Prediction of carbon dioxide emissions from crude palm oil industry case study: Palm Oil Mill X in Kampar Regency of Riau Province

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Abstract. The effects of solar radiation that are trapped in Earth's atmosphere, because these events take place repeatedly, then there is accumulation of solar radiation in the earth's atmosphere that causes the temperature on earth to become warmer. One of the industrial sectors that contribute to greenhouse gas emissions in Indonesia is the palm oil mill. Indonesia is one of the largest producers of crude palm oil in the world. Palm oil agribusiness invites national and global attention related to environmental issues because they're one of major contributor to greenhouse gas emissions. The research will be conducted on one of the existing Palm Oil Mill in Riau Province. The Mill that sampled is located at Kampar Regency. Primary data was obtained through field observation and interview with company employee. While the secondary data is obtained from the company's regular reports and the relevant literature. From this research, the total emissions generated from the palm oil mill X are 1,405.83 Kiloton CO₂ equivalent/year, with the largest emissions coming from the use of boilers in POM X which account for 81% of total emissions of 1,138.77 Kiloton CO₂ equivalent/year.

1. Introduction
Climate change refers to an increase in average global temperatures. Natural events and human activities are believed to be contributing to an increase in average global temperatures. This is caused primarily by increases in greenhouse gases [5], [3] The average global surface temperature increased at a rate of 0.74°C ± 0.18°C which resulted in drastic climate change in various places including Indonesia. There are six types of gases classified as Green House Gases (GHG), namely carbon dioxide (CO₂), methane (CH₄), nitrooxide (N₂O), sulphurhexafluoride (SF₆), perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs). Carbon dioxide (CO₂), though not the most potent of greenhouse gases, is the most significant one it is released into the atmosphere through animal respiration and when wood and fossil fuels burn or decay [4].

The Government of Indonesia is paying great attention to this issue by committing to reduce greenhouse gas emissions. In the Conference of Parties (COP) 21 at the UN Framework Convention on Climate Change in Paris, France on 30 November 2015. In his speech President Jokowi declared Indonesia's commitment to reducing greenhouse gas emissions by 29% by self-employment and 41% international assistance until 2030. This is an affirmation of 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 [6] [7].

One of the industrial sectors that contribute greenhouse gas emissions in Indonesia is Palm Oil Mill (POM). Indonesia is one of the largest producers of crude palm oil (CPO) in the world. By 2015, Indonesia is the world's largest CPO producer with a total production of 31.28 million tons [9]. The
area of oil palm plantations in Indonesia reached 11.3 million hectares with the number of POM as many as 1600 units. Oil palm plantations in Indonesia are mostly located on the island of Sumatra with the largest area located in Riau Province. Riau Province is the largest producer of palm oil in Indonesia which amounted to 7.33 million tons with the number of POM as many as 146 units.

Indonesia's oil palm potential shows that oil agribusiness plays a role in the economy of 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, 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 contributor to greenhouse gas (GHG) emissions. In 2011, the issue of Indonesia's environmentally unfriendly CPO product since EPA (Environmental Protection Agency) issued a NoDA (Notice of Data Availability) policy that reduces GHG emissions from Indonesia only 11-17% [1]. While the GHG emission reduction standard is at least 20% in accordance with Renewable Fuel Standards (RFS) standards. Therefore, the calculation of greenhouse gas emission (GHG) emission from palm oil agribusiness especially from oil palm mill is needed, before know how to reduce the emission of GHG produced.

2. METHODOLOGY
2.1. Research sites
The research will be conducted on one of POM in Kampar Regency, Riau Province, Indonesia.

2.2. Types and Data Sources
Data types used include primary and secondary data. Primary data is data that is not available and obtained by way of direct retrieval in the field. Primary data was obtained through field observation interview with company side. Secondary data is obtained from corporate newsletters (documented data) and relevant literature. The description of the type and source of the complete data can be seen in Table 1.

| Data Description                        | Data Type   | Data source          |
|----------------------------------------|-------------|----------------------|
| Fuel consumption of diesel (ton / year)| Secondary data | Company annual report |
| Electricity requirements (MWh/thun)    | 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 m³ / hour         | Secondary data | Company annual report |
| CODin dan CODout                       | Secondary data | Company annual report |
| Factory condition and waste water treatment | Primary Data | Field observations |
| Emission factor                        | Secondary data | Literature |

2.3. Data collection technique
The availability of data while in the field is one of the factors in determining the aspects of the constraint system. The data used is data from 2016.

1. Method of GHG Emission Calculation from Energy and from Industrial process
Greenhouse gas emission calculation method using emission factor in [2] is as follows:

\[ E = A \times NCV \times EF \times GWP \]  
\[ E = \text{Fuel emissions} \]
A = Amount of fuel (liter) 
NCV = Net Caloric Value (TJ/Liter) 
EF = emission factor (kg/TJ) 
GWP = Global warming potential

2. The method of GHG Emission Calculation from Liquid Waste

The method of GHG Emission Calculation from Liquid Waste Processing using the method established by UNFCCC is AMS-III.H (Approved Methodology): "Methane recovery in waste treatment", for calculating the amount of methane gas released from waste treatment pond and for calculation of reduction the amount of greenhouse gases for fossil fuel replacement to generate electricity is used in AMS-ID (Grid connection renewable electricity) [8].

The calculation of the total initial emissions prior to the catching and burning of methane gas is as follows:

\[ BE_y = (MEP_{y,ww,treatment} + MEP_{y,s,nontreatment}) \times GWP_{CH_4} \]  \[ BE_y \] Initial emissions before catching and burning of methane gas in year \( y \) (ton CO2 e/year)

\[ MEP_{y,ww,treatment} \] Potential emissions of methane from waste water treatment system in year \( y \) (ton)

\[ MEP_{y,s,nontreatment} \] Potential emissions of methane from sludge not treated in year \( y \) (ton)

\[ GWP_{CH_4} \] The potential for global warming from methane gas (value 21)

3. Discussion

3.1. Equivalent CO2 Emissions in Palm Oil Mill X

The equivalent CO2 emissions in this study are equivalent CO2 emissions from the plant’s activities, where the plant that is the site of the research is the POM X. The source of emissions derived from POM X is divided into three sources: from diesel use in POM X, the use of boiler in POM X, and wastewater treatment at POM X. According to IPCC, the types of greenhouse gases emitted from the industrial sector are CO2, CH4 and N2O. Emission calculations are generated based on the IPCC method. As for the value of emission factor and the heating potential value (GWP) used to calculate emissions produced [2].

3.2. Use of Diesel in POM X

To calculate the amount of emissions generated from diesel use in POM X we use the equation 1 and 2. The fuel used is diesel. The calorific value of diesel fuel is \( 36 \times 10^6 \) TJ/Liter. Greenhouse Gases emitted by the energy sector are CO2, CH4, and N2O. [2] one source of GHG emissions from the energy sector is emissions from combustion of fuel. Solar is one type of liquid fuel. The emission calculation results from each gas will be passed to CO2 e/yr. Therefore, the value of global warming potential (GWP) of each gas is needed. GWP for CO2 is 1, GWP untk CH4 is 21, and GWP N2O is 310.

The result of emission calculation which is sourced from diesel usage in POM X can be seen in Table 2.

| Table 2. Amount of Emissions Sourced from Diesel Use in POM X |
|-------------------------------------------------------------|
| Emissions Value | Emissions Value |
| (Kilotons CO2 equivalent/year) |
| CO2 Emissions  | 255420.032 tons CO2 e/year | 255.420 |
| CH4 Emissions  | 10.341 tons CH4 e/year | 0.271 |
| N2O Emissions  | 2.068 tons NO2 e/year | 0.641 |
| Total emissions | | 256.330 |
The largest greenhouse gas emissions resulted from diesel use in POM X are CO₂ emissions with emissions of 256,330 Kilotons of CO₂ e/year. This result is in line with the theory that the main kind of GHG from the combustion process of fuel is CO₂. The second largest GHG emissions are CH₄ gas emissions and the smallest GHG emissions are N₂O. Although the value of emissions of CH₄ and N₂O is small, but this gas is very influential on greenhouse gases. Because, this gas has the effectiveness of higher heat absorption compared with carbon dioxide.

3.3. Boiler Use in POM X

To calculate the amount of emissions resulting from the use of boiler in POM X used equation 2. The fuel used by the boiler is biomass with the calorific value of biomass fuel is 11.6 x 10⁻⁶ TJ/kg. GHG emitted by the energy sector are CO₂, CH₄, and N₂O. Based on [2], one source of GHG emissions from the energy sector is emissions from combustion of fuel. Biomass is one of solid fuel. The emission calculation results from each gas will be passed to CO₂ e/yr. Therefore, the value of global warming potential of each gas is needed. The greater the GWP value indicates the gas has a higher heat absorption effectiveness compared to carbon dioxide.

From the above calculation can be seen that the emissions generated from the use of boilers in POM X in 2016 amounted to 1,139 Kilotons CO₂ e/year. The type of gas calculated as emissions on the use of boilers is the N₂O gas which is equivalent to CO₂. CO₂ gas produced from biomass feeding is not included as emissions but N₂O gas from biomass combustion is included as emissions because this gas does not participate in the CO₂ recirculation process in the atmosphere. [10] Almost all carbon in the combustion of biomass energy will become CO₂. However, CO₂ from biomass burning is said to be non-existent based on the assumption that new trees or plants will be replanted and replace the CO₂ produced during burning of biomass energy. Fiber and shells are solid waste from the processing of fresh fruit bunches into crude palm oil, this palm oil trees can still absorb CO₂. Thus, the type of gas calculated as emissions on the use of boilers is the N₂O gas which is equivalent to CO₂.

3.4. Liquid Waste Processing in POM X

The amount of liquid waste in POM X by 2016 is 142,873 m³/year. To calculate the amount of methane gas produced then the COD value of inlet which is contained in the liquid waste. During the degradation process, the substrate will decrease the amount of organic material it contains. This happens because the bacteria utilize oxygen in the substrate remodel. The value of COD decrease depends on the amount of decomposed organic matter into biogas. These results indicate that the greater the decrease in COD value can be an indicator of the amount of biogas produced. The inlet COD value was 78.75 mg/l. To calculate the amount of emissions generated from liquid waste treatment in POM X using AMS-III.H (Approved Methodology) method: "Methane recovery in waste treatment". The methane gas generation capacity of treated wastewater is 0.21 kg CH₄/kg COD and the methane gas correction factor is 0.8. To calculate the amount of emission generated from liquid waste treatment in POM X used equation 2.

The result of emission calculation sourced from liquid waste treatment in POM X can be seen in Table 3.

| Symbol                   | Value     | Unit      |
|--------------------------|-----------|-----------|
| MEP_{y,ww,process}       | 510.777   | ton CH₄/year |
| MEP_{y,s,process}        | 0         |           |
| GWP_CH4                  | 21        |           |
| Total Initial Emissions (BEₚ) | 10,726.317 | ton CO₂e/year |
From table 3, the total emissions obtained in the initial conditions from waste water treatment in POM X in 2016 without the method of catching and burning methane gas amounted to 10,726.317 tons CO₂/year (10.73 Kiloton CO₂/year). Potential emissions of methane from unprocessed sludge does not exist, because sludge or sludge treatment does not undergo any changes either before the capture of methane gas into renewable energy (biogas). After methane gas capture where the mud is taken from the anaerobic pond on a regular basis to maintain the quality of water released to the plantation area.

3.5. Total CO₂ Emissions Equivalent in Palm Oil Mill X
GHG emission sources in POM X are divided into three sources: from diesel use in POM X, boiler use in POM X, and waste water treatment in POM X. After calculating the value of GHG emission from each source it can be added how much total GHG value of POM X. Total GHG emissions from POM X activities in 2016 amounted to 1,405.83 Kiloton CO₂ e/year. The calculation result of total emissions from POM X can be seen in Table 4.

| Emissions Source                      | Emissions value Kiloton (CO₂ Equivalent/year) | Percentage (%) |
|---------------------------------------|-----------------------------------------------|----------------|
| Sources of Emissions From Use of Diesel | 256.33                                        | 18.2           |
| Use of Boiler                         | 1.138.77                                      | 81.0           |
| Liquid Waste Treatment                | 10.73                                         | 0.8            |
| Total Emissions                       | 1,405.83                                      | 100            |

The use of shell and fiber boilers resulted in the largest emissions (81%), because boilers were the first energy source for the plant. In addition to generate electrical energy for the plant, steam boiler is also used for the process of boiling fresh fruit bunches. Although CO₂ from biomass combustion does not include emissions, but N₂O emissions from biomass combustion are included in the calculations, since these gases do not participate in the CO₂ recirculation process in the atmosphere. Emissions from the use of electrical energy from diesel-fueled generators accounted for the second-largest emission of 256.33 Kiloton CO₂ e/year (18.2%). A diesel-fueled generator is used when the boiler does not work, so the emissions generated from the use of diesel-fueled generators are not so great. While the smallest emission value comes from the processing of liquid waste in POM X that is equal to 10.73 Kiloton CO₂ e/year (0.8%).

4. Conclusion
Based on the results of the research can be obtained the following conclusions:
1. Total emissions generated from oil palm mill X are 1,405.83 Kiloton CO₂ equivalent/year
2. The largest emissions come from the use of boilers in POM X which accounted for 81% of total emissions of 1,138.77 Kiloton CO₂ equivalent/year. Then followed by emissions sourced from the use of diesel in POM X accounted for 18% of total emissions of 256,33 Kiloton CO₂ equivalent/year and emissions sourced from liquid waste treatment in POM X accounted for 0.8% of total emissions of 10.73 Kiloton CO₂ equivalent/year.

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

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