

Life Cycle Assessment Using Supply Chain Strategy on Palm Oil Agro-industry

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Abstract

This case study was conducted in the Indonesian government's palm oil agro-industry. This company shows that pollution from exhaust emissions is the most pollution data during the palm oil processing process. This study aims to determine how much environmental impact is caused and strategies to minimize environmental impacts in the supply chain in the oil palm agro-industry. The problem-solving approach is carried out by identifying supply chain strategies ranging from oil palm plantations to crude palm oil (CPO) using the SCOR model and life cycle assessment methods. Furthermore, the calculation of greenhouse gas emissions in the palm oil agro-industry is carried out using the environmental impact analysis method. The results of this study indicate that the analysis of greenhouse gas emissions in the palm oil agro-industry involves the plantation process unit is 62 Kg CO₂-Eq/ton CPO, the distribution process unit is 1069 Kg CO₂-Eq/ton CPO and the CPO production process unit is 49 Kg CO₂-Eq/ton CPO. The most significant emission occurs in the distribution process unit in the supply chain strategy in the palm oil agro-industry. The implication of this study is to provide a solution to overcome the problem by recommending the efficient use of trucks and the transportation distance from the plantation to the factory. In the palm oil agro-industry, it is better to use trucks with a larger capacity so that later this can reduce the number of trucks and reduce truck fuel used in transportation activities.

Keywords

Palm oil agro-industry, environmental pollution, greenhouse gas emissions, life cycle assessment, supply chain.

1. Introduction

A case study was conducted on the oil palm agroindustry, which is a state-owned enterprise (BUMN). This palm oil agro-industry has a capacity of 75 tons/hour, with two plants covering 30 tons of FFB and 45 tons of FFB in one hour. Then, this company has 13 plantations. Fresh fruit bunches from the plantation serve as the raw material for the Palm Oil Mill. This company also manufactures Crude Palm Oil (CPO) and palm kernel (Kernel). This palm oil agro-industry has issues with air pollution, which has an environmental impact because of the palm oil processing process. Thus, this causes problems in the form of greenhouse gas emissions. These issues affect and sometimes even harm the environment in which they occur. As a result, actions are required to reduce the environmental damage caused by the palm oil agro-industry.

The root cause must be found to reduce environmental contamination (Hosseini & Wahid, 2015; Kurniawan et al., 2019). Then, A study also stated management must consider environmental effects that could impair a company's operational procedures in addition to concentrating on the output of agricultural products (Sajid & Rahman, 2021). Therefore, suggestions for reducing environmental effects are required to help policymakers come up with plans to

keep businesses sustainable. Additionally, business process activities have an impact on how the palm oil agroindustry affects the environment. The palm oil agro-industry consists of three primary activities: plantations, the conversion of palm oil into value-added products, and the distribution of products from one entity to another. To minimize environmental impacts, this business process activity needs a supply chain strategy study from upstream to downstream. Environmental issues may be resolved with the use of supply chain methods (Herrmann et al., 2021; Zhu et al., 2019).

1.1 Objectives

A method to resolve environmental issues is necessary for this study. To reduce the effects of the palm oil agroindustry on the environment, various strategies are required. The first step is to identify the business processes that take place in the agricultural sector that produces palm oil. Then, an analysis of the environmental impact that occurs is needed by the palm oil agro-industry. The last stage is to offer suggestions for improvement to reduce the effects of the palm oil agroindustry on the environment. The research's focus on the FFB production process from oil palm fruit planting, maintenance of immature oil palm plants, pollination, maintenance of mature oil palm plants, and processing in the oil palm agroindustry limits the scope of the issue. Afterward, the utilized Global Warming Potential unit was converted to kilos of carbon dioxide equivalent (Kg CO₂-eq).

2. Literature Review

The supply chain is an organizational framework for distributing commodities to clients (the flow of goods). The supply chain is a network of interrelated corporate organizations that have the same purpose of efficiently and effectively coordinating the distribution of goods (Felea & Albăstroi, 2013). However, in this study, the supply chain is employed to examine the environmental impact of a corporation. Experts examined the utilization of the supply chain in determining environmental impact. A study used a supply chain technique to analyze waste in a company that has an impact on the surrounding environment since waste is generated during production (Mahajan & Vakharia, 2016). The findings of this study can also be used to identify supply chain activities that have a significant environmental impact. As a result, this research can provide remedies in the form of recommendations. Furthermore, the research conducted succeeded in minimizing the negative impact of a business unit supply chain by using the concept of Green Supply Chain Management (Lestari & Dinata, 2019).

Harimurti et al., (2019) also researched the effects of LCA on CPO manufacturing in a corporation. According to this study, the highest emission results from one of the supply chain units, which includes the plantation process unit, particularly fertilization activities. According to Siregar et al., (2020), the LCA yield on CPO production was 1530.43 Kg CO₂-Eq. The plantation process unit, specifically fertilization, is responsible for the emission outputs. According to a prior study, the palm oil agroindustry has various emission sources. Emissions from the FFB distribution process unit from the plantation to the CPO production plant can also be sourced in the palm oil agro-industry. The study argues that in a product manufacturing organization, choosing the correct distribution route is critical to reducing distance, distribution time, travel costs, and the number of vehicles, and other resources (Fitri, 2015).

3. Methods

This study used a case study approach. It took place in an Indonesian oil palm agricultural enterprise. Then, fieldwork-based interviews and direct observations were used to gather research data. According to Sudrajat et al., (2021), case study research in the agroindustry can be done by making in-person observations, reading documents or texts, and interviewing respondents. Additionally, the North Sumatra-based oil palm agro-industry used in this study converts palm oil into crude palm oil (CPO) and palm kernel (Kernel). The palm oil processing process is now causing air pollution, which will lead to greenhouse gas emissions in 2020 for the palm oil agro-industry.

3.1 Data Collection Techniques

Purposive sampling, a non-probability sampling method, was used in this study. This method was chosen because it allows researchers to select samples following their goals and specific criteria (Lamm & Lamm, 2019). Managers of oil palm plantation enterprises and oil palm plantation experts both participated in the selection of the study's sample. Primary information was gathered by researchers through direct surveys of the company's location and the outcomes of conversations with management and oil palm experts. The researchers' initial strategy for gathering the necessary data involved direct field surveys of the palm oil agro-industry. The researcher served as an observer who did not participate in the study. This implies that researchers do not engage in any activity in oil palm plantations other than to observe those that are already underway. After that, the area around the palm oil company was observed. The study

also used an open-ended interview that is guided by the researcher, known as an unstructured interview. One of the state-owned plantation firms, the palm oil agro-industry corporation, was interviewed. The criteria in line with the research were taken into consideration when building the research instrument. Additionally, secondary data for this study in the form of emission factor information was gleaned from books and journals that dealt with the issues it was trying to address. The instruments used in the interview are listed in Table 1.

Table 1. Interview Instruments

No	Indicator of Plantation	Plantation Data Inquiry Instrument
1	FFB Production	How much FFB is produced in a year?
2	Fertilizer Used	What fertilizers are used, and how much is used during the year?
3	Chemical Used	What chemicals and how many are used during the year?
No	Indicator of Transportation	Distribution Data Inquiry Instrument
1	FFB Sent To Mill	How much FFB is delivered to the mill in a year?
2	Distance To Mill	How far is it from the plantation to the factory?
3	Weight Of One Load	What is the weight of one load (FFB) transported to the factory in one shipment?
4	Diesel Consumption For FFB Transport	What is the truck's diesel consumption for FFB transportation?
No	Indikator of Milling Process	CPO Production Inquiry Instrument
1	FFB Processed Nett	How much is the net processed FFB for a year?
2	CPO Produced	How much CPO production in a year?
3	PK Produced	How much is the Palm Kernel produced in a year?
4	CPO Moist	What percentage of Moist CPO do you get?
5	PK Moist	What percentage of PK Moist did you get?
6	Electricity Generated By Steam Turbine	How much electrical energy is produced by the steam turbine?
7	Electricity Generated By Gensets	How much electrical energy is generated by the generator?
8	Fossil Diesel Consumption	What is the consumption of fossil diesel?
9	Wheel Loader	What is the energy consumption of the wheel loader?
10	Genset	What is the energy consumption of the generator?
11	Water For Steam Production	How much water is used for steam production?
12	Water Used For Processing	How much water is used for treatment?
13	Chemical Used	How many chemicals are used?
14	Lubricant Used	How much-used lubricant was used?
15	Fibre Formed in Production	How many fibers are formed in production?
16	Fibre Used in Combustion	How much fiber is used in combustion?
17	Shell Formed in Production	How many shells are formed in production?
18	Shell Sold to Other Operators	How many shells were sold to other operators?
19	EFB Formed in Production	How Much EFB is formed in production?
20	EFB For Mulching	How much EFB for mulch?
21	POME Formed In Processing	How much POME is formed in the processing?

4. Stages of Data Processing

Data analysis in this study is divided into three stages. There are several methods adopted in this study which are provided in Figure 1.

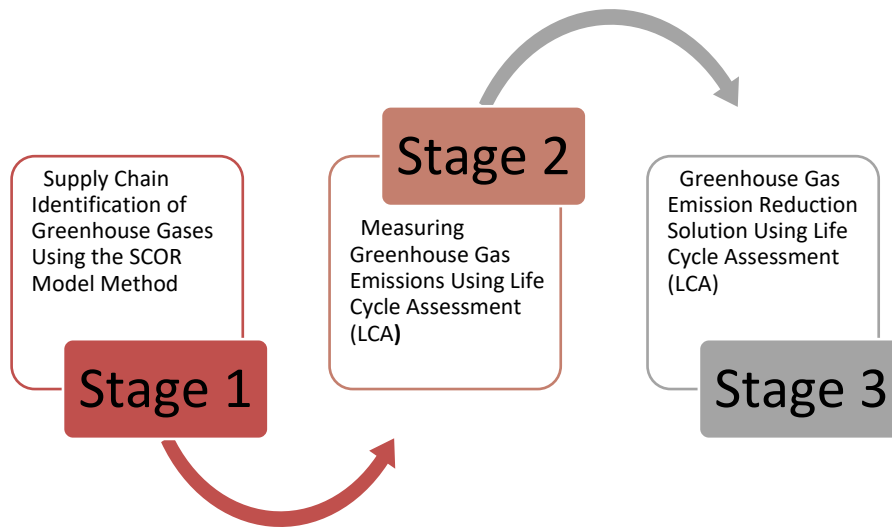


Figure 1. Stages of data processing

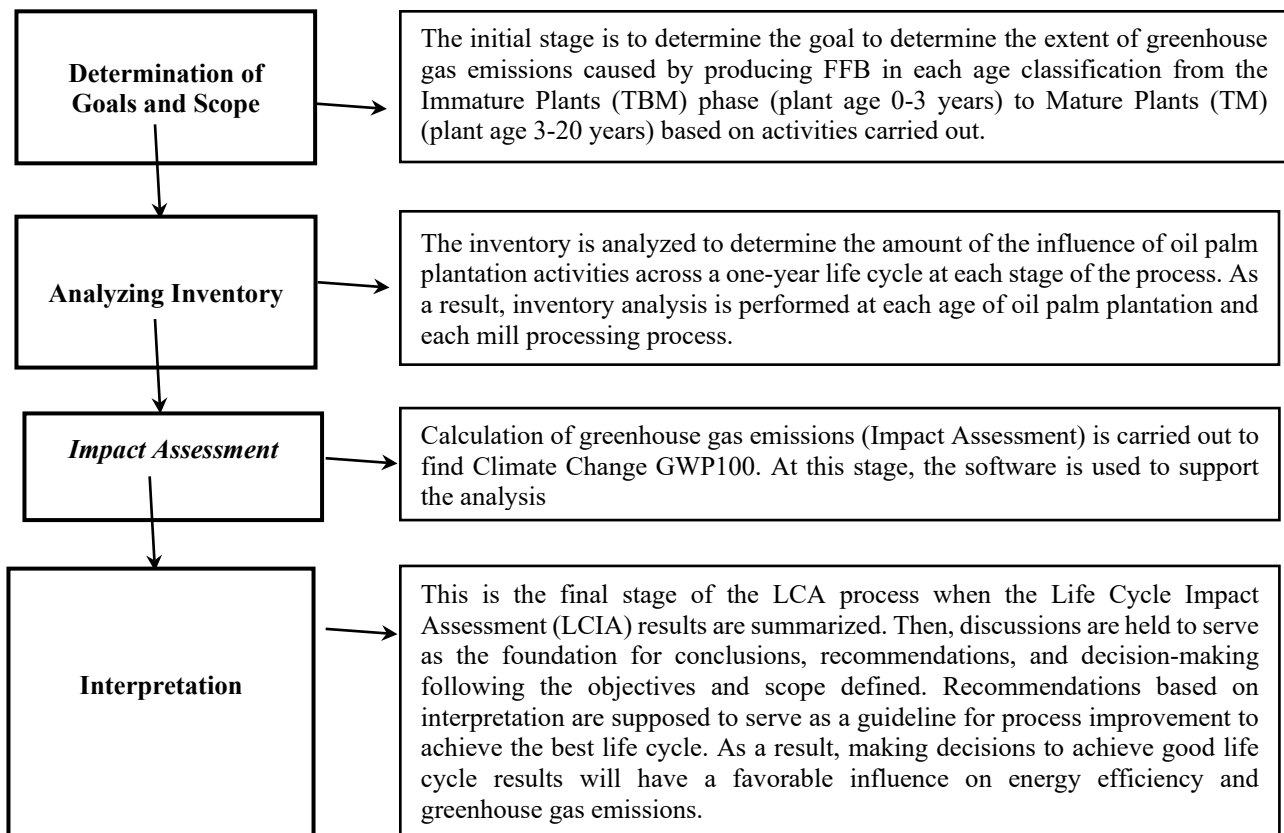


Figure 2. Stages of Life Cycle Assessment

The first stage is to determine the most significant greenhouse gas (GHG) in the Fresh Fruit Bunches (FFB) manufacturing process by determining the supply chain strategy and then describing the supply chain in the FFB production process. The following data processing step is to determine the greatest greenhouse gas emissions from the FFB production process to determine efficient mitigation actions. The researcher uses the Life Cycle Assessment Method at this point. According to the ISO 14040 standard. Figure 2 depicts four work sequences for Life Cycle

Assessment. By developing LCA scenarios, the final stage of LCA is utilized to discover strategies for lowering potential CO₂ greenhouse gas emissions and enhancing energy efficiency.

5. Results and Discussion

The SCOR model was utilized by the researchers to determine the supply chain in the palm oil agro-industry. The SCOR Model is a performance assessment model for supply chain management. It splits the supply chain process into five core processes: plan, source, make, deliver, and return, which are SCM operations from upstream to downstream (Stephens, 2001). In the supply chain, the oil palm agro-industry is separated into three system boundaries: oil palm maintenance, oil palm production, and distribution. Figure 3 shows a flow diagram of the oil palm agroindustry based on the SCOR Model.

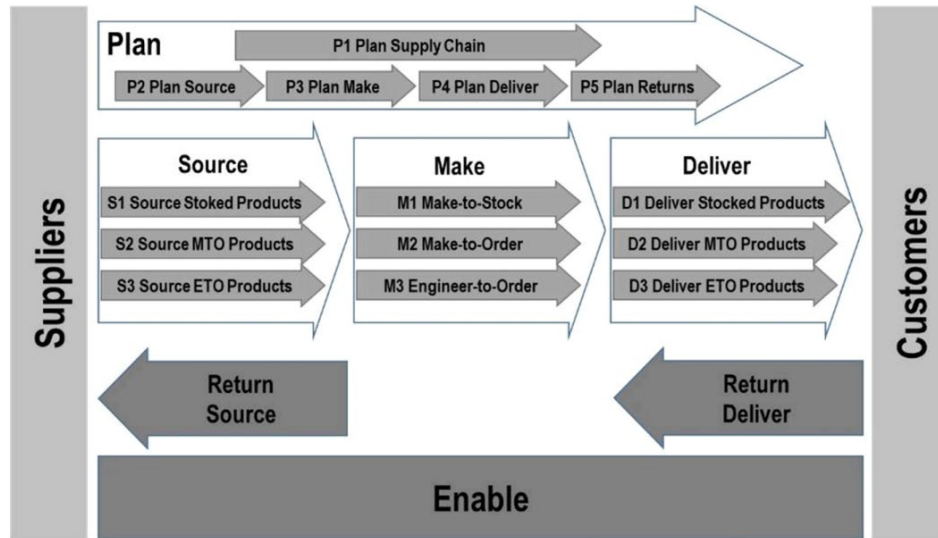


Figure 3. SCOR Framework (Stephens, 2001)

Figure 3 was elaborated to become the Supply Chain Strategy in Oil Palm Plantations. It involves:

- a. The flow in the plantation section involves the following processes:
 - S1 = Sourcing, the process of planting, maintaining, and harvesting FFB in each plantation unit.
 - D2 = Delivery, receiving FFB orders and returning damaged product from collection point.
- b. The flow in the distribution section involves the following processes:
 - S1 = Sourcing, transportation of FFB located at the collection point of each plantation.
 - D1 = Delivery, distribution of FFB to the loading ramp of the palm oil agro-industry.
 - R2 = Return and distribution of damaged oil palm fruit to each plantation unit.
 - D2 = Delivery, reordering FFB to each plantation unit.
- c. The flow in the CPO production section of the palm oil agroindustry involves the following processes:
 - D1 = Delivery, receiving the FFB from the plantation at the loading ramp.
 - M1 = Making, the process of distributing FFB from the loading ramp station to the processing station.
 - M2 = Making, the process of processing FFB into CPO in the Palm Oil Agroindustry.
 - R1 = Return, return of damaged oil palm fruit and reorder of FFB to each plantation unit.
 - R2 = Return and distribution of damaged oil palm fruit to each plantation unit.

Then, to determine the environmental impact, do an environmental analysis using the Life Cycle Assessment (LCA) technique. The initial stage of evaluation is to analyze data using the Life Cycle Assessment (LCA) approach by entering plantation data, CPO production data, and distribution data as input. Table 2-4 is input data into a software. The data that has been entered is then automatically processed using one of the Life Cycle Assessment tools. More detail, plantation data involve Potash (MOP), NPK, Sida Up 490 SL Glyphosphate, Metsulfuron Methyl, Argistik

(Alk. Poli. Eter 400 ml/l), Metarex (Insecticide), Decis 25 ec (Deltametrin), Polydor 25 EC (λ Sihalotrin), Asefat, Marshal 5Gr, Ammonium chloride (Urea), Ground rock phosphate (RP), Ground Magnesium Limestone (Dolomit), Triple Super Phosphate (TSP), Fossil Diesel consumption. The input data is then divided into three categories based on the system boundaries, which include oil palm plantation operations, distribution activities, and CPO production activities. Furthermore, the palm oil agro-industry contribution has been used in the form of a histogram graphic. Thus, the ranking results of each aspect of the cause of greenhouse gas emissions based on the location with the most potential may be observed. Figure 4 shows the outcome of data processing with one of the Life Cycle Assessment applications.

Table 2. Plantation data

Plantation	FFB Production (MT)
Plantation A	39.863,28
Plantation B	36.998,59
Plantation C	2.961,72
Plantation D	33.552,00
Plantation E	12.739,97
Plantation F	38.026,43
Plantation G	32.091,71
Plantation H	10.370,77
Plantation I	19.778,37
Plantation J	5.954,87
Plantation K	69.594
Plantation L	51.778
Plantation M	95.424,00

Table 3. Milling production data

Item	Data	Unit
FFB Processed Nett	266.936,46	Ton
CPO Produced	61.382,73	Ton
PK Produced	11.103,97	Ton
CPO Moist	0,11	%
PK Moist	6,30	%
Electricity Generated By Steam Turbine	3.527,00	MWh
Electricity Generated By Gensets	1.540,40	MWh
Fossil Diesel Consumption	106.695,00	L
Wheel Loader	54.955,00	L
Genset	51.740,00	L
Water For Steam Production	326.395,00	Ton
Water Used For Processing	349.298,00	Ton
Chemical Used : -BL 2808 SS/EON ALKALOX (B 1414)	4,28 4,23	Ton

-BL 4818 SS/EON SCALE (B 5100) - BP 1807 SS (Oxygen Scavenger)/EON OXY (B 8100) -BL 3809 SS (Sludge Conditioner/Dispensar)/EON DESCALER (B 2550) -Caustic Soda/Soda Api (NaOH) -Sulfuric Acid (H ₂ SO ₄)	4,23 3,20 21,35 9,56	
Lubricant Used	14.858,00	L
Fibre Formed in Production	32.032,38	Ton
Fibre Used In Combustion	32.032,32	Ton
Shell Formed In Production	18.685,55	Ton
Shell Sold To Other Operators	356,00	Ton
EFB Formed In Production	6.210,28	Ton
EFB For Mulching	6.210,28	Ton
POME Formed In Processing	169.200	Ton

Table 4. Distribution data

Plantation	Distance To Mill (Km)	Diesel Consumption For FFB Transport on Truck (L)	FFB Sent To Mill (Ton)	Weight Of One Load (Ton)
Plantation A	70,00	99.659,95	39.863,98	7,00
Plantation B	58,00	79.203,43	38.236,14	7,00
Plantation C	42,00	4.442,58	2.961,72	7,00
Plantation D	162,00	104.066,66	17.986,83	7,00
Plantation E	160,00	49.935,60	8.738,73	7,00
Plantation F	182,00	7.630,94	1.173,99	7,00
Plantation G	172,00	4.868,09	792,48	7,00
Plantation H	168,00	713,04	118,84	7,00
Plantation I	176,00	1.026,33	163,28	7,00
Plantation J	204,00	459,87	63,12	7,00
Plantation K	122,00	244.347,70	56.079,80	7,00
Plantation L	142,00	186.966,23	36.866,58	7,00
Plantation M	220,00	235.602,87	29.985,82	7,00
Total	1.878	1.018.923	233.031	91

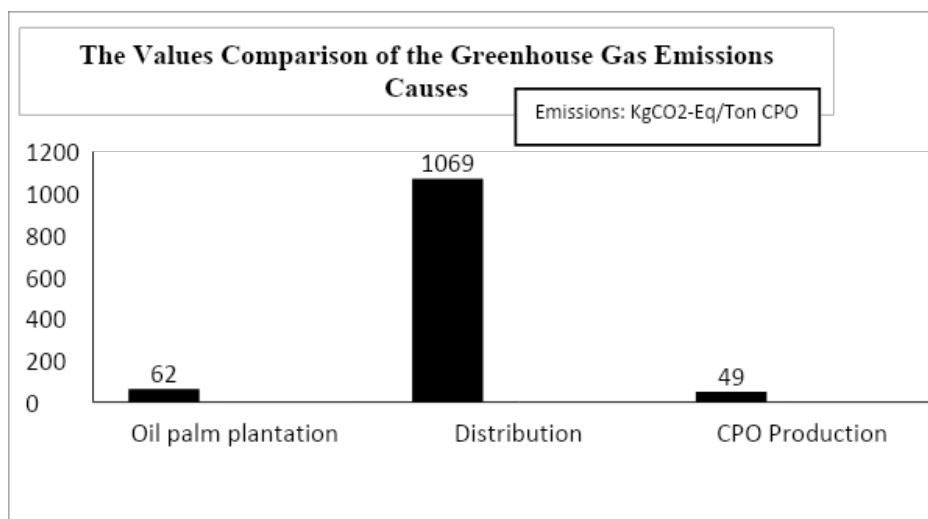


Figure 4. Comparison of Greenhouse Gas Emission Values

The supply chain strategy was effectively analyzed using the SCOR Model approach, demonstrating that the SCOR Model can reveal the relationship between the company's aims or strategies and the functioning of the supply chain activities in the palm oil agro-industry. The SCOR Model then describes each supply chain management activity that might improve effectiveness and productivity. The life cycle assessment calculation revealed that the greenhouse gas emission values from the three processing units, specifically the planting process unit, amounted to 62 Kg CO₂-Eq/ton CPO (5.28%), and the distribution process unit is 1069 Kg CO₂-Eq/ton CPO (90.56%) and the CPO production process unit is 49 Kg CO₂-Eq/ton CPO (4.16%). The most significant value of greenhouse gas emissions on

environmental impacts is in the distribution process unit. This is due to an imbalance between the capacity of trucks and the capacity of fresh fruit bunches (FFB) to be transported from the plantation. The ideas resulted in more effective truck use and shorter transportation routes from the plantation to the factory. It is preferable to employ higher capacity trucks in the palm oil agro-industry to reduce the number of trucks and truck fuel used in transportation activities. This recommendation is consistent with research conducted by Fitri, (2015) which states that choosing the right distribution channel is critical in a product manufacturing company to reduce distance, distribution time, distribution costs, the number of vehicles, and other resources.

6. Conclusion

The oil palm agro-industry research was successful in defining the supply chain strategy of the oil palm plantation agro-industry from planting to becoming CPO. This study also discusses the impact of environmental emissions on the environment of the company. Pollution in the form of the highest greenhouse gas emissions in the distribution, with a value of 1069 Kg CO₂-Eq/ton CPO (90.56 percent), has an environmental impact. This is due to an imbalance between the amount of FFB to be transported from the plantation and the truck capacity. The development of a life cycle assessment (LCA) scenario is the solution for reducing potential CO₂ greenhouse emissions and enhancing energy efficiency. Recommendations to minimize emissions are implemented by enhancing the efficiency of truck use and transportation distances from the plantation to the factory. The purpose of this research is to provide recommendations for difficulties. To obtain changes that occur, it is preferable to create a recommended modification with the application of simulation results for further investigation. It will then be able to identify more effective approaches to enhance business productivity.

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