/year. Mitigation efforts to reduce GHG emissions at palm oil mill is carried out by capturing methane gas into biogas and converted into electricity. This method can reduce total GHG emissions from palm oil mill activities to 99.23%

Acknowledgments

Authors wishing to acknowledge assistance or encouragement from colleagues at Environmental Engineering Program, Faculty of Engineering, Riau University.

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