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Evaluation of Environmental Impact and Energy Consumption for Development of Oil Palm Plantation in Aceh Province

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Abstract: Currently, environmental consideration becomes the most important issue in biodiesel production. The objective of this study is to evaluate environmental impact of biodiesel production using catalyst from crude palm oil in Aceh province. The results of this study show that biodiesel production from oil palm have differend resulted which is depent on various of material inputs. The environmental impact and energy consumption due to pre-harvest activity was higher compared to post harvest activity. The characteristics of Greenhouse Gas (GHG) emission value before stable productivity is 2.30-2.56 kg-CO_2 eq./kg-Biodiesel Fuel from Crude Palm Oil (BDF-CPO). When the productivity has reached stability, the GHG value is 1.66-1.71 kg-CO_2 eq./kg-BDF-CPO. The total value of energy consumption before stable production is 46.31-49.83 MJ/kg-BDF-CPO. Utilization of agrochemical in form of fertilizer and plant protection generate significant contribution to environmental impact of biodiesel production from Crude Palm Oil (CPO) is 50.46% for scenario 1 and 68.14% for scenario 2. The combination reduction of CO_2 eq. emission values of before and after stable production for BDF-CPO is 37.83% for scenario 1 and 49.96% for scenario 2.

Key words: Energy consumption, environmental impact, crude palm oil, biodiesel.

1. Introduction

Biodiesel can be produced from various oil borne plants, such as palm oil, *Jatropha curcas*, rapeseed, soybean, etc.. Availability of the feedstock is one important consideration for effective production of biodiesel. Thereby, USA produced their biodiesels from soybean, Euoropean countries from rapeseed, while Indonesia mainly from palm oil. Currently, environmental consideration becomes the most important issue in biodiesel production. Even though the source of the energy is considered as carbon neutral, the production path can emit various environmentally hazardous gasses. European countries claim that production of biodiesel from palm oil contributes carbon emission to atmosphere along its production path. Furthermore, EPA-NODA states that palm oil based biodiesel can only reduce GWP emission by 17% compared to fossil-fuel based. The minimum requirement to enter their market is 20% for US and 35% for EU. This condition could make barrier to Indonesia as one of the world's largest CPO producer. Sheehan, J. et al. [1] reported that biodiesel B100 from soybean will reduce CO_2 emission by 78.45% compared to oil produced from fossil (fossil-fuel based). Biodiesel as source of the energy is considered as carbon neutral, the production path can emit various environmentally hazardous gasses. In regard to this result, Indonesia should analyze the equilibrium balance between carbon emission produced from biodiesel utilization and its biodiesel production path. This analysis should be conducted for oil palm. Scientific approach through Life Cycle Assessment (LCA) can be used as a tool to assess this issue. LCA can be used to ensure that all environmental impacts has been considered for deciding action, calculating environmental impact that

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might occur, comparing process performance and developing data base for further research. In this regard, LCA can be used as a tool to support decision making on environmental improvement conducted by enterprise or government [2].

The target of LCA is to compare the whole environmental damage caused by product or particular activity and then select one option which have the least damage risk. This step is incorporated in Life Cycle Impact Assessment (LCIA) or evaluation of environmental impact. The result generated from LCA is highly influenced by the validity and sufficiency of data inventory of the object being assessed. Collecting data in Indonesia is the main focus in analyzing the stock and the most time consuming among other process involved in LCA. Number of LCA study in Indonesian biodiesel production come up with different result. This difference could be due to data inconsistency and did not present the actual condition found in the field. The objective of this study is to evaluate environmental impact of biodiesel production using catalyst from Crude Palm Oil (CPO) in Aceh province.

2. Material and Methods

The system boundary for LCA study is shown in Fig. 1, where cradle to gate consists of eight sub-processes. The Functional Unit (FU) of this study is one ton of Biodiesel Fuel (BDF). LCI analysis was performed based on data collected from palm oil plantation in Aceh province. Each stage of analysis and calculations was carried out before and after the plants yield the usable fruits.

Impact evaluation was made and analyzed in 2 scenarios:

Scenario 1: Using primary data from PTPN 1 Lhoksukon-Aceh Timur and private company national in Aceh province, i.e. PT.SPS 1 and 2 in Nagan Raya, PT.Soxfindo in Nagan Raya, PT.Kurnia Tanah Subur in Meulaboh, PT.PKS in Biureun and oil palm plantation from people, i.e. Kabupaten Nagan Raya, Kabupaten Aceh Barat, Kabupaten Aceh Timur, Kabupaten Biureun and dan Kabupaten Lhoksemumawe. So used data primer from PTPN VIII *Unit Kebun Kertajaya Lebak Banten*.

Scenario 2: The calculation same, but secondary data was conducted in this scenario, and did not calculate the transportation to transport material used from the store to the location of the material used.

3. Results and Discussion

3.1 Life Cycle Inventory (LCI)

The main key in the inventory phase is data collection. It usually relates the number of primary data, secondary data which obtained from national and international journal, student field practice report on palm oil, undergraduate thesis, graduate thesis, relevant research report and also publication released from national private plantation companies. The biodiesel has marked

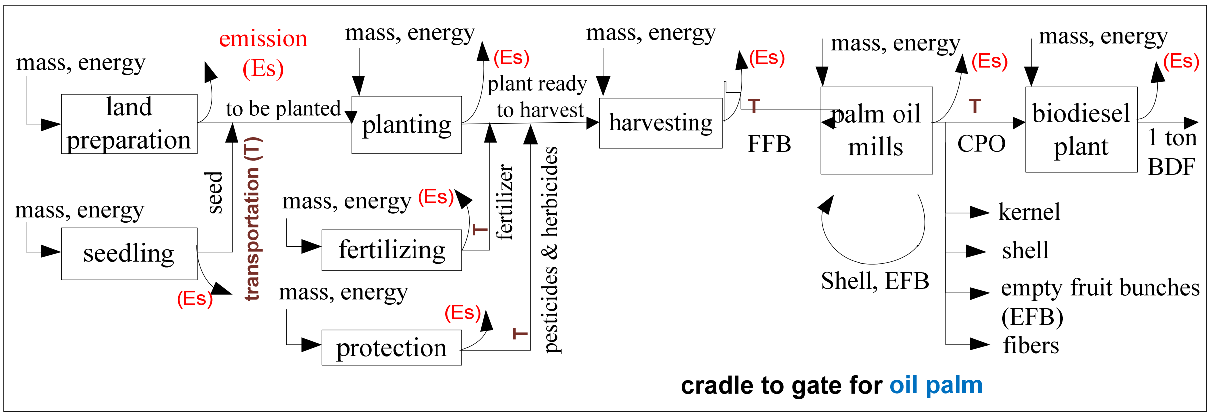

Fig. 1 **The system boundary of this study.**

an increased acceptance in the global market as an environmentally friendly diesel fuel [3]. LCI was conducted based on input-output analysis of mass and energy at each production line, as shown in Fig. 1. Stable productivity of oil palm at PTPN VIII is approximately 20 tons per ha per year. Overall averaged data (primary and secondary data) has been collected [4-10]. Data inventory shows that production of small holder's palm oil plantation is around 10 tons FFB per ha per year. While private estate with better seedling, maintenance and fertilization produces approximately 30 tons FFB per ha per year, with average yield about 20 tons FFB per ha per year. During stable production, palm oil can produce biodiesel up to 4 tons per ha per year. Pleanjai, S. et al [11] said that 6-7 tons FFB (yield 15.38%) or 1.14 tons of CPO (yield 87.7%) is needed in order to produce 1 ton of biodiesel.

During the first five years growth, oil palm plantation needs more fertilizer, as well as other agro-chemicals for protection. Oil palm is more susceptible to plant pests. Doses application will change continuously based on the plant's requirement, which is analyzed and determined by soil and leaves nutrient needs. This analysis will give appropriate amount of fertilizer and agro-chemicals. The use of fertilizer in oil palm is higher, especially in the use of urea, rock phosphate, muriate of potash and ammonia. This occurs due to fundamental nature of oil palm which needs high fertilizers, especially fertilizer N, P and K.

3.2 Evaluation of Environmental Impact Assessment

Scenario 1: Evaluation of impact assessment was carried out using data produced in inventory data and Multiple Interface Life Cycle Assessment-Japan Environmental Management Association for Industry (MILCA-JEMAI) version 1.1.2.5 for data processing. Five categories of environmental impacts are of interest, namely Greenhouse Gas (GHG), acidification, waste for landfill volume, eutrophication and energy consumption. Fig. 2 shows the value of GHG emission before stable production for biodiesel production from palm oil. And shows that GHG emission produced from utilization of agro-chemical is in the form of fertilizer and plant protection which is accounted by 50.46% of the total emission released from palm oil. The total value of GHG emission before stable production is 2,568.82 kg-CO_2 eq./ton-BDF for oil palm. Fig. 2 shows that oil palm's GHG value of eight sub-processes which consist of land preparation, seedling, planting, fertilizing, protection, harvesting, palm oil mills and biodiesel production is 0.44%, 0.61%, 0.91%, 35.15%, 15.31%, 1.23%, 22.90% and 23.44%, respectively. The percentation of proportion of each stage including pre-harvest, harvest and post-harvest is 52.42%, 1.23% and 46.34%, respectively.

Lord, S. et al. [12] stated that environmental impact towards aquatic, land, air and others of palm oil processing from operation to processing stage was 47%, 24%, 8% and 21%, respectively. The calculation analysis for stable production for GHG value is 1,658.50 kg-CO_2 eq./ton-BDF for oil palm. The trend of impact assessment for 25 years including GHG emission, acidification, eutrophication and landfill waste as shown in Figs. 3-6.

Scenario 2: For this scenario, calculation includes overall average primary and secondary data before-stable production. The results of second scenario found different with scenario 1. It is because different input data. The greatest portion of GHG value percentage also emerges from utilization of agro-chemical in fertilizer and plant protection is 68.14% for palm oil. The most significant GHG value is also caused by the fertilization phase and biodiesel production for palm oil. The total value of GHG emission before stable production is 2,300.24 kg-CO_2 eq./ton-BDF from CPO. Due to the existence of data input differences, it caused the differences in impact evaluations.

According to Fig. 7, the percentage value of eight sub-process consisting of land preparation, seedling,

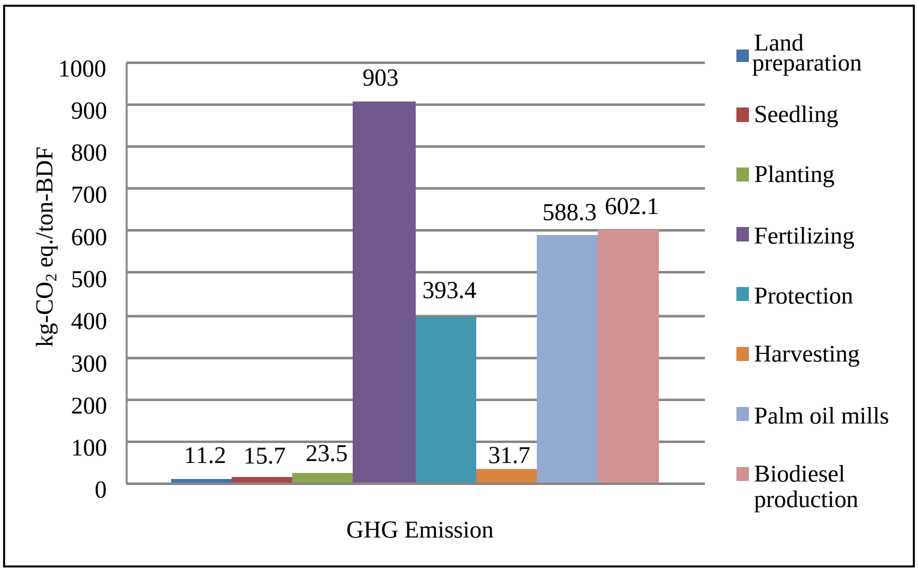

Fig. 2 The value of GHG emission of oil palm before stable production (1-5 years) for scenario 1.

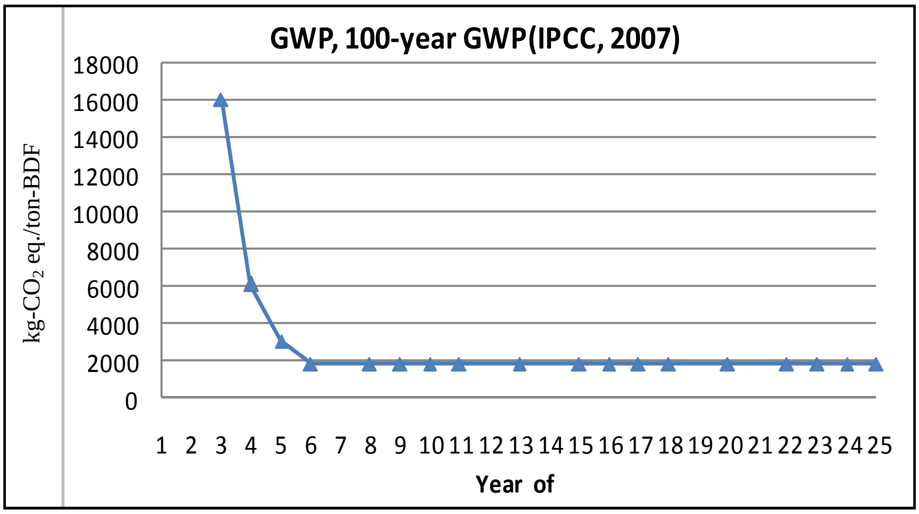

Fig 3 The value of GHG emission of oil palm before and after stable production (1-25 years).

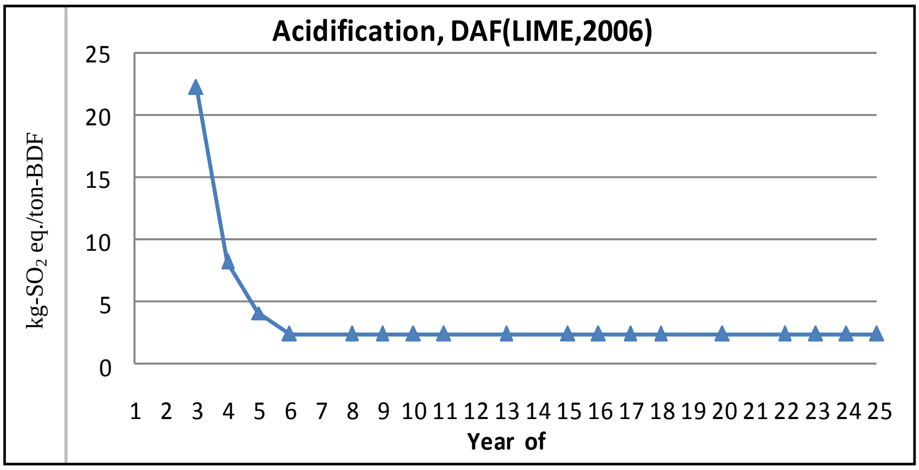

Fig. 4 The acidification value of oil palm before and after stable production (1-25 years).

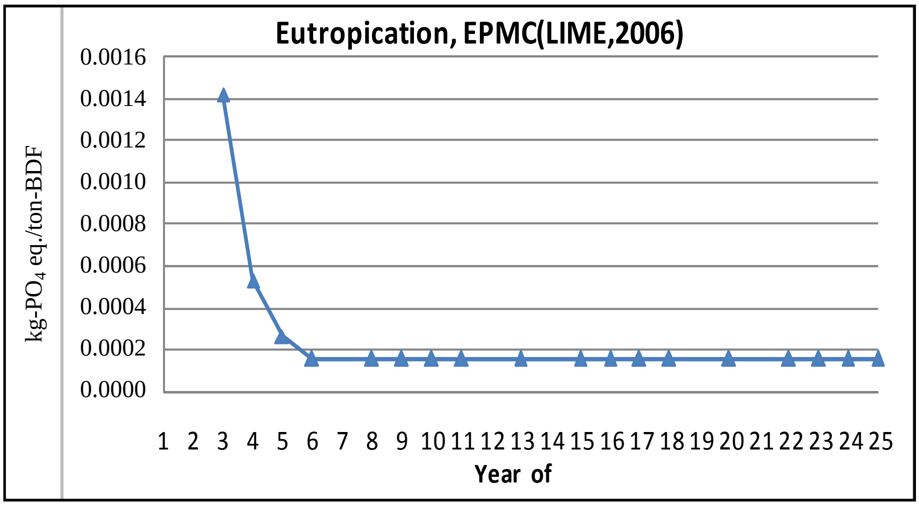

Fig. 5 **The eutrophication value of oil palm before and after stable production (1-25 years).**

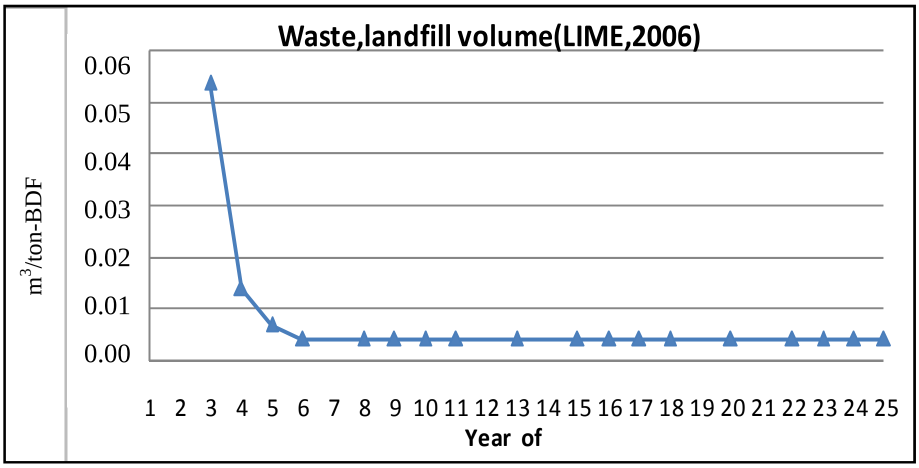

Fig. 6 **The waste landfill volume value of oil palm and before and after stable production (1-25 years).**

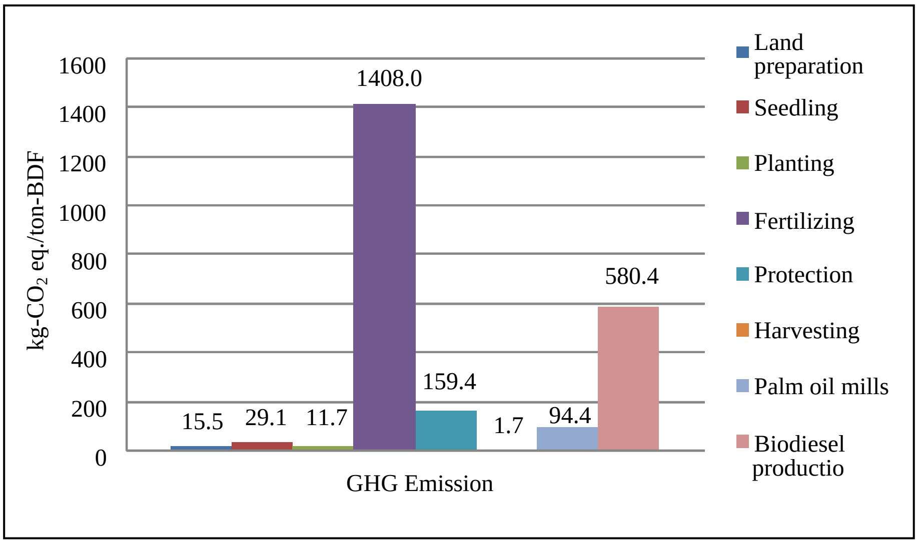

Fig. 7 **The total value of GHG emission of BDF-CPO before stable production (1-5 years).**

planting, fertilizing, protection, harvesting, constructing palm oil plant and biodiesel production is 0.67%, 1.27%, 0.51%, 61.21%, 6.93%, 0.08%, 4.1% and 25.23%, respectively. The percentation of proportion of each stage including pre-harvest, harvest and post-harvest is 70.59%, 0.08% and 29.34%, respectively. The calculation analysis for stable production is shown that GHG at stable production is 1,711.96 kg-CO_2 eq./ton-BDF for oil palm.

3.3 Energy Consumption

Scenario 1: Fig. 8 shows energy consumption for oil palm. The largest energy consumption for oil palm is fertilization sub-process i.e. 18,240.00 MJ/ton-BDF-CPO. The total value of energy consumption before stable production for oil palm is 49,831.17 MJ/ton-BDF-CPO. Fig. 8 shows that oil palm energy consumption during land preparation, seedling, planting, fertilizing, protection, harvesting, palm oil mills and biodiesel production is 0.33%, 0.49%, 0.78%, 36.60%, 12.47%, 0.85%, 16.04% and 32.45%, respectively. The percentation of proportion of each stage including pre-harvest, harvest and post-harvest is 50.66%, 0.85% and 48.9%, respectively. James, A. D. et al. [3] explained that the amount of energy required to produce biodiesel is relative to the energy content. This is due to renewable energy characteristic on the feedstock itself, such as palm oil, where the waste still can be used as a source of energy during processing and it also because that most agriculture energy analyst believes that solar energy is freely provided.

Scenario 2: The second scenario in Fig. 9 also shows the value of energy consumption for oil palm. The highest energy consumption for oil palm occurs at fertilization stage i.e. 24,330.00 MJ/ton-BDF-CPO. The total value of energy consumption of oil palm before stable production is 46,307.60 MJ/ton-BDF from CPO. According to Fig. 9, it can also be described the percentage distribution of energy consumption of oil palm from land preparation, seedling, planting, fertilization, protection, harvesting, palm oil mills and the production of biodiesel, i.e. 0.58%, 1.28%; 0.54%, 52.54%, 5.84%, 0.49%, 3.12% and 35.61%, respectively. The percentation of proportion of each stage including pre-harvest, harvest and post-harvest is 60.78%, 0.49% and 38.73%, respectively. Energy for fossil fuel during stable production is 25,468.13 MJ/ton-BDF for oil palm.

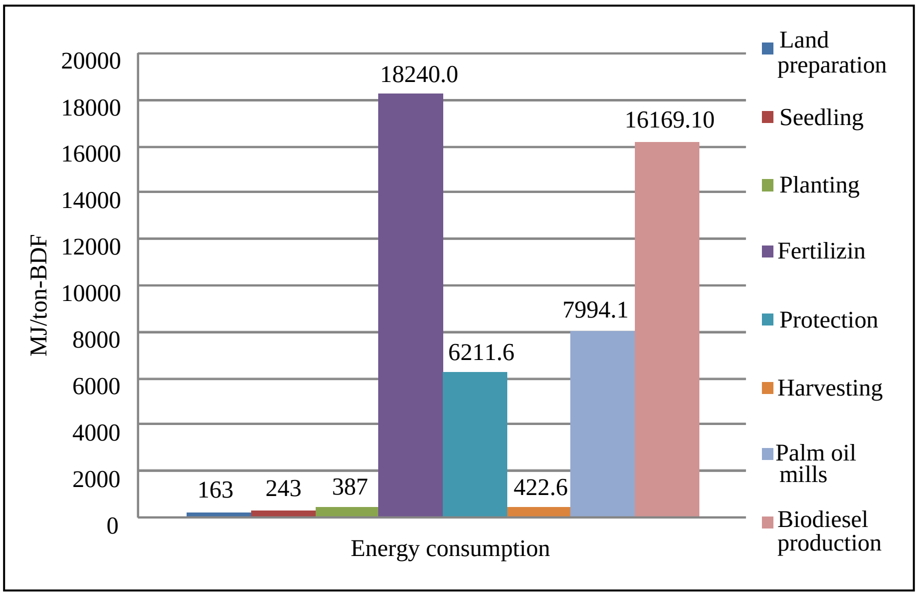

Fig. 8 The energy consumption value of oil palm before stable production (1-5 years) for scenario 1.

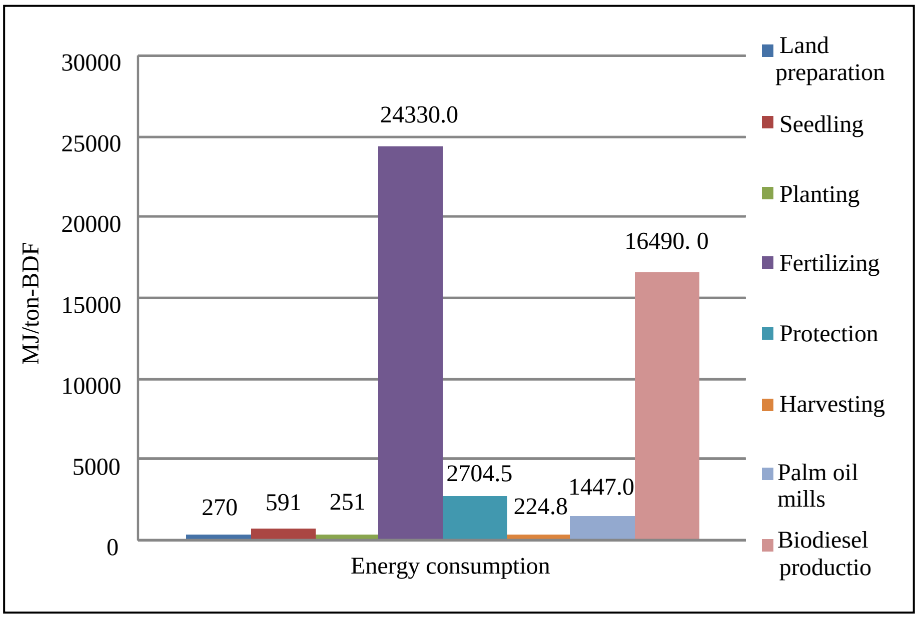

Fig. 9 The energy consumption value of oil palm before stable production (1-5 years) for scenario 2.

3.4 The Reduction of GWP (CO_2 eq.) Emission for Scenario 1 and Scenario 2

The reduction of emission in CO_2 eq. is lower at stable productivity due to lower input energy and mass which only used for maintenance, fertilizing and harvesting. The sub-processes of land preparation, seedling and planting are not carried out in this phase. The combination reduction of CO_2 eq. emission values of before and after stable production for BDF-CPO is 37.83% for scenario 1 and 49.96% for scenario 2. Pehnelt, G. et al. [13] concluded the more accurate GHG emission saving value of palm oil feedstock for electricity generation and biodiesel by 52% and between 38.5%-41%, respectively, depending on the fossil fuel comparator.

4. Conclusions

Based on the calculation on in scenarios 1 and scenario 2, obtained different results due to input data and method different calculation. Because the value of GHG emissions first 5 years far higher than the next 20 years, hence calculation of the value GHG emissions and energy consumption to be done for 25 years if want to judge on the life cycle of palm oil. And to get results environmental impact assessment corresponding to Indonesia, the authors must inventory data in Indonesia without doing assumptions rough.

Utilization of agrochemical in form of fertilizer and plant protection generate significant contribution to environmental impact of biodiesel production from CPO is 50.46% for scenario 1 and 68.14% for scenario 2. The characteristics of GHG emission value before stable productivity is 2,568.82 kg-CO_2 eq./ton-BDF-CPO for scenario 1 and 2,300.24 kg-CO_2 eq./ton-BDF-CPO. When the productivity has reached stability, the GHG value is 1,658.50 kg-CO_2 eq./ton-BDF-CPO for scenario 1 and 1,711.96 kg-CO_2 eq./ton-BDF-CPO for scenario 2. The total value of energy consumption before stable production is 49,831.17 MJ/ton-BDF-CPO for scenario 1 and 46,307.60 MJ/ton-BDF-CPO. The combination reduction of CO_2 eq. emission values of before and after stable production for biodiesel fuel from crude palm oil (BDF-CPO) is 37.83% for scenario 1 and 49.96% for scenario 2

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