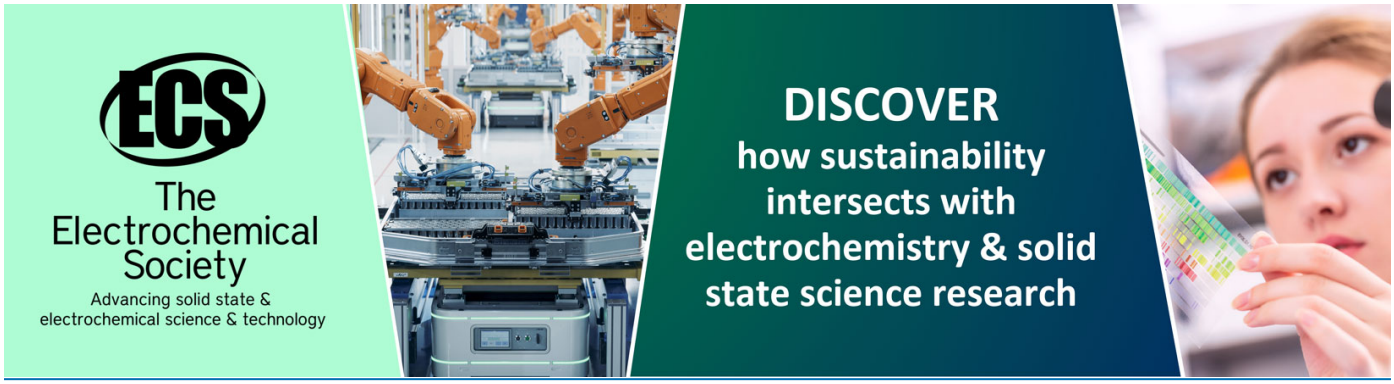
Study of life cycle assessment in biodiesel production from crude palm oil and its benefits for the sustainability of oil palm industry in Aceh province Indonesia



Study of life cycle assessment in biodiesel production from crude palm oil and its benefits for the sustainability of oil palm industry in Aceh province Indonesia

K Siregar[1*], H Sofyan[2], I S Nasution[1], R Ichwana[1], S Syafriandi[1], Sholihati[3], I Sofiah[4], T Miharza[4]

[1]Department of Agricultural Engineering, Syiah Kuala University, Jl.Tgk.Hasan Krueng Kalee No.3, Banda Aceh, 23111, Indonesia
[2]Department of Statistics, Faculty of Mathematics and Natural Sciences, Syiah Kuala University, Banda Aceh, 23111, Indonesia
[3]Department of Agricultural Industry Technology, Serambi Mekkah University, Jl. Unmuha, Batoh, Lueng Bata, Banda Aceh, 23245, Indonesia
[4]Department of Environment of PT Dakara Consulting LCA Indonesia, Jl. Lingkar Baru Laladon No. 9 Kampus IPB Dramaga Bogor, Jawa Barat, 16680, Indonesia

*E-mail : ksiregar.tep@unsyiah.ac.id

Abstract. LCA is a method used to quantificate impact especially environmental aspect from production of product. The environmental impact that can be calculated by LCA is very diverse, approximately 18 impacts, which called midpoint impact. The most commonly calculated impact is GWP, which is derived from GHG emissions. In Indonesia LCA began to develop and be used by govermnet or industry to calculate impact from their activities especially production of product. One of the industry that use LCA is palm oil industry. Indonesia palm oil is criticsm from both domestic and international level because of the environmental impact and unsustainable. However, production of biodiesel from CPO in Indonesia can reduced emission is 47 % if we compare to diesel fuel. Even though the source of the energy is considered as carbon neutral, the production path can emit various environmentally hazardous gasses. Scientific approach through Life Cycle Assessment can be used as a tool to assess this issue. Number of LCA study on 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. According to those aforementioned situations, an effort to address this issue should be conducted by identifying and presenting actual condition of Indonesian palm oil estate. This study is aimed to analyze implementation of life cycle assessment for oil palm industry from oil palm cultivation to biodiesel combustion in vehicle (upstream to downstream) in Indonesia.

1. Introduction

Biodiesel is a biofuel from plant or animal, that can be used as a mixture with diesel fossil fuel. The use of biodiesel could contribute to energy sustainability, because biodiesel is from renewable sources. Research on the production of biodiesel has increased significantly in recent years because of the need for an alternative fuel [1]. Alternative fuel needed should biodegradable, renewable and low toxicity [1]. One of the material that can be used to produce biodiesel is palm oil. Indonesia is the largest palm oil producer in the world and palm oil industry has provided a large income and contribute the nation's

economic growth. Despite its economic advantage, Indonesia palm oil has become the subject of criticism from both domestic and international level. Environmental consideration becomes the most important issue in application of oil palm industry in Indonesia. Even though the source of the energy is considered as carbon neutral, the production path can emit various environmentally hazardous gasses. Siregar et.al. said that production of biodiesel from CPO in Indonesia can reduced emission is 47 % if we compare to diesel fuel [2]. Social conflict and land dispute also have long been addressed to the sector [3]. Therefore we need a method that can be used to calculate the impact especially in nevironmental aspect resulting from palm oil industry. Scientific approach through Life Cycle Assessment (LCA) can be used as a tool to assess this issue.

LCA is a method that trusted by whole world and has been widely used by America and Europe for many products and materials. Life cycle assessment (LCA) is a holistic environmental accounting procedure which quantifies and evaluates all wastes discharged to the environmental and raw materials consumed throughout the entire life cycle, beginning with sourcing raw materials from the earth through manufacturing and distribution to consumer use and disposal. LCA can be used to ensure that all environmental impacts has been considered for deciding action, calculating environmental impact that might occur, comparing process performance and developing data base for further research. LCA can be used as a tool to support decision making on environmental improvement conducted by enterprise or government. LCA also can be used for comparing and evaluating products which have similar functions or uses and then select one option which have the least damage risk.

This study is aimed to analyze the implementation of life cycle assessment in biodiesel production and identification the benefits from the implementation of LCA. Research results obtained by Siregar [2], that biodiesel from palm oil can reduce emissions of fuel usage by almost half, shows that we should do more research to analyze the equilibrium balance between carbon emission produced from biodiesel utilization and its biodiesel production path. Number of LCA study on Indonesian biodiesel production come up with different result, which could be due to data inconsistency and did not present the actual condition found in the field. So this study is using the actual data from the field and the result expected accordance with the existing circumstances. There are two assumption in this study which compares LCA value with methane capture and LCA value without methane capture.

2. Material and Method

LCA is a tool to quantificate the environmental impact from production of product. LCA consist of four stage, such as scope and goal definition, inventory analysis, impact analysis and interpretation. This study scope is cradle to grave, from land preparation until combustion of fuel in vehicle. The process unit which included in the scope is shown in Figure 1. The data used for analysis is from our previous publication, with the title is implementation of life cycle assessment (LCA) for oil palm industry in Aceh Province, Indonesia [4]. Siregar et al. using LCA to calculate the environmental impact from production 1 ton CPO (crude palm oil) before and after stable production, and oil palm will have stable productivity after 5th years from seed plantation [4]. So, the environmental impact after stable production is less than before stable production. This study used the data from before stable production or within the first-fifth year of plantation. Production of palm oil consist of activities, such as land preparation, seedling, planting, fertilizing, protection, harvesting and palm oil mill. Palm oil then used as raw material for biodiesel production through transesterification process. After that biodiesel is blended with diesel fuel oil in oil station and used as fuel for car vehicles, which emission factor is based on the EPA [5]. The yield of biodiesel is approximately 92% based on direct measurement in field. Based on the inventory that already done by Siregar et al. [4], the environmental impact that calculated with LCA is global warming potential (GPW), which derives form greenhouse gas (GHG) emission of 1 kg biodiesel that used by vehicle.

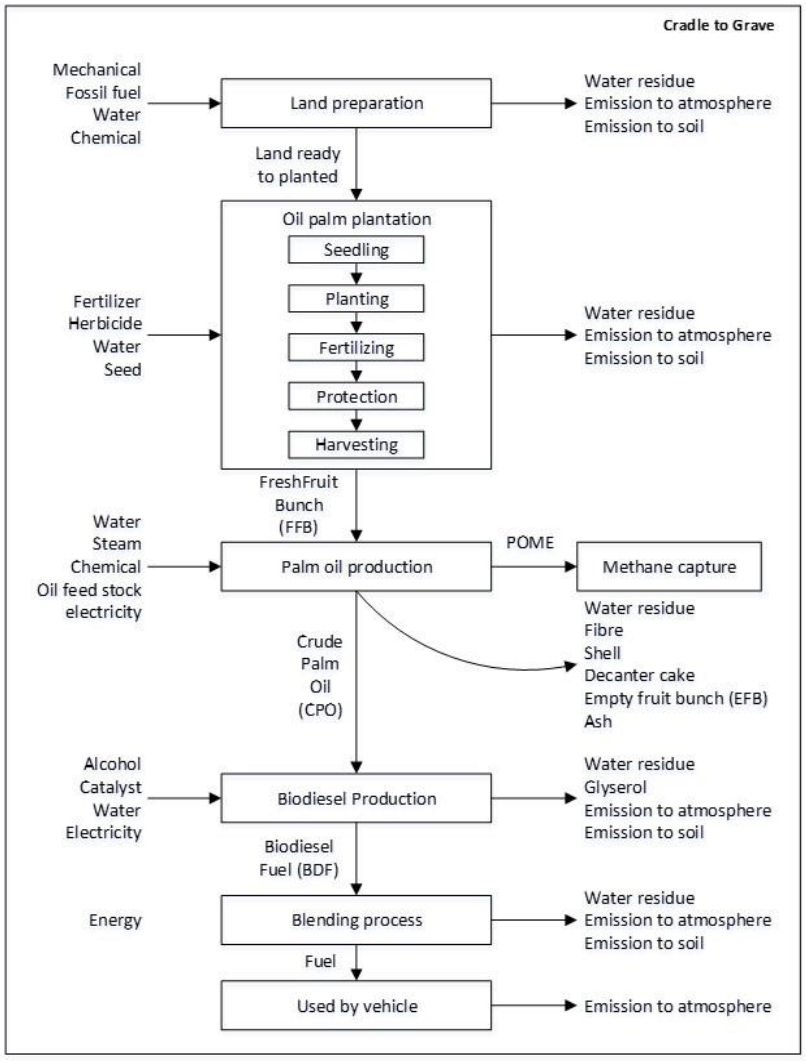


Figure 1. The scope for this study

Palm oil mill produced various waste, such as empty fruit bunch (EFB), fibre, shell, decanter cake, ash and POME. One of the most produced is palm oil mill effluent (POME), which is waste water that contains very high amount of organic matter and highly polluting. Generally, POME was treated biologically using a series of open ponds followed by land application or aerobic process. However, this treatment produces significant methane emission to the atmosphere. This methane can be reduced by applying methane capture and converted methane as fuels for biogas power plant. According to that, this study have two assumption, the first one has implemented methane capture and the second one not yet implemented methane capture.

3. Results and Discussion

3.1. Life cycle impact assessment

The impact calculated in this study is global warming potential (GWP). According to Figure 2, it can be seen the GWP value for palm oil mill that has implemented the methane capture. The total value of GWP is 2,58 kg-CO_2eq/kg BDF with the most produced by fertilizing process unit in oil palm plantation. The utilization of agro-chemical in the form of fertilizer is accounted by 54.57% of the total emission released. Figure 2 shows that oil palm's GWP value of ten sub-processes which consist of land preparation, seedling, planting, fertilizing, protection, harvesting, palm oil plants, biodiesel production,

blending process & vehicle/user are 0.60%; 1.13%; 0.45%; 54,57%; 6,17%; 0.07%, 3.66%; 22.49%; 0.33% and 10.46%, respectively. And if the process unit in the scope is grouped, there are 3 stage which is pre-harvest, harvest and post-harvets. Pre-harvest stage consist of land preparation, seedling, planting, fertilizing and protection. The harvest stage is the harvest process and post-harvest stage consist of palm oil mill, biodiesel production, blending process and vehicle process unit. The GWP emission released of each stage are 62.93%, 0.08 %, and 37.00%, respectively.

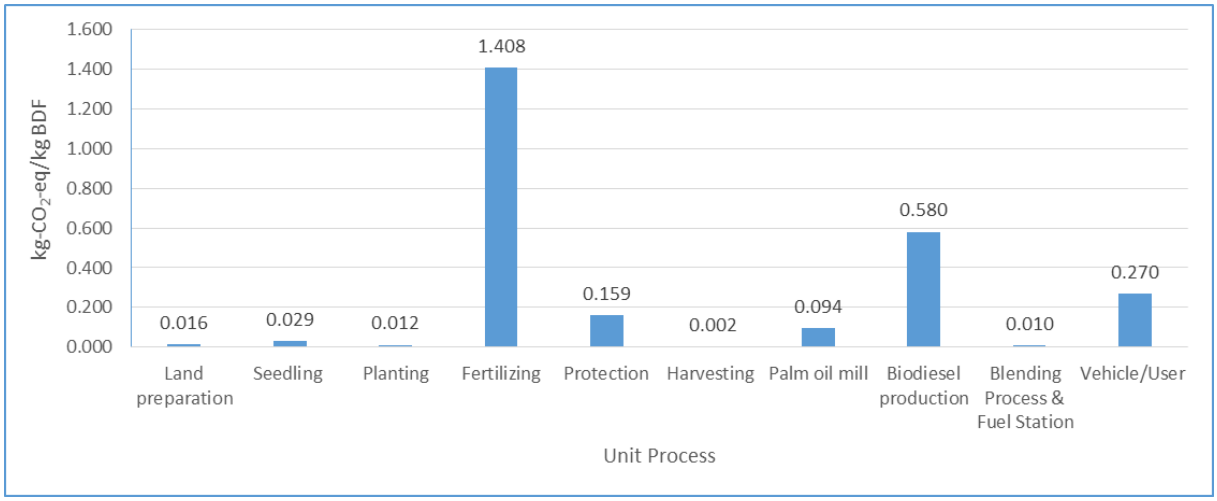


Figure 2. The value of GWP of biodiesel with methane capture

If the palm oil not yet implemented methane capture, most of GHG emission produced from utilization of agro-chemical is in the form of fertilizer and palm oil mill which is accounted by 37.25% and 34.24% of the total emission released. According to Figure 3, it can be seen the GWP for palm oil mill which not yet implemented methane capture. The total value of GWP is 3,78 kg-CO_2eq/kg BDF. Figure 3 shows that oil palm's GHG value of ten sub-processes which consist of land preparation, seedling, planting, fertilizing, protection, harvesting, palm oil plants, biodiesel production, blending process & vehicle/user are 0.42%; 0.78%; 0.31%; 37.87%; 4.28%; 0.05%, 33.13%; 15.61%;0.27% and 7.14%, respectively. The GWP emission released of each stage are 43.67%, 0.04%, and 56.27%, respectively.

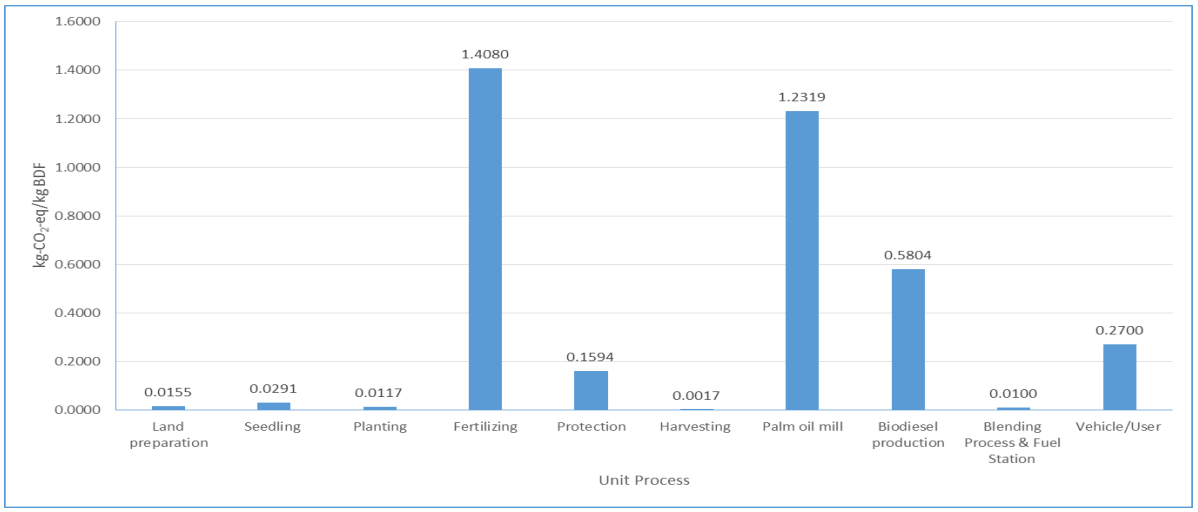


Figure 3. The value of GWP of biodiesel without methane capture

It can be concluded that if the palm oil mill has implemented methane capture, most of GWP emission released is from pre-harvest stage or plantation of oil palm. And if the palm oil mill not yet implemented methane capture, then most of GWP emission released is from post-harvest stage or processing palm oil into biodiesel and fuel use in vehicle. According to that result, it was recommended that the palm oil mill to capture biogas from POME and convert it into renewable energy in order to significantly reduce the GHG emissions from palm oil mills operation. However, most of palm oil mill not yet conducted methane capture to capture biogas due to high cost of investment and the lack of infrastructures associated with national grid connection.

3.2. Benefits of LCA Implementation in Biodiesel Production

LCA is a holistic environmental accounting procedure which quantifies and evaluates all wastes and emissions discharged to the environmental and raw materials consumed throughout the entire life cycle, beginning with sourcing raw materials from the earth through manufacturing and distribution to consumer use and disposal. Wiloso et.al. conducted a systematic review study on life cycle assessment and research application in Indonesia from 1996 to 2016 [6]. They found 107 research articles written by the authors who are affiliated with Indonesian's institutions. From those publications they found that LCA research in Indonesia fell into 3 major categories; environmental sciences (26%), engineering (23 – 24%), and energy (14 – 17%). LCA study on Indonesia palm oil industry have been conducted, but the data are still very limited. Several LCA studies on the palm oil sector conducted by Subramaniam et. al, and Tan et. al. to name a few [7,8]. In their research paper, Subramaniam et. al. examined the CO_2-eq release from the production of 1-ton CPO at the palm oil mill [7]. They found that in production crude palm oil, the impact came from the production of the fertilizers used as well as diesel usage for transportation and harvesting in the nursery and plantation phases, and form palm oil mill effluent (POME) in the mill. Tan et al. explored the LCA on Refined Palm Oil Products (RPOs) and found that RPOs which source is CPO, most impact is from the mills and the biogas capture system (methane capture) can greatly reduce GHG emission by about 40% [8].

Currently in Indonesia, the assessment of industrial activities to produce products especially environmental aspect has begun to be assessed through LCA method as a calculation approach. In 2018 the government through the Directorate General of Environmental Pollution Control Number P.14/2018 which contains about the Material for the Implementation of LCA on the PROPER criteria in Indonesia becomes an entry point for LCA implementation in Indonesia. The palm oil industry, which has become the world's spotlight and carries out many activities in the production process, has to apply LCA. So far, LCA calculations have been carried out by academics for research purposes. Research on LCA oil palm in Indonesia especially biodiesel production has been conducted by Siregar et. al., Hidayatno et. al. and Hasibuan et. al. [2,9,10]. Study conducted by Hidayatno revealed the best scenario for a minimal environmental impact for biodiesel production is by choosing non burn technique as the land clearing technique and the selection of forest-land instead of peat-land [9]. Figure 4 shows the comparison between the feedstock of biodiesel, such as soybean, rapseed and palm oil over the world.

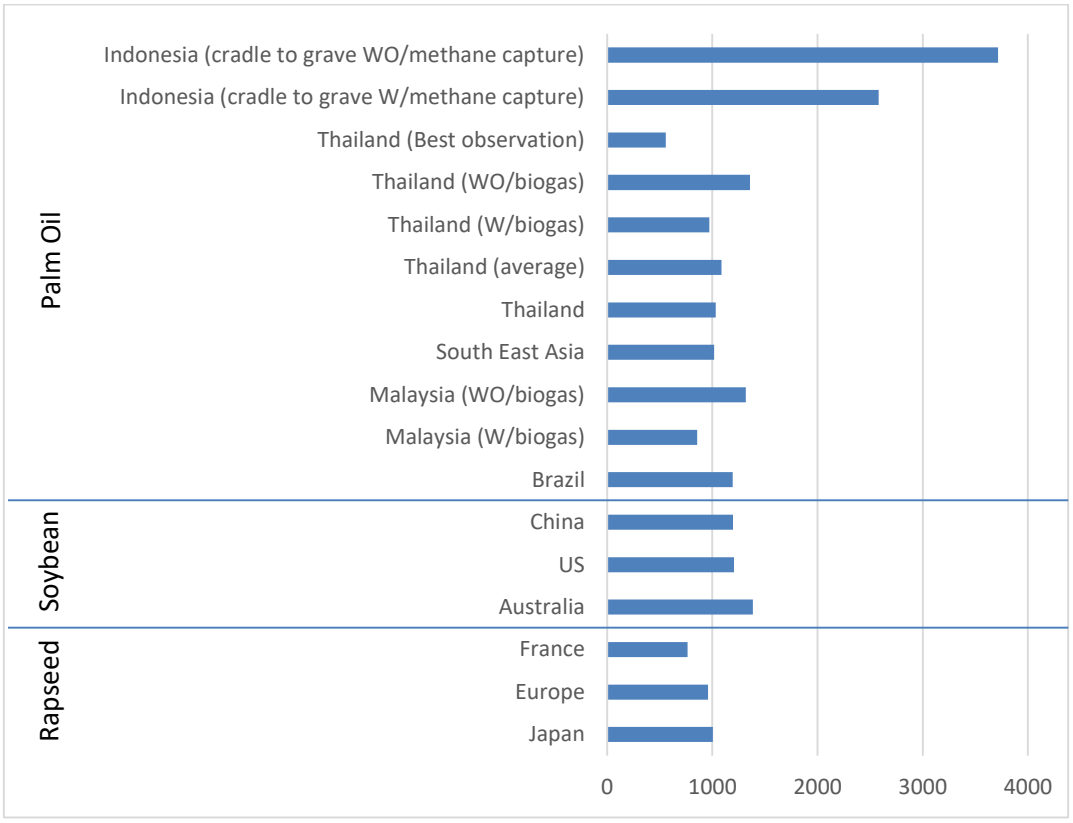


Figure 4. Comparison of LCA result in biodiesel

From that Figure 4, can be concluded that LCA value of biodiesel from palm oil in Indonesia greater than LCA value of other feedstocks or another biodiesel of palm oil from different country. In Indonesia case, it is potential since palm oil is the favorable crop in Indonesia and become the largest source of income. Palm oil industry also can accomodate many people as their primary income. Palm oil is considered as potential feedstock for biodiesel due to various advantages. Moreover, the physical and chemical properties of the palm oil-derived biodiesel shows that it is more favorable compared to other feedstocks. Some researcher also revealed that the kinematic viscosity of palm oil is close to that of conventional diesel and also, it has the highest cetane number among all the fuels [11,12]. The combustion of palm oil biodiesel was found to be more climate friendly, with 38% reduction of CO_2 emission compared to petroleum-derived diesel [13]. CPO-based biodiesel is the strongest candidates to be developed because of this commodity has a relatively low production cost and has equal performance compared with diesel fuel properties [9]. All the advantages from palm oil, make Indonesia's palm oil industry have to improve the process, so that resulting emissions released at least equal to the average of emission calculation in the world. LCA as the method that trusted by the whole world can be used to calculate and proved that biodiesel from palm oil is environmental friendly.

From this LCA study, plantation stage that using fertilizer is the hotspot in the biodiesel production from palm oil. The usage of fertilizer should be reduce or efficient, is the best option to reduce the GWP impact from biodiesel production. Another option that should be considered is using methane capture to reduce the GHG emission released to atmosphere. Shirai et al. conducted study to reduce methane released from palm oil mill in Malaysia [14]. They found that in Malaysia methane emission form palm oil industry is approximately 0.214 million tons or 9.59% of all methane emitted yearly [14]. The emitted methane can be used for electricity, which 1 m^3 of biogas (65% methane) can result 1.8 kWh [14]. Based on Shirai et. al. research methane capture can be one of the solution that can be used to sustainability of palm oil industry.

4. Conclusion

The result of the study that implementation of LCA in biodiesel production from cradle to grave with two assumption (with methane capture and without methane capture) found that the hotspot is fertilizing stage. The use of methane capture can reduce the GHG emission from palm oil mill stage and the overall emissions. Recommendation from reasearch should do efficiency the usage of fertilizer application and using methane capture are the best choice to reduce the GHG emission

References

[1] Ghaly AE, Dave D, Brooks M et. al. 2010 Production of biodiesel by enzimatic transesterification: review *Am J Biochem Biotechnol* **6**: 54-76
[2] Siregar et al 2015 A comparison of life cycle assessment on oil palm (*Elaeis guineensis* Jacq.) and physic nut (*Jatropha curcas* Linn.) as feedstock for biodiesel production in Indonesia *Energy Procedia* **65**: 170-179 doi: 10.1016/j.egypro.2015.01.054
[3] James AD, Shapouri H and Wang M 2006 Assessment of biofuels, renewables-based technology: sustainability assessment USA: John Wiley & Sons
[4] Siregar K, Ichwana, Nasution IS, Sholihati, Sofiah I and Miharza T 2019 Implementation of life cycle assessment (LCA) for oil palm industry in Aceh Province Indonesia IOP Conference Series: Earth dan Environmental Science 542 (2020) 012046 doi: 10.1088/1755-1315/542/1/012046
[5] Environmental Protection Agency. 2014. Greenhouse gas inventory guidance: direct fugitive emissions from refrigeration, air conditioning, fire suppression and industrial gases. USA: US EPA.
[6] Wiloso et al 2018 Life cycle assessment research and application in Indonesia *The Int. J. Of Life Cycle Assessment* **24**: 386-396 doi: 10.1007/s11367-018-1459-3
[7] Subramaniam V, May CY, Muhammad H, Hashim Z, Tan YA and Wei PC 2010 Life cycle assessment of the production of crude palm oil (part 3) *Journal of Oil Palm Research* **22**:895-903
[8] Tan YA, Muhammad H, Hashim Z, Subramaniam V, Wei PC, Let CC, Ngan MA and May CY 2010 Life cycle assessment of refined palm oil production and fractination (part 4) *Journal of Palm Oil Research* **22**: 913-926
[9] Hidayatno A, Zagloel TYM, Purwanto WW, Carissa and Anggraini L 2011 Cradle to gate simple life cycle assessment of biodiesel prodcution in Indonesia *Makara Teknologi* **15**:9-16
[10] Hasibuan S and Thaheer H 2017 Life cycle impact assessment produksi biodiesel sawit untuk mendukung keberlanjutan hilirisasi industri sawit Indonesia Malang: *Seminar Nasional Inovasi dan Aplikasi Teknologi di Industri*
[11] Fukuda H, Kondo A and Noda H 2001 Biodiesel fuel production by transesterification of oils *J Biosci Bioeng* **92**:405–416
[12] Al-Zuhair S 2007 Production of biodiesel: possibilities and challenges *Biofuels Bioprod Bioref* **1**:57–66
[13] Yee KF, Tan KT, Abdullah AZ and Lee KT 2009 Life cycle assessment of palm biodiesel: revealing facts and benefits for sustainability *App Energy* **86**:S189–S196
[14] Shirai Y, Wakisaka M, Yacob S, Hassan MA and Suzuki S 2003 Reduction of methane released from palm oil mill lagoon in Malaysia and its countermeasures *Mitigation and Adaptation Strategies for Global Change* **8**: 237-252

Acknowledgment

This research was supported by DGHE, Ministry of Research, Technology and Higher Education, under H-Index Scheme with Syiah Kuala University with number 54/UN11.2/PP/PNBP/SP3/2019