Estimation of a Palm Oil Company's Carbon Footprint Reduction Using the Organizational Life Cycle Assessment Method

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Abstract

Climate change has an extensive impact on human life. The increase in earth's temperature does not only have an impact on rising temperatures but also changes the climate system, which affects various aspects of nature and human life. The attempt to restrain the pace of climate change cannot only be carried out by the state without the involvement of all parties. Over the past few decades, the palm oil industry has shown significant growth, especially in Indonesia. To deal with problems and issues of environmental damage caused by the palm oil industry, especially the high carbon footprint, a method or tool is needed to measure the organisation's environmental impact. This study aims to calculate the Carbon Footprint generated in the business processes of a palm oil company as a trigger for global warming and climate change. The result of this research will be presented in the form of the carbon footprint on a palm oil agro-industry company's business process, which are then analyzed using Pareto diagram to obtain the priority of process improvements that will be carried out.

Keywords
Organizational Life Cycle Assessment (O-LCA), Palm Oil, Carbon Footprint, Climate Change, Sustainability.

1. Introduction

In 2020, the average temperature in Indonesia had reached 27.3°C and was predicted to continue to rise in the year after. Greenhouse gas emissions are responsible for more than 90% of global climate anomalies, according to the Intergovernmental Panel on Climate Change's (IPCC) fourth assessment report in 2007. The IPCC's fifth comprehensive assessment in 2013 stated that the increased impact of Human activities on the climate system is very significant and have been seen in various parts of the world (Luisetti et al. 2020).

The amount of greenhouse gas emissions (Figure 1) produced in every human activity is called the carbon footprint (Luisetti et al. 2020). The higher the carbon footprint produced, the higher the concentration of greenhouse gases in the atmosphere. Therefore, it is essential to consider every activity carried out for the individual or company. According to data obtained from the Greenhouse Gas (GHG) Inventory Report and Monitoring, Reporting, Verification (MPV) in Figure 1.2, GHG emissions are driven by five sectors: The Energy sector, Industrial Processes and Product Use (IPPU), Agricultural, Forestry and Other Land Use (AFOLU), and also Waste Sector. Figure 1 depicts a decrease in GHG emissions in 2016 before increasing in 2018. According to the Ministry of Environment and Forestry, GHG emissions are extremely volatile, but the trend is upward. Human activities, both individual and corporate, impact these sectors significantly.

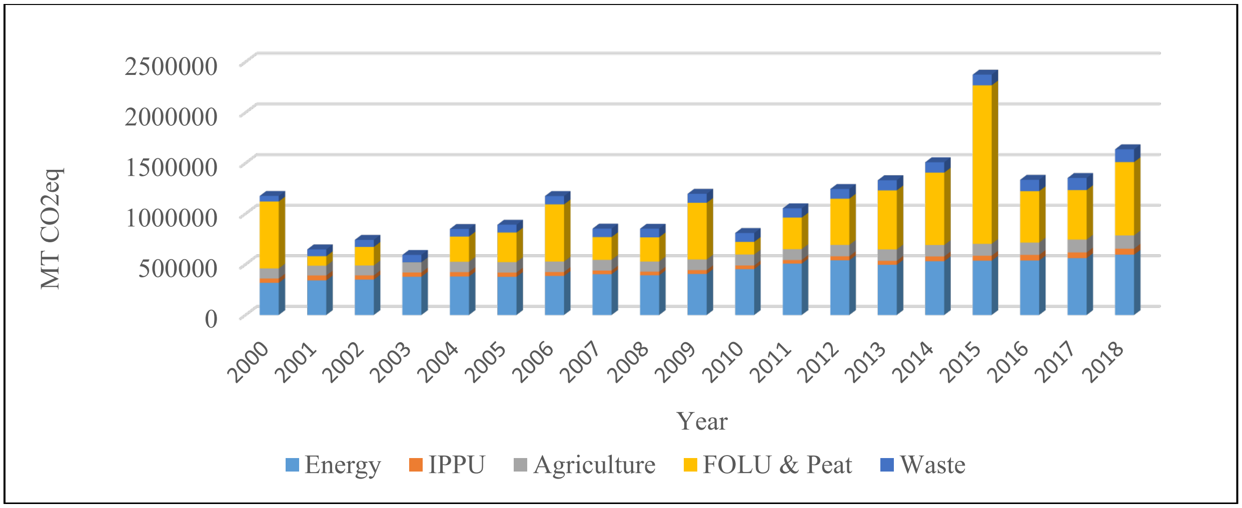


Figure 1. Indonesia Greenhouse Gas Emission 2000-2018 (KLHK, 2019)

The Paris agreement in 2015 was the culmination of ongoing global climate change negotiations that lasted for 20 years. Indonesia, which was also present at the agreement, decided to participate in the fight against climate change. Efforts to contain the pace of climate change cannot only be made state without the involvement of all parties. Climate change becomes a warning that the companies also need to reduce carbon footprint and negative impact on the environment.

The palm oil industry, which is one of Indonesia's most important industries, has risen substantially in recent decades. (Schmidt and De Rosa 2020). The palm oil business has been related to important environmental issues such as fertilizer use, waste treatment, transportation and biomass burning, releasing greenhouse gases into the atmosphere and contributing to climate change (Khatiwada et al. 2021). Meanwhile, to be able to compete with their competitors, companies must be able to improve the concept of sustainability which also includes environmental aspects in it (Astria et al. 2021)

To deal with problems and issues of environmental damage caused by the palm oil industry, especially the high carbon footprint, a method or tool is needed to measure and compare the environmental impacts of human activities in the supply of their products. These environmental impacts include emissions to the environment, consumption of resources, and other interventions. Given this context, organizations need to assess the consequences of their activities in various fields, especially the environment, which is one of the most critical aspects. International standards on life cycles are continuously being developed with a sustainability perspective (Toniolo et al. 2019).

Over the past two decades, several different frameworks for calculating organizational LCAs have been developed in parallel (Martínez-Blanco et al. 2018). At the same time as the UNEP/SETAC Life Cycle Initiative, the 'Guidelines on organizational LCAs' (Martínez-Blanco et al. 2015). Conventional LCAs and O-LCAs can complement each other in different ways. More clearly, the application of O-LCA identifies the most prominent environmental impacts of activities that add value to the company. Meanwhile, conventional LCA is generally used to select products with a better life cycle than other products.

This study aims to calculate the Carbon Footprint generated in the business processes of palm oil companies as a trigger for global warming and climate change, Using the Organizational Life Cycle Assessment (O-LCA) approach and calculating several alternative improvements that can be made by the company to contribute to the overall industry in assessing and reducing the environmental impact of business. This research is expected to be one of the opportunities to develop environmentally friendly and sustainable business processes.

2. Literature Review

The literature study discusses the concept and formulation of the carbon footprint. calculation. Theoretical foundation for the Organizational Life Cycle Assessment approach is also provided in this part.

2.1. Organizational Life Cycle Assessment

Life Cycle Assessment (LCA) is considered the most appropriate method in assessing the impact of an activity on the environment. However, LCA has limitations, namely in the scope of products and calculations carried out indirect emissions. For an organization to take reasonable steps towards environmental protection, a stable scheme is needed to map out the approach to be taken. A new method of initiating environmental impact assessment with Life Cycle Assessment was developed by UNEP and SETAC in 2015, later known as Organizational Life Cycle Assessment (O-LCA). Similar to Conventional LCA, O-LCA is also used to assess the impact of activities undertaken on the environment. The difference that can be seen between the two methods are the scope of the assessment. LCA focuses on assessing the life cycle of a product, while O-LCA analyzes the entire organization, not only company facilities but also upstream and downstream activities (Martínez-Blanco et al. 2015). Both LCA and O-LCA consist of 4 phases, including Goal and Scope Definition, Life Cycle Inventory, Life Cycle Impact Assessment and Interpretation (Martínez-Blanco et al. 2015)

2.1.1Goal and Scope Definition

The first phase of O-LCA is to define the goals and scope. These must be specified in accordance with the intended use. The purpose and scope heavily influence the remaining phases of O-LCA, and due to the iterative nature of the technique, they may need to be refined during the study. As a result, the key to O-LCA's success is lowering the complexity of the system boundary relevant to the LCA study's purpose during the goal and scope defining phase. Simplification can be classified into two approaches: one that decreases the effort required for data collection (quantitative), and the other that reduces the effort required for data collection (qualitative).

2.1.2 Life Cycle Inventory

Life Cycle Inventory consists of Data collection and emission source definition. Based on the study's purpose and scope specification, this should be done iteratively with the other O-LCA phases. All inputs, such as energy, water, and materials, and outputs, such as products, co-products, waste should be included in the inventory. The inventory results should be linked to the actions involved in providing the reporting flow and considered when defining system boundaries.

2.1.3 Life Cycle Impact Assessment

The third phase of O-LCA is approached in the same way as product LCA; as a result, the precise requirements and guidelines apply, and the problems to be overcome are very similar. Product LCIA has a lot in common with O-LCA in terms of problems. Two major issues are determining which effects are critical and should be analyzed and dealing with location-specific implications. This research will focus on carbon footprint, which is comparable to a life-cycle impact assessment indicator known as Global Warming Potential (GWP) over some time period. This research will use the GWP 20 year and GWP 100 year as a measure of the relative impact of different GHGs.

2.1.4 Interpretation

Interpretation is the phase of O-LCA, which considers the results of the inventory analysis, and the effect evaluation are combined in this analysis. According to the interpretation phase, the findings should be consistent across all aspects stated during the aim and scope phase. Conclusions must be outlined, constraints must be explained, and recommendations must be made.

2.2. Carbon Footprint

The mapping of GHG emission sources is an important step toward climate change mitigation. A comprehensive inventory will enable the identification of opportunities to implement critical GHG emission reduction strategies, particularly in energy-intensive businesses with major environmental implications (Anyaoha and Zhang 2021). When it comes to environmental issues in multi-criteria analyses, practitioners usually rely on single indicators such as carbon footprint, which is the most studied (D'Ammaro et al. 2021). Most studies in the subject of environmental sustainability have focused on the carbon footprint of stakeholders in the production/manufacturing industries (Khan et al. 2021)

Environmental footprint indicators such as carbon footprint (CF) and water footprint (WF) have been widely utilized to evaluate food production and consumption's direct and indirect environmental consequences due to their success in reaching a large audience and ease of understanding methodologies. Reliable and consistent CF analysis of generic processes, in particular, should be carried out following a life cycle assessment (LCA) approach (ISO 14040:2006; ISO 14044:2006). LCA allows evaluation of impacts from a cradle-to-grave perspective, following the requirements of international reference standards for product-oriented studies and organizational-oriented studies (Scrucca et al. 2017)

The concept of carbon footprint consists of primary and secondary carbon footprints. The primary carbon footprint measures CO2 emissions resulting from the direct use of oil or LPG for cooking and transportation fuels. The secondary carbon footprint is a carbon footprint that is generated indirectly. Secondary carbon footprint can be generated from household electronic equipment, where electronics can be used by using electricity from power plants with fossil fuels. Consumers who use electricity contributes indirectly in emitting GHG emissions by burning fossil fuels to get electricity (Purwanto et al. 2019).

Additionally, various daily activities, such as the mode of transportation people use to go to work, the usage of electricity, all add to the built environment's carbon footprint. Overall, people can measure carbon footprint in three ways: (1) considering carbon dioxide alone; (2) including the six gases identified by the Kyoto Protocol, i.e., CO2, CH4, N2O, HFCs, PFCs, and SF6; or (3) including numerous GHG emissions specified by the Intergovernmental Panel on Climate Change (IPCC) framework (Fenner et al. 2018).

A life cycle assessment systematically evaluates multiple environmental impacts of a product, activity, or process over its entire life cycle. However, this study focused on the carbon footprint analysis, a subset of a complete life cycle assessment of a product, activity, or process. The GHG gases that are assessed in this study consists of CO2, CH4 , N2O and other precursor gases.

3. Methods

To calculate emissions, this methodology uses individual emissions multiplied by activity data. The GHGs produced by each process or subprocess during various stages of the life cycle. Therefore, GHG emissions associated with the *i* process included in the product life cycle (CFi) are calculated using the following equation:

$$\text{CFi} = CF_{RJ} + CF_{Transport} + CF_{Seedling} + CF_{Plantation} + CF_{Protection} + CF_{Mills} \quad (1)$$

Where CFi is a palm oil company's carbon footprint emitted in a year from both upstream and downstream activities. CF_{RJ} is a quantification of emissions produced from the Rejuvenation Activities, $CF_{Transport}$' refers as a carbon footprint resulting from transportation activities namely transportation seeds, fresh fruit bunches and transportation from the company to the port. $CF_{Seeding}$ is the carbon footprint generated from nursery activities, $CF_{Plantation}$ is stated as a carbon footprint resulting from planting activities. $CF_{Protection}$ is the carbon footprint resulting from plantation maintenance activities and CF_{Mills} can be expressed as a carbon footprint resulting from activities in the palm oil mill.

$$\text{CFj} = Activity\ Data \times EF_j \quad (2)$$

CFj denotes the carbon footprint for each activity. The requirement for activity data is for activities that cause emissions. The anticipated value (EF) for a specific emission is stated. The IPCC 2006 and IPCC 2019 refinement guidelines are used for direct emissions, and the standard value of Biograce 4a for indirect emissions is used in the carbon footprint calculation, which is the quantification of greenhouse gas emissions.

4. Data Collection

The data collection stage is included in one of the stages of the Organizational Life Cycle Assessment, namely the Life Cycle Inventory. This research requires secondary data on material needs or company energy consumption needed in rejuvenation activities, nurseries, transportation, oil palm plantations, both plantations owned by companies and plantations owned by partners, and Palm Oil (CPO) processing activities in 2021. In addition, primary data is also needed to estimate material and energy requirements that the company does not record.

Rejuvenation or replanting activities are carried out by the company starting in 2021. This activity aims to maintain land productivity by cutting down old and non-productive trees and replanting new oil palm seeds. In rejuvenation activities, the usual technique is burning the felled trees or using heavy equipment such as excavators. Fuel consumption for excavators can be seen in table 1.

Table 1. Diesel Consumption For Excavator in Land Clearing

Plantation Sites	Area (ha)	Excavator Units	Excavator Diesel Fuel Consumption (L)
Company's Site	91	3	1710
Partner Farmer's Site	398	7	7468
Total of Diesel Fuel Consumption			9178

The application of dolomite is generally needed to elevate soil pH after trees are felled using an excavator, with doses calibrated to soil conditions. Oil palm plants may thrive in pH ranges of 6.0 to 6.5. The total amounts of dolomite used are provided in Table 2.

Table 2. Dolomite Application in Rejuvenation

Plantation Sites	Area (ha)	Dolomite (kg/ha)	Application Frequency	Total
Company's Site	91	45500	1	45500
Partner Farmer's Site	398	398000	1	25000
Total of Dolomite Application				443500

Due to replanting, oil palm nurseries are carried out at the beginning of the year to plant oil palm seeds in the new area. Oil palm seedlings were carried out for 51 weeks and were shipped the following week. In addition, nursery activities also require fuel for irrigation pump machines, spraying insecticides and fungicides to protect seedlings from pests. Hence, the material inputs are stated in Table 3.

Table 3. Material Inputs in Seeding Activities

Input	Unit	Quantity
NPK Fertilizer (15-15-6)	kg	36036.53
Insecticide	L	104598.7
Fungicide	L	69732.48
Irrigation pump Diesel Fuel	L	39157.8

Oil palm seeds that are ready to be planted must be removed immediately. Seedlings are arranged in one layer on a truck and should be watered beforehand to reduce the risk of drying out in transit. Heavy-duty vehicles are used for shipping with more than 7.5 tons capacity, transporting around 500 oil palm seeds. The total distances from both sites are stated in Table 4.

Table 4. Transportation Distances from Seeding Plant to Plantation Sites

Transportation To Sites	Vehicles	Total Distances (km)
Company's Plantation Site	HDV > 7.5 ton	760
Partner Farmer's Plantation Site	HDV > 7.5 ton	5101.4

Protection activities of the company's oil palm plantations requires the provision of fertilizers for plants, which are macro and micro fertilizers. The company uses a compound fertilizer of 16-16-16 and ash organic fertilizer, while partner farmers use a compound fertilizer of 15-15-15. In addition, the protection of palm oil plantations in plantations requires the provision of micro-fertilizers, namely kieserite and weeding with herbicides as tated in Table 5.

Table 5. Material Inputs for Palm Oil Protection Activity

Plantation Sites	Area (ha)	NPK Fertilizer (ton)	Kieserite (ton)	Herbicide (L)	Organic Fertilizer
Company's Site	1823	2163	237	3646	237
Partner Farmer's Site	7688	6813	974	15376	
Total	9511	8976	1211	19022	237

The types of trucks used for the transportation of Fresh Fruit Bunches are High Duty Vehicles (HDV), trucks with a payload of more than 7.5 tons, Light Commercial Vehicles, trucks with a payload of fewer than 3.5 tons, and Heavy-Duty Vehicles with a capacity of more than 16 tons. The detail of total distance traveled can be seen in the Table 6.

Table 6. Transportation Distances from Plantation Sites to Palm Oil Mill

Transportation From Sites	Vehicles	Distances (km/year)
Company's Plantation Site	HDV > 7.5 ton	180223.6
Partner Farmer's Plantation Site	HDV > 7.5 ton	1053701
	LCV > 3.5 ton	1297093
Loading Ramp Site	HDV >7.5 ton	9772
	HDV >16 ton	19544

Processing of fresh fruit bunches into CPO requires electricity generated from biomass burning. Heavy machines and engine room facilities also consume diesel fuel. In addition, the treatment of wastewater and solid waste by incineration also generates emissions. The inputs required for Palm Oil Mill Processing can be seen in Table 7.

Table 7. Palm Oil Mill Processing

Processing Station	Fuel Consumption	Quantity	Unit
Sterilization	Electricity from Fibre and Shell	2750092.08	kwh
Threshing	Electricity from Fibre and Shell	3850128.91	kwh
Pressing	Electricity from Fibre and Shell	6600220.99	kwh
Clarification	Electricity from Fibre and Shell	7150239.41	kwh
Nut Separation	Electricity from Fibre and Shell	19250644.6	kwh
Water Treatment Plant	Electricity from Fibre and Shell	8800294.66	kwh
Office Electricity	Electricity from Fibre and Shell	8250276.24	kwh
Other Infrastructures	Fuel Consumption	Quantity	Unit
Engine Room	Solar	32587	L
Heavy Machine	Solar	56160	L
Waste	Treatment Method	Quantity	Unit
Palm Oil Mill Effluent (POME)	Anaerobic	109211	m3
Empty Fruit Bunches	Incineration	63280	ton
Palm Kernel Shell	Boiler	429.62	ton
Palm Oil Fibres	Boiler	34925	ton

CPO and Kernel are made from fresh fruit bunches. CPO is transported by tanker trucks with a 20-ton capacity, while Kernel is transported by vehicles with a 10-ton capacity. This final product is sent to the port for further delivery by the distributor agent to the final consumer. The distances data are provided in Table 8

Table 8. Transportation Distances from Palm Oil Mill to Harbour

Distribution to Site	Vehicles	Distances (km)
Harbour	HDV > 16 ton	760
	HDV > 7.5 ton	5101.4

CPO and Kernel are made from fresh fruit bunches. CPO is transported by tanker trucks with a 20-ton capacity, while Kernel is transported by vehicles with a 10-ton capacity. This final product is sent to the port for further delivery by the distributor agent to the final consumer.

5. Results and Discussion

The study results include 4 phases of organizational life cycle assessment: goal and scope definition, life cycle inventory, life cycle impact assessment, and interpretation.

5.1. Goal and Scope Definition

This organizational life cycle assessment aims to assess the impact of activities on greenhouse gas emissions, which is expressed as a carbon footprint. This assessment aims to determine environmental hotspots that are expected to consider companies to make improvements. The boundaries of the system are described more clearly in Figure 2.

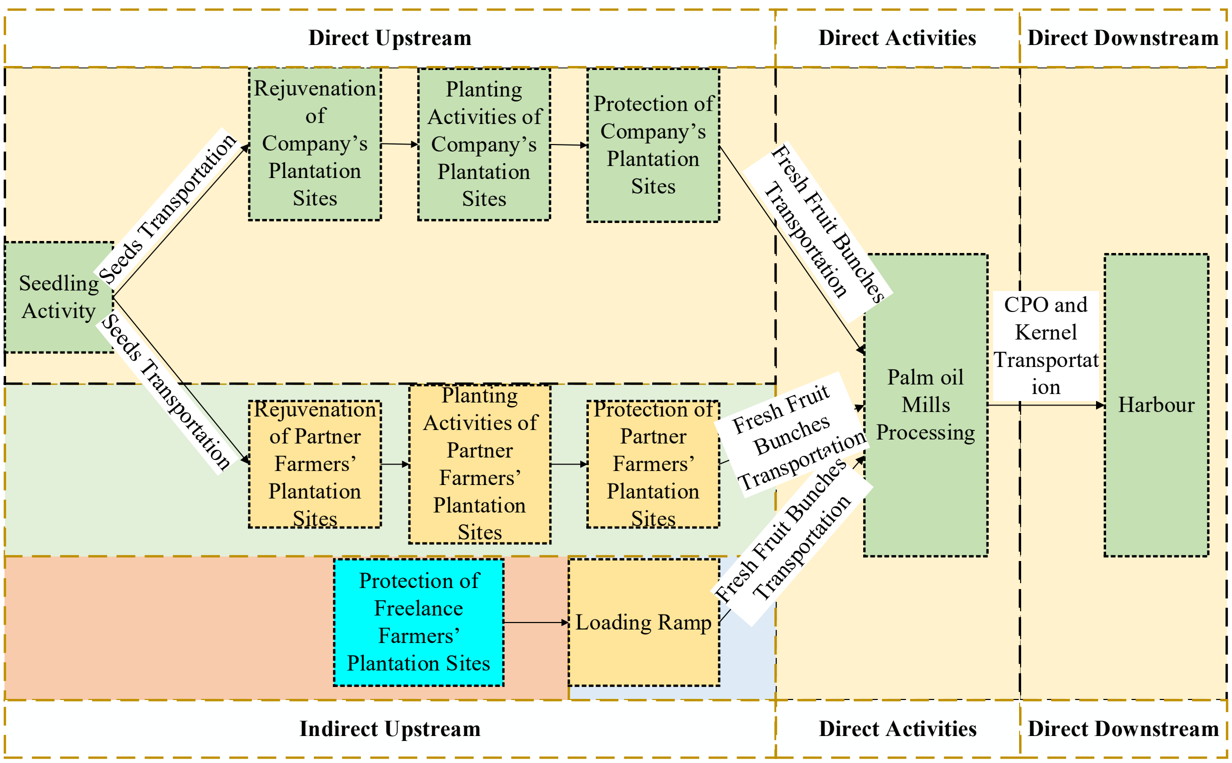


Figure 2. System Boundary of Palm Oil Organization Activities

5.2. Life Cycle Inventory

The life cycle inventory stage collects data on the input needs of every activity carried out by the company. This stage has been explained in the data collection sub-chapter, so it is not attached to it to avoid repetition.

5.3. Life Cycle Impact Assessment

The life cycle impact assessment focused on the global warming potential category equal to the carbon footprint value. The global warming potential value is adjusted to the value with the IPCC 2013 assessment category using OpenLCA Software.

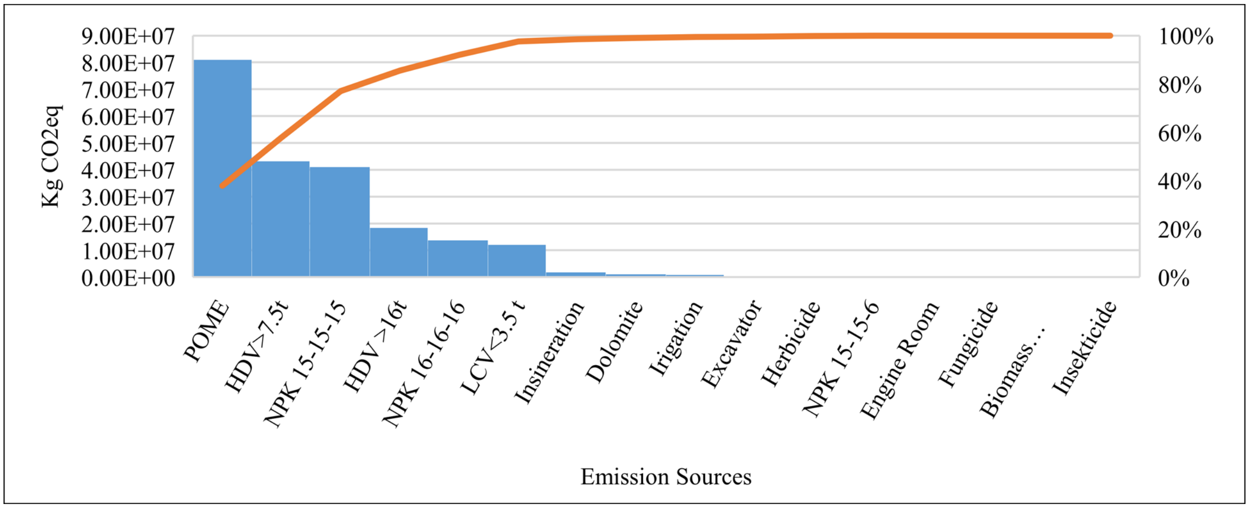


Figure 3. Global Warming Potential 20 Result

The Global Warming Potential 20 (GWP 20) assessment in Figure 3 shows that the highest value is in the treatment of palm oil mill effluent (POME), which is known to produce relatively high methane gas. HDV transportation > 7.5 tons and the use of NPK Fertilizer 15-15-15 also contribute to the highest global warming potential after POME processing. The global warming values of POME, HDV > 7.5 tons, and the use of NPK 15-15-15 were 81.05 Gg, 43.17 Gg, and 41.02 Gg CO2eq, respectively. The total value of carbon footprint in GWP 20 is 214.73 Gg CO2eq.

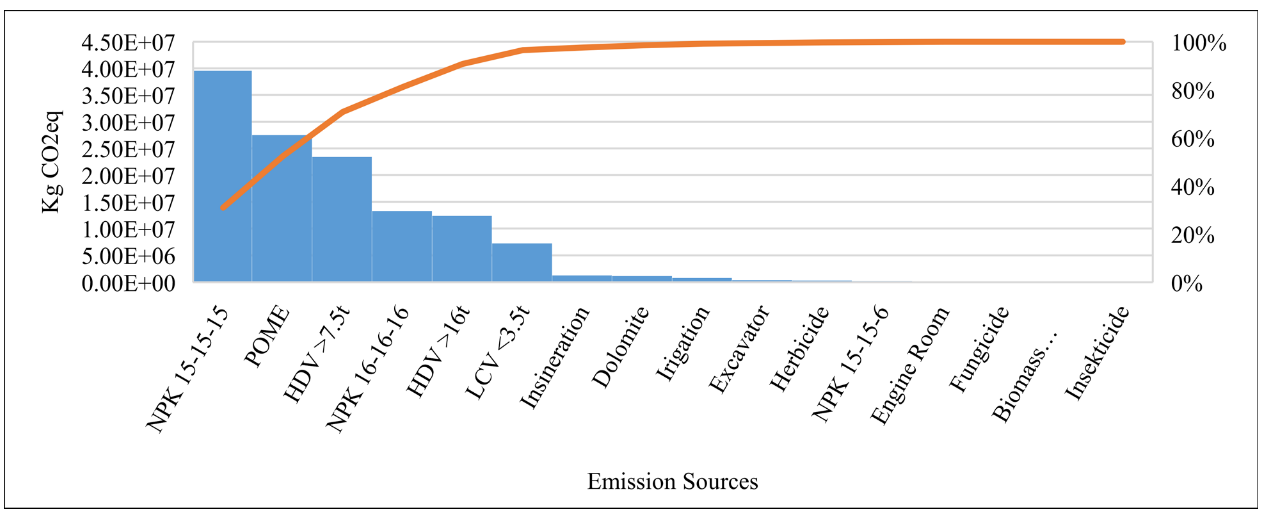


Figure 4. Global Warming Potential 100 Results

Figure 4 shows that the total carbon footprint for GWP 100 is 128.05 Gg CO2eq. The highest value are from the same emission source as the GWP 20 assessment results, namely NPK 15-15-15, POME Processing, and HDV

Transportation > 7.5 tons. For this reason, an analysis using a Pareto diagram is also carried out, where the source of emissions that produce more than 80% of the Global Warming Potential will be sought for alternative mitigation. Three primary sources generate 80% of global warming potential within 20 and 100 years: NPK fertilizer, POME, and HDV transportation > 7.5 tons.

5.4. Interpretation

The interpretation stage is the analysis stage of the impacts obtained through the life cycle impact assessment. This study proposes several alternative scenarios to get the best carbon footprint reduction. In Scenario 1, things to do is reducing the use of chemical fertilizers by replacing it with EFB mulch. The 40 tons EFB mulch per hectare application can also increase yields (Boafo et al. 2020). EFB is currently burned by the incineration process, which generates relatively high emissions. Solid waste handling must be appropriately handled to improve environmental quality (Ekky and Farizal 2019). Apart from being a fertilizer, this mulch is also used as a form of erosion control and helps the absorption of carbon by plants (Anyaoha et al. 2018). With 63280 tons of EFB produced by the company, there are savings in fertilizer use for 1417 hectares of land. Scenario 2 uses HDV vehicles > 7.5 tons that apply the Euro 4 standard, reducing the carbon footprint and reducing air pollution (Haryanto 2018).

In Scenario 3, the company will be use anaerobic digester and methane capture technology to convert biogas into bio-CNG, which can be sold in tubes and sold to the community or partner farmers who still use fossil fuels. One solution to overcome the adverse effects of fossil fuels is renewable energy due to low emission factors and abundant energy availability (Putra et al. 2020). Using bio-CNG for cooking will produce cleaner emissions than LPG fuel (Black et al. 2021). Although using methane capture technology, emissions can be generated from electricity to process waste into biogas and purify biogas into bio-CNG. In addition, emissions can also result from biogas processing and compressor technology leaks (Singh and Kalamdhad 2022).

Scenario 4 is that if the company converts biogas into electricity, the electricity can be sold to PLN or local communities and farmers. The need for electricity will increase every year in line with population growth, so it needs a reasonable allocation, especially on renewable energy (Wicaksono et al. 2020). It can also support the country's transition to a low carbon economy and increase renewable energy (Rajani et al. 2019). Scenario 5 is if the company converts biogas into bio-CNG and fuels vehicles used for company transportation activities. The use of CNG also has the potential for higher NOx gas reduction (Machado et al. 2021). Substitution of diesel fuel into bio-CNG in Light-Duty Vehicles and Heavy-Duty Vehicles is very beneficial for reducing greenhouse gas emissions and other environmental aspects (Ferreira et al. 2019).

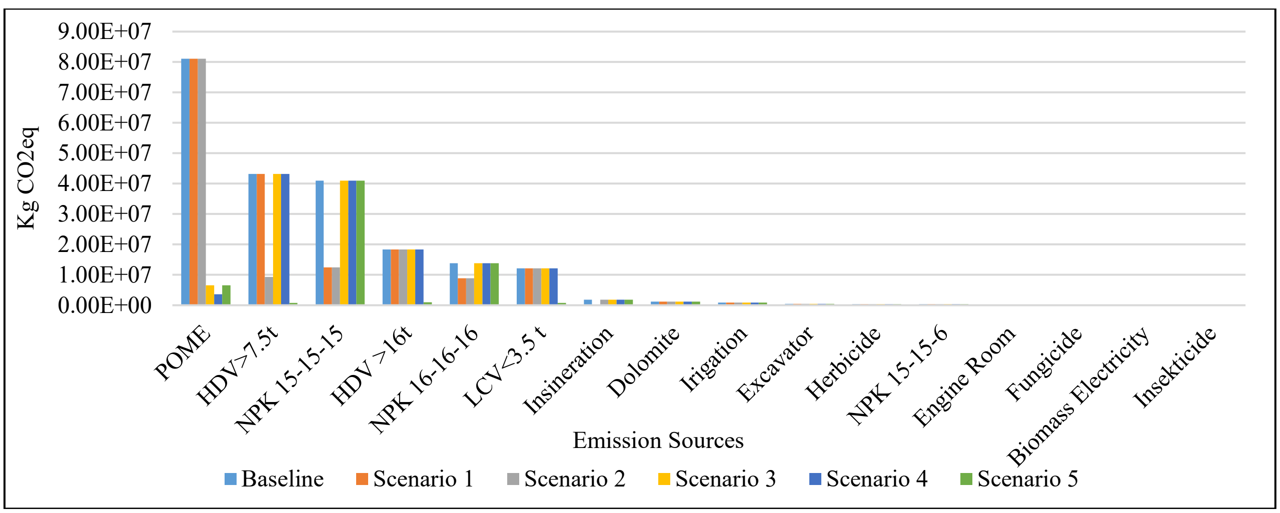


Figure 5. Carbon Footprint Reduction Results for Different Scenarios in GWP 100

Figure 5 shows that Scenario 1 shows a reduction in the use of fertilizers and the elimination of emissions from the incineration process of 1.87 Gg CO2eq. Scenario 2 shows a reduction in HDV emissions > 7.5 tons by 33.95 Gg

CO2eq. The reduction from scenario 3 is obtained from the POME processing emission source, 74.50 Gg CO2eq. Meanwhile, scenario 4 reduces 77.44 Gg CO2eq and scenario 5 with a reduced carbon footprint of 146 Gg CO2eq.

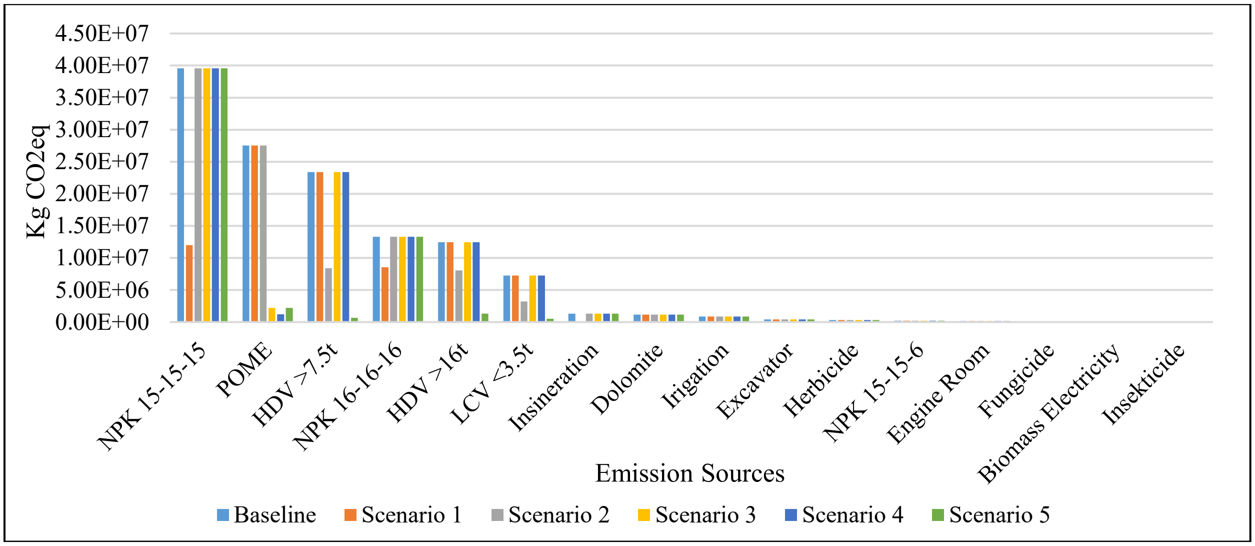
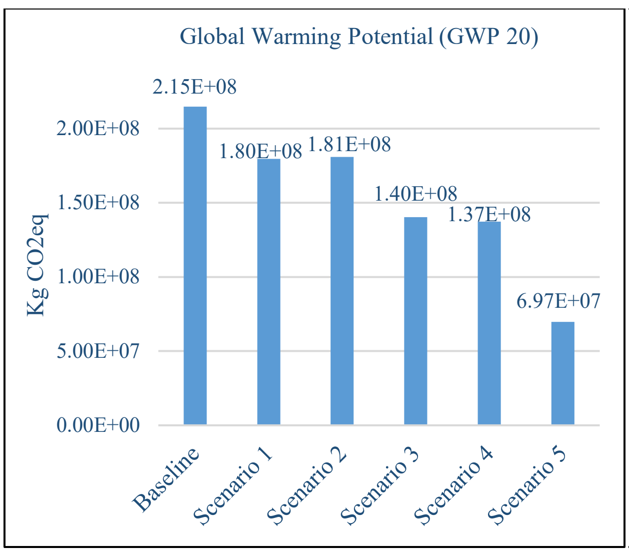
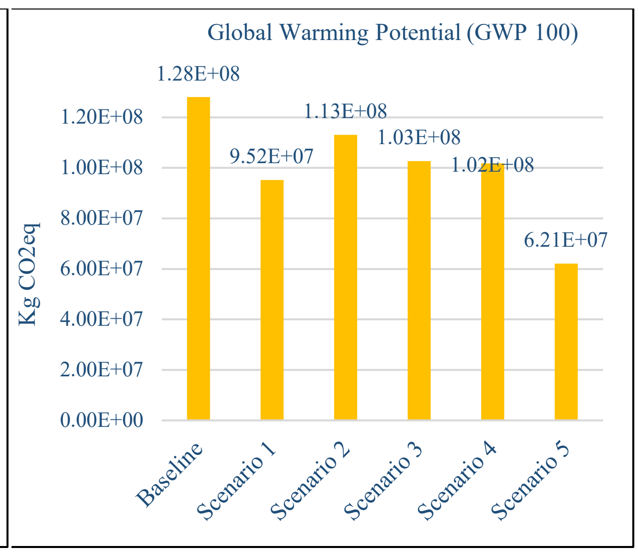


Figure 6. Carbon Footprint Reduction Results for Different Scenarios in GWP 100

In the GWP 20 assessment as shown in figure 6, Scenario 1 shows a reduction in fertilizer use by as much as and eliminates emissions from the incineration process by 33.6 Gg CO2eq. Scenario 2 shows a reduction in HDV emissions > 7.5 tons by 23.4 Gg CO2eq. The reduction from scenario 3 is 25.29 Gg, obtained from processing emission sources. Meanwhile, scenario 4 reduces 26,294 Gg CO2eq, and scenario 5 reduces the carbon footprint for 65.96 Gg CO2eq.





(a) (b)

Figure 7. (a) GWP 20 Scenarios Reduction (b) GWP 100 Scenarios Reduction

As shown in figure 7, scenario 1, scenario 2, scenario 3, scenario 4, and scenario 5 show a reduction of 84%, 84%, 65%, 64% and 32%, respectively in the GWP 20 assessment. Meanwhile, on the GWP 100 assessment, the reduction in carbon footprint is 74%, 88%, 80%, 79%, 49%, respectively.

6. Conclusion

The best alternative in reducing the carbon footprint of the GWP 20 assessment is to convert POME to electricity. Meanwhile, in the GWP 100 assessment, the highest alternative value is in scenario 4, namely converting POME into bio-CNG, which is then used as fuel for vehicles. The three alternatives that use methane capture result in a significant reduction in carbon footprint, whether used for biogas, electricity, or vehicles. In order to obtain better results, it is necessary to use the multi-criteria decision-making method for further research. Alternative selection should be assessed by considering other environmental and sustainability aspects, especially in an uncertain environment (Sarasati and Dachyar 2021). The TOPSIS multi-criteria method can generate a closeness coefficient concerning relevant factors' weighted value and ranks the alternative performance (Sahir and Dachyar 2021). As a result, different experts must evaluate and choose the best alternative based on various criterias.

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