THE COMPARATIVE OF ENVIRONMENTAL IMPACTS ON WASTE-TO-ENERGY POTENTIAL OF PALM OIL BIOMASS WASTES FOR ELECTRICITY GENERATION

SHARIFAH SYAHIRA BINTI SYED NAROLHISA

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Science (Energy Management)

School of Chemical and Energy Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

AUGUST 2018

ACKNOWLEDGEMENT

First and foremost, I would like to thank Allah S.W.T for giving me the strength to complete my master project. I would like to express my gratitude to my supervisor, Prof. Madya Dr. Zainura Zainon Noor for giving me the opportunity to conduct my research under her supervise besides gives guidance and support throughout this project. There are a lot of knowledge and new things I have learned from her.

Besides that, I would like to express my deepest gratitude to coordinator of Energy Management programme, Dr. Azizul Azri bin Mustaffa for guiding us throughout this programme. And, special appreciation to Sharvini, PhD student, who help me a lot to complete this Master project. Thank you for always guide me from the beginning and help me when I faced problem with my research.

Also, I would like to thank my classmates, Aufa, Hazirah, Huda, Jamal and Ghaleb whom always help me during my tough time and share information with me to finish my project. Without their help, I would have not been able to complete my final Master project.

Next, I would like to thank my family for their constant support in everything I do and sacrifice their time and money through my education journey. Thank you for always being there for me.

Last but not least, I am grateful towards School of Chemical and Energy Engineering, University Teknologi Malaysia and all staffs for the help and facilities throughout the accomplishment of my Master project.

ABSTRAK

Malaysia sebagai antara negara terbesar menghasilkan kelapa sawit di dunia jelas sekali akan turut menghasilkan sejumlah lebihan dan sisa yang besar daripada industrinya. Industri kelapa sawit menghasilkan biomas lignoselulosa seperti tandan kelapa sawit , pelepah kelapa sawit, cengkerang kelapa sawit, serat kelapa sawit, tandan buah kosong (EFB) dan POME. Walaubagaimanapun, kesemua hasil daripada tandan buah kelapa sawit segar ini akan menyebabkan masalah kepada persekitaran ketika pelupusannya. Tujuan utama kajian ini dijalankan adalah untuk mengkaji penilaian kitaran hayat (LCA) dua jenis biomas kelapa sawit iaitu tandan buah kosong (EFB) dan juga POME sebagai bahan yang berpotensi untuk menjana elektrik. Kajian ini bertujuan untuk menilai kesan terhadap persekitaran daripada proses penjanaan elektrik dengan menggunakan EFB dan POME sebagai bahan api. Unit fungsi yang digunakan dalam kajian ini berasaskan 1 MWh yang dihasilkan. Skop dan sempadan sistem kajian ini adalah termasuk penghasilan bahan lebihan dan sisa kelapa sawit, penjanaan elektrik dan semua pengangkutan yang terlibat di sepanjang proses dengan menggunakan konsep "*gate-to-gate*". Kesemua data inventori, kemasukan dan pengeluaran dikumpul dari sumber kedua kajian terdahulu. Perisian GaBi8 digunakan untuk menilai impak terhadap persekitaran seperti potensi pemanasan global (GWP), potensi keasidan (AP) dan potensi eutrofikasi.

ABSTRACT

Malaysia as one of the largest palm oil producer in the world obviously will also generate a large quantity of residues and wastes from its industry. Palm oil industries produced lignocellulosic biomass such as palm oil fronds, palm oil trunks, palm kernel shells (PKS), mesocarp fibres (MF), empty fruit bunches (EFB), and palm oil mill effluent (POME). However, all these biomass wastes may lead to notable environmental concerns in their disposal stages. The main purpose of this research is to assess on life cycle assessment (LCA) of two different types of palm oil biomass; palm oil mill effluent (POME) and empty fruit bunch (EFB) as a potential waste-to-energy sources for electricity generation. This study aims to evaluate the environmental impacts of electricity generation by using POME and EFB as source of fuel. The functional unit in this study was defined as 1 MWh of electricity produced. The scope and system boundary of this study includes palm oil biomass wastes production, electricity production and all transportation activities along its life cycle from *'gate-to-gate'*. All inventory data, inputs and outputs were collected from secondary data of previous studies. Gabi8 software was used to evaluate the environmental impacts such as global warming potential (GWP), acidification potential (AP), human toxicity potential (HTP) and eutrophication potential (EP).

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AP	-	Acidification potential
EFB	-	Empty fruit bunch
EP	-	Eutrophication potential
GWP	-	Global warming potential
LCA	-	Life cycle assessment
LCI	-	Life cycle inventory
LCIA	-	Life cycle inventory assessment
MF	-	Mesocarp fiber
PKS	-	Palm kernel shell
POME	-	Palm oil mill effluent

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the Problem

Global warming issues keep at an alarming rate from year to year. The planet's temperature is rising and it is reported that in 2016 is the hottest year on record (*Union of Concerned Scientist, 2017*). The earth temperature increase when the gases trap heat then act like a blanket to warm the earth. It is believes that the effects of fossil fuel is one of the major contributor towards this issues. The burning of fossil fuel releases a large amount of carbon dioxide (CO2) gas to the atmosphere which also becomes biggest concern nowadays. In order to overcome this problem, the use of renewable energy is the most promising way to replace as resources without lack in their performance.

The limitations of non-renewable resources like fossil fuel have encourages people to search for another initiative towards the other source of energy. Nowadays, renewable energy sources are one of the promising and widely used sources. It is emphasized as new unlimited sources due to its potential to contribute to economics and sustainable developments. Among all the renewable sources, biomass has the highest potential to be utilized as the source of renewable energy. In Malaysia for example, biomass has highest potential as energy source to overcome the increasing energy needs while preserving the environment (Shafie *et. al.*, 2012).

Malaysia as one of the largest palm oil producer in the world obviously will also generate a large quantity of residues and wastes from its industry. Palm oil industries produced lignocellulosic biomass such as palm oil fronds, palm oil trunks, palm kernel shells (PKS), mesocarp fibres (MF), empty fruit bunches (EFB), and palm oil mill effluent (POME) (Abdullah & Sulaiman,2013). However, all these biomass may lead to notable environmental concerns in their disposal stages. According to Dalton *et al*. (2017), palm oil waste management status is important by considering the sustainability in the industry and the environment. Waste-to-energy concept also has been widely applied nowadays in order to meet the sustainable energy consumption. There are several ways of palm oil waste management has been use such as, composting and mulching the waste, conversion of the wastes as fuel to generate steam in boilers and then produce electricity with steam turbines, incineration of the wastes, or disposal of the waste to landfills and many more. This study aims to identify and quantify the environmental impact of electricity generation from two types of palm oil biomass which are; empty fruit bunches (EFB) and palm oil mill effluent (POME). The life cycle approach is conduct in this study in order to assess the environmental performance of the processes involves.

The life cycle assessment (LCA) could be an efficient way to assess environmental loads in one single assessment. The LCA is focus more on environmental performance impact in the future like carbon emission. In LCA, there are four main phases to be carried out in the assessments which involve data collection starting from receiving palm oil biomass from mill until production of electricity from each processes of palm oil biomass or from *gate-to-gate.* Therefore, a software called GaBi is used to help in the assessment of the impact. All the data used to carry this study will take from secondary sources from previous studies and annual report from palm oil industries. After all the result from the assessments obtained, the selection for the best route of the process can be done.

1.2 Statement of the Problem

The growth of palm oil industry in this country day by day will also result in abundance of wastes from it. Despite of all its benefit, palm oil biomass wastes also may contributes to environmental degradation. So, the presence of these wastes may lead to the environment concerns during its disposal stage. In order to get the best solution of palm oil utilization wastes, the technology, economic, energy balance, and environmental consideration must be balance (Abdullah & Sulaiman, 2013). For certain waste management, might give impact towards environment and some of them also may reduce the bad impact towards environment.

The demands for electricity generation keep increasing from year to year. In Malaysia, power generation mainly depends on three major fossil fuel sources which are; coal, natural gas and fuel-oil (Ong *et al.,* 2011). This situation may cause excessive exploitation of the non-renewable resources. As a result, power generation from fossil fuels may cause depletion of the natural resources and also contributes to several environmental crisis.

Malaysia is a country that blessed with abundant of biomass resources due to its plantations activities. It is also reported that biomass is one of the potential resource that can be used to replace the non-renewable resources. Biomass can have the same performance output same as the conventional resource while preserving cost and environment as well. However, biomass technology involves high processing and transportation cost which this is the only big challenges to have renewable resources from biomass.

1.3 Objectives of Study

The main purpose of this research is to assess on environmental impacts of potential waste-to- energy of palm oil biomass wastes for electricity generation from different types of palm oil biomass which are empty fruit bunch (EFB) and palm oil mill effluent (POME) by using the LCA approach. The assessments involve the

evaluation of life cycle for each type of palm oil biomass's energy input and output and its emissions. The objectives of this study are:

i) To conduct inventory of inputs and outputs of different type of palm oil biomass to generate electricity.
ii) To quantify the potential environmental impacts from different type of palm oil biomass using life cycle approach.
iii) To compare different scenarios processes and valuation of palm oil biomass.

1.4 Scope of Study

This study covers four route processes of palm oil biomass that focus on the utilization of empty fruit bunches (EFB) and palm oil mill effluent (POME to generate electricity. It is involved processes from palm oil biomass generation from palm oil mill to end-product from the palm oil biomass processes. The Life Cycle approach also applied along this study.

The scope of work involve in this study are; first is to analyze input and output data of each processing of renewable resources from the palm oil biomass. After that, the assessment of environmental impacts of the process for each biomass resources is conduct using LCA approach. Once the environmental impacts have been analyze, the final steps is to select the best processing route based on the result obtain from the analysis in order to achieve a better performance.

1.5 Significance of Study

The abundance of palm oil biomass is increasing with the demand of the palm oil nowadays. Its disposal stage is the critical part where it might give effect in terms of environmental as well as economic. This study will shows the effective processes

utilization of palm oil biomass in order to overcome its disposal problem as environmental concern today. Other than that, the evaluation of environment impact by conducting life cycle assessment for each process of palm oil biomass will identify the hotspot in each process. So, the precautionary steps can be taken to reduce the impacts on environment and economic.

Next, palm oil companies does not concerned about the generated palm oil biomass because usually the process might involves other external cost such as processing and transportation cost. So, in term of social impacts, this study will encourage the palm oil company to utilize palm oil biomass generated from their company based on the reduction in environmental impact and economically.

REFERENCES

Ahmad, S., Kadir, M. Z. A. A., and Shafie, S. (2010). Current perspective of the renewable energy development in Malaysia. *Renewable and Sustainable Energy Reviews*.

B. Trisakti, P. Mhaedela, T. Husaini, Irvan, and H. Daimon. (2018). Effect Of Pieces Size of Empty Fruit Bunches (EFB) on Composting of EFB Mixed with Activated Liquid Organic Fertilizer. *IOP Conf. Series: Materials Science and Engineering.*

Baharuddin, A. S., Hock, L. S., Yusof, M., Rahman, N. A., Shah, U., and Hassan, M. (2010). Effects Of Palm Oil Mill Effluent (POME) Anaerobic Sludge From 500 m^3 of Closed Anaerobic Methane Digested Tank on Pressed-Shredded Empty Fruit Bunch (EFB) Composting Process. *African Journal of Biotechnology*, 2427–2436.

Bakar, S. N., Hasan, H. A., Mohammad, A. W., Siti Rozaimah Sheikh Abdullah, T. Y., and Ngteni, R. (2017). A review of moving-bed biofilm reactor technology for palm oil mill. *Journal of Cleaner Production*, 1532-1545.

Barje, F., El Fels, L., El Hajjouji, H., Amir, S., Winterton, P., and Hafidi, M. (2012). Molecular Behaviour of Humic Acid-Like Substances During Co-Composting of Olive Mill Waste and The Organic Part of Municipal Solid Waste. *International Biodeterioration and Biodegradation* 74, 17–23.

D. Ravemark. (2003). "State of the art study of LCA and LCC tools".

Dalton, O. S., Mohamed, A. F., and Aja, O. C. (2017). Status Evaluation of Palm Oil Waste Management Sustainability in Malaysia. *OIDA International Journal of Sustainable Development 10:1*, 42-47.

Guinée, J. B., Heijungs, R., Huppes, G., Zamagni A., Masoni, P., and Buonamici R. (2011). Life cycle assessment: past, present, and future. *EnvironSci Technol;45*, 90–96.

Gutierrez, L. F., Sanchez, O.J., and Cardona, C.A. (2009). Process Integration Possibilities for Biodiesel Production from Palm Oil using Ethanol obtained

from Palm Lignocellulosic Residues Oil Palm Industry. *Bioresource Technology100*, 1227-123

Herbert, G.M.J., and Krishnan, A.U. (2016). Quantifying Environmental Performance of Biomass Energy. *Renew. Sustain. Energy Rev. 59*, 292–308.

Khor, Cheng Seong, and G. Lalchand. (2014). A Review on Sustainable Power Generation in Malaysia to 2030: Historical perspective, Current Assessment, and Future Strategies. *Renewable and Sustainable Energy Reviews 29*, 952-960.

Loh, S.K. (2016). The Potential of the Malaysian Oil Palm Biomass as a Renewable Energy Source. *Energy Conversion and Management,* 1-13.

Mokanatas E. R. (2010). Use palm oil waste for biomass project. Available in The Star Online.

N. Abdullah and F. Sulaiman. (2013). The Oil Palm Wastes in Malaysia. *INTECH, Biomass Now- Sustainable Growth and Use, 3*, 75-100.

O. Sadeghi, A. Fazeli and M. Bakhtiarinejad. (2015). Waste to Energy in Malaysia.

Odavic P., Zekic V., and Milic D. (2017). Life Cycle Cost of Biomass Power Plant-Monte Carlo Simulation of Investment. *Economics of Agriculture 2/2017.*

Ong, H. C., T. M. I. Mahlia, and H. H. Masjuki. (2011). A review on energy scenario and sustainable energy in Malaysia. *Renewable and Sustainable Energy Reviews 15*, no. 1, 639-647.

Onoja E., Chandren S., Razak F. I. A., Mahat N. A., and Wahab R. A. (2018). Oil Palm (Elaeis guineensis) Biomass in Malaysia: The Present and Future Prospects. *Waste and Biomass Valorization*.

Ramadhani, L. I., Damayanti, S. I., Sudibyo, H., and Budhijanto, W. (2018). Kinetics of Anaerobic Digestion of Palm Oil Mill Effluent (POME) in Double-Stage Batch Bioreactor with Recirculation and Fluidization of Microbial Immobilization Media. *IOP Conference Series: Materials Science and Engineering*.

Sarunya C., Seksan P., Pomthong M., and Thumrongrut M. (2015). Life Cycle Assessment of Palm Empty Fruit Bunch Utilization for Power Plants in Thailand. *International Conference on Biological, Environment and Food Engineering.*

Shafie, S. M., Mahliaa, T. M. I., Masjuki, H. H., and Rismanchi, B. (2011). Life Cycle Assessment (LCA) of Electricity Generation from Rice Husk in Malaysia. Energy Procedia 14, 499-504

Shafie, S. M., Mahliaa, T. M. I., Masjuki, H. H., and Ahmad Yazid, A.(2012). A Review on Electricity Generation Based on Biomass Residue in Malaysia. Renewable and Sustainable Energy Reviews, 16, 5879- 5889.

Safaai N. S. M., Noor Z. Z., Hashim H., Ujang Z., and Talib J. (2010). Projection of CO_2 Emissions in Malaysia.

Said, M., Abdullah, S. R., and Mohammad, A. W. (2016). Palm Oil Mill Effluent Treatment Through Combined Process Adsorption and Membrane Filtration. *Sriwijaya Journal of Environment*, Vol. 1 No. 2, 36-41.

Vakili M., Rafatullah M., Ibrahim M. H., and Salamatinia B. (2014). A Review on Composting of Oil Palm Biomass. *Environ Dev Sustain* (2015), 17, 691–709

Yusoff S. (2006). Renewable Energy from Palm Oil - Innovation on Effective Utilization of Waste. J*ournal of Cleaner Production* , 14, 87-93