POLICY ENHANCEMENT FRAMEWORK FOR ENERGY GENERATION FROM PALM OIL MILL EFFLUENT USING LIFE CYCLE MULTI CRITERIA ANALYSIS

SHARVINI SIVA RAMAN

UNIVERSITI TEKNOLOGI MALAYSIA

ACKNOWLEDGEMENT

In preparing this thesis, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor, Professor Dr Zainura binti Zainon Noor, for encouragement, guidance, critics and friendship. I am also very thankful to my internal co supervisor Dr Chong Chun Shiong and external co supervisor Professor Lindsay C. Stringer for their guidance, advices and motivation. Without their continued support and interest, this thesis would not have been the same as presented here.

I am also indebted to Universiti Teknologi Malaysia (UTM), Ministry of Education Malaysia and Biotechnology and Biological Sciences Research Council (BBSRC) United Kingdom under program of United Kingdom-Southeast Asia Newton Ungku Omar Fund (UK-SEA-NUOF) for funding my Ph.D. study. Librarians at UTM, University of Leeds and University of York also deserve special thanks for their assistance in supplying the relevant literatures and guidance.

My fellow postgraduate student should also be recognised for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family member.

ABSTRACT

One of the most challenging problems in palm oil industry in Malaysia is the management of palm oil mill effluent (POME). Majority of the palm oil mills treat POME using anaerobic ponding system, which is not environmentally friendly as large amount of generated greenhouse gases is not captured but released to the atmosphere. Therefore, it is crucial to ensure a sustainable practise of closed anaerobic digestion system in the palm oil industry. This study was mainly aimed to provide evidence-based policy enhancement for POME treatment to energy generation. For this, life cycle assessment (LCA) was carried out to assess environmental impacts and life cycle cost-benefit analysis to assess the economic aspects focusing on two commercially available POME treatment technologies which are covered lagoon bio-digester (CLB, representing 36 palm oil mills with covered lagoon system) and continuous stirred tank reactor (CSTR, representing majority of the 54 palm oil mills employing closed tank system). Based on the output of life cycle analysis and interviews with palm oil mill management, thirteen possible solutions for policy enhancement were suggested. Possible solutions were ranked by experts and weighting were assigned to the possible solutions by using analytical hierarchy process, which were then used for policy enhancement. In terms of LCA, the global warming potential and acidification potential for CSTR were -4.48 kg CO_2 eq/kWh and -2.21 kg SO_2 eq/kWh, respectively, while for CLB the values were -4.09 kg CO_2 eq/kWh and -0.15 kg SO_2 eq/kWh. Both technologies produced a negative result, which equates to a net environmental benefit. However, both systems had a negative impact in terms of eutrophication potential. The CSTR nevertheless achieved a better eutrophication potential result of 0.048 kg PO_4^{3-}eq/kWh than the CLB with 0.054 kg PO_4^{3-}eq/kWh. With respect to life cycle cost (LCC), CSTR has a higher LCC of RM 2.60 million/year compared to CLB with LCC value of RM 2.29 million/year. In terms of cost-benefit, CSTR has a higher net present value (NPV) of RM 2.21 million/year, higher return on investment (ROI) of 11.80% and shorter payback period (PP) of 8.5 years compared to the CLB system with NPV of RM 0.91 million/year, ROI of 7.79% and PP of 12.8 years. ‘Provide detailed environmental guidelines’ followed by ‘standardise technical guidelines for biogas installation’ and ‘cover open pond wall using lining’ were the top three possible solutions to be considered in order to improve the existing policy for the POME treatment for energy generation. Future researchers may wish to consider social aspects related to job creation, safety and health of workers besides environmental and economic aspects. As a whole, this study allows policy makers to understand the current situation faced by palm oil mill managers and the rankings of possible solutions, offering important inputs for consideration in policy development for the treatment of POME for energy generation.

ABSTRAK

Salah satu masalah yang paling mencabar dalam industri minyak kelapa sawit di Malaysia ialah pengurusan kilang kumbahan minyak kelapa sawit (POME). Kebanyakan kilang kumbahan minyak kelapa sawit merawat POME dengan menggunakan sistem pengolaman anaerobik yang tidak mesra alam kerana sebahagian besar gas rumah hijau yang terjana tidak diperangkap tapi terbebas ke atmosfera. Oleh itu, adalah penting untuk memastikan amalan lestari sistem pencernaan anaerobik tertutup dalam industri kelapa sawit. Tujuan utama kajian ini adalah untuk mengemukakan bukti bagi pengukuhan dasar untuk rawatan POME terhadap penjanaan tenaga. Dengan itu, penilaian kitaran hidup (LCA) untuk menilai impak terhadap alam sekitar dan analisis kos-faedah kitaran hidup untuk menilai aspek ekonomi yang tertumpu kepada dua teknologi rawatan POME yang didapati secara komersial, iaitu pencerna biogas lagun tertutup (CLB, diwakili 36 kilang minyak kelapa sawit menggunakan sistem lagun tertutup) dan reaktor tangki teraduk selanjar (CSTR, diwakili majoriti 54 kilang minyak kelapa sawit menggunakan sistem tangki tertutup), telah dijalankan. Berdasarkan hasil analisis kitaran hidup dan temu ramah bersama pihak pengurusan kilang kelapa sawit, tiga belas penyelesaian munasabah bagi pengukuhan dasar telah dicadangkan. Penyelesaian munasabah dinilai oleh pakar dan pemberat diberikan pada penyelesaian munasabah tersebut dengan menggunakan proses hierarki analisis, yang kemudian digunakan dalam pengukuhan dasar. Daripada aspek LCA, potensi pemanasan global dan potensi pengasidan bagi CSTR masing-masing ialah -4.48 kg CO_2 eq/kWh dan -2.21 kg SO_2 eq/kWh. Bagi CLB, potensi pemanasan global ialah -4.09 kg CO_2 eq/kWh dan potensi pengasidan ialah -0.15 kg SO_2 eq/kWh. Kedua-dua teknologi memperolehi keputusan negatif menunjukkan bahawa ianya setara dengan keuntungan persekitaran bersih. Namun begitu, kedua-dua sistem mempunyai impak negatif dari segi potensi eutrofikasi. Walau bagaimanapun, CSTR telah mencapai keputusan potensi eutrofikasi yang lebih baik iaitu 0.048 kg PO_4^{3-}eq/kWh berbanding CLB iaitu 0.054 kg PO_4^{3-}eq/kWh. Berdasarkan kos kitaran hidup (LCC), CSTR mempunyai nilai LCC yang lebih tinggi iaitu RM 2.60 juta/tahun berbanding CLB iaitu dengan nilai LCC sebanyak RM 2.29 juta/tahun. Dari segi kos-faedah, CSTR mempunyai nilai kini bersih (NPV) yang lebih tinggi iaitu sebanyak RM 2.21 juta/tahun, pulangan pelaburan yang lebih tinggi (ROI) iaitu sebanyak 11.80 % dan tempoh bayar balik (PP) yang lebih pendek iaitu 8.5 tahun berbanding sistem CLB dengan nilai NPV sebanyak RM 0.91 juta/tahun, ROI sebanyak 7.79% dan PP selama 12.8 tahun. ‘Menyediakan garis panduan alam sekitar yang terperinci’ diikuti dengan ‘menyeragamkan garis panduan teknikal untuk pemasangan biogas’ dan ‘menutup dinding kolam terbuka menggunakan pelapik’ adalah tiga penyelesaian yang paling munasabah untuk dipertimbangkan bagi menambah baik dasar sedia ada untuk rawatan POME bagi penjanaan tenaga. Penyelidik masa hadapan boleh mempertimbangkan aspek sosial berkaitan penciptaan pekerjaan dan kesihatan pekerja selain aspek ekonomi dan alam sekitar. Secara keseluruhannya, kajian ini boleh memberikan peluang kepada para pembuat dasar untuk memahami situasi semasa yang dihadapi oleh pengurus kilang kelapa sawit dan pemeringkatan penyelesaian yang munasabah, dengan memberikan input penting untuk dipertimbangkan dalam pembangunan dasar bagi rawatan POME untuk penjanaan tenaga.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AD	-	Anaerobic digestion
AHP	-	Analytical hierarchy process
AOP	-	Advanced oxidation process
AP	-	Acidification potential
AS-GMP	-	Assessment System Genetically Modified Plants
BA	-	Break-Even analysis
B.E.P	-	Break-Even point
BOD	-	Biological oxygen demand
BPMSG	-	Business Performance Management Singapore
C&D	-	Construction and demolition
CBA	-	Cost benefit analysis
CDM	-	Clean Development Mechanism
CI	-	Consistency index
CLB	-	Covered lagoon bio-digester
COD	-	Chemical oxygen demand
COLT	-	Combination of open lagoon technology
CPO	-	Crude palm oil
CR	-	Consistency ratio
CSTR	-	Continuous stirred tank reactor
CT	-	Carbon trading
DALY	-	Disability adjusted life year
DG	-	Distributed generation
DOE	-	Department of Environment
DOSH	-	Department of Occupational Safety and Health
EFB	-	Empty fruit bunch
EGSB	-	Expanded granular sludge bed reactor
EP	-	Eutrophication potential
EPP	-	Entry Point Projects
EQA	-	Environmental Quality Act
ETSs	-	Emission trading systems

FBR	-	Fluidised bed reactor
FDI	-	Foreign direct investment
FFB	-	Fresh fruit bunch
FiT	-	Feed-in Tariff
FU	-	Functional unit
GHG	-	Greenhouse gas
GMM	-	Geometric means method
GITA	-	Green Investment Tax Allowance
GITE	-	Green Investment Tax Exemption
GTFS	-	Green Technology Financing Scheme
GWP	-	Global warming potential
HRT	-	Hydraulic retention time
IRB	-	Inland Revenue Board
IRR	-	Internal rate of return
ITA	-	Investment Tax Allowance
ITE	-	Income tax exemption
JKR	-	Jabatan Kerja Raya
KAU	-	Korean allowance units
KETS	-	Korea emission trading system
kWh	-	Kilowatt-hour
LCA	-	Life cycle assessment
LCC	-	Life cycle costing
LCCBA	-	Life cycle cost benefit analysis
LCI	-	Life cycle inventory
LCIA	-	Life cycle impact assessment
LUC	-	Land use change
MCDM	-	Multi Criteria Decision Making
MGTC	-	Malaysia Green Technology Corporation
MIDA	-	Malaysian Investment Development Authority
MMBtu	-	One million British Thermal Units
MOP	-	Multi Objective Programming
MPOB	-	Malaysian Palm Oil Board
MSW	-	Municipal Solid Waste

Mtoe	-	Millions of tonnes of oil equivalent
MW	-	Megawatts
NKEA	-	National Key Economic Area
NPV	-	Net present value
NVivo	-	Qualitative data management software
O&G	-	Oil and grease
OLR	-	Organic loading rate
POME	-	Palm oil mill effluent
POMs	-	Palm oil mills
PP	-	Payback period
PV	-	Photovoltaic
RE	-	Renewable energy
RI	-	Random index
RM	-	Ringgit Malaysia
ROI	-	Return on investment
RSPO	-	Roundtable on Sustainable Palm Oil
SEDA	-	Sustainable Energy Development Authority
SPSS	-	Statistical Package for Social Sciences
SS	-	Suspended solids
SSCM	-	Sustainable supply chain management
TN	-	Total nitrogen
TNB	-	Tenaga Nasional Berhad
TS	-	Total solids
UASB	-	Upflow anaerobic sludge blanket
UASFF	-	Upflow anaerobic sludge fixed film
UFF	-	Upflow fixed film
UNFCCC	-	United Nations Framework Convention on Climate Change
USD	-	United States Dollar
WAMM	-	Weighted arithmetic means method
WC	-	Water consumption
ZCB	-	Zero carbon building

LIST OF SYMBOLS

$B_{o,ww}$	-	Methane production per kg COD digester
°C	-	Degree Celsius
C_i	-	Electricity
CFE_{ww}	-	Digester efficiency
CH_4	-	Methane
CO_2	-	Carbon dioxide
D_r	-	dumping rate
EF_{CO_2}	-	Grid displacement
EW_r	-	earth works rate
GWP_{CH_4}	-	Global warming potential
H_2	-	Hydrogen
h/d	-	hour per day
m^3/hr	-	cubic meter per hour
$MCF_{ww,digestate}$	-	Digestate POME
$MCF_{ww,anaerobic}$	-	Recovery/combustion utilisation
mg/L	-	milligram per litre
N	-	Nitrogen
NH_3-N	-	Ammoniacal nitrogen
PO_{COD}	-	Phosphate equivalence factor (in terms of COD)
PO_{tn}	-	Phosphate equivalence factor (in terms of TN)
r	-	interest rate
SO_2	-	Sulphur dioxide
SO_{ww}	-	SO_2 equivalence factor (acidification potential)
t	-	tonne
λ_{max}	-	Largest eigenvalue

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

In this chapter, an introduction about this study is made where the background of study is described to give a general overview of the study. Then, the problem that this study is focusing on is leading to the presentation of the goal of the study and the research objectives. The scope of this study is described to reflect the boundary of what was considered, and information is given on how this study was conducted. The significance of the study is discussed to highlight the importance and contribution to society. At the end of this chapter, the layout of the thesis is briefly discussed.

1.2 Background of the Study

Renewable energy (RE) is emphasised globally as a new unlimited source of power due to its potential to contribute to economic and sustainable development (Kaplan, 2015). For a long period of time, the majority of countries have depended on fossil fuels including coal, diesel and natural gas as the main sources of electricity generation. Decades of excessive exploitation of these non-renewable resources cause not only pollution but also contribute towards global warming and climate change. Renewable resources are then prioritised in line with the realisation of rapidly diminishing resources, only they are not being taken up fast enough to cater for such unrelenting consumption. In addition, RE offers major economic opportunities, especially in the elimination of energy poverty (Vidadili et al., 2017). RE is a vital underpinning to the development of sustainability as well as helping to overcome the global environmental and energy crisis.

Biomass is one of the emerging credible fuel resources. Bioethanol and biodiesel are some of the biomass energy sources which have been commercialised in some countries of the world (Ohimain and Izah, 2017). Oil palm processing feedstock is the most notable feedstock for biomass energy, and can be used for the production of bioproducts like bioelectricity, bio-hydrogen, biodiesel, bioethanol, briquette, bio-methanol, biogas (Ohimain and Izah, 2014a, b), bio-butanol, briquette and bio-oil. Biofuels reduce the utilisation of fossil fuels and reduce carbon dioxide (CO_2) emissions as biofuels are carbon neutral (Hanaki and Portugal-Pereira, 2018). Biogas is a renewable, colorless, combustible and relatively odourless inflammable (Igoni et al., 2007; 2008).

In Malaysia, 5.8 million hectares (MPOB, 2018a) of land are covered by oil palm plantations and there are approximately 450 palm oil mills (POMs) in operation (Oshegale et al., 2016). Each oil palm tree produces 8 to 15 fresh fruit bunches (FFBs) annually (Yasin et al., 2017). Oil extracted from these FFBs consists of 10% of the whole dry matter of the palm, while the remaining 90% is palm oil biomass (Sue and Pantzaris, 2017), comprising empty fruit bunches (EFBs), palm oil mill effluent (POME), palm kernel shells, mesocarp fibres and palm oil trunks and fronds (Abdulrazik et al., 2017; Loh, 2017a). Both POME and EFBs are generated in huge quantities of 67% and 22%, respectively for every one tonne (t) of FFB (Loh, 2017a; Saelor et al., 2017). POME is a non-toxic, thick, viscous liquid waste that can cause damage if it is directly released into the environment as it is a highly polluting wastewater (Kamyab et al., 2018). POME has high organic content. An anaerobic treatment method is thus most suitable POME treatment method because such a method is more efficient (Choong et al., 2018). Anaerobic digestion (AD) is currently considered the most environmentally friendly biological treatment process because the waste subjected to AD can be converted into value-added products such as bio-energy (Li et al., 2019).

POME has a high organic content making a highly polluting effluent (MPOB, 2014). It has been a great challenge and it is critical to have a proper management system for handling the abundance of POME (Choong et al., 2018). However, more than 80% of POMs have been using a low cost ponding system which is a conventional system to treat POME (Oshegale et al., 2016). Another serious threat to the environment from the conventional system is the escaping greenhouse gases (GHGs) as a result of applying this treatment method, in addition to the large land area required (Choong et al., 2018). Thus, sustainable management of POME is crucial for the development of a cleaner palm oil industry (Choong et al., 2018) as to meet the requirement of environmental quality.

The current conventional system to treat the POME is inefficient due to the failure to comply with the standard discharge limit set by the Department of Environment (DOE) in many cases. This scenario leads to disruption of the water ecosystem (Iskandar et al., 2018). Khadaroo et al. (2019) agrees that POME has been identified as one of the most challenging waste products to dispose of in the palm oil industry due to its high organic content. Thus, identifying and using a proper disposal method is critically important. Efficient treatment can enable POME to supply useful products like biogas and A grade biosolids used in fertilisers (Khadaroo et al., 2019), which offer important new options and income streams from what would otherwise be waste.

Biogas production is one of the best ways to manage POME by-product particularly in developing countries (Hanafiah et al., 2017). Other countries around the world including Malaysia are shifting towards RE substituting the depleting and polluting fossil fuel sources. Ensuring the sustainability of biogas production from POME is the utmost important as Malaysia is one of the biggest producers and exporters of palm oil biomass sources for biogas generation (Aziz, Hanafiah and Gheewala, 2019). If biogas is captured from POME, there are two benefits: RE recovery and direct GHG emission reduction (Ohimain and Izah, 2017). Also, it is crucial to implement biogas facilities in all POMs in accordance with the Palm Oil National Key Economic Areas programme plans to implement eight core Entry Point Projects (EPPs) where EPP 5 particularly targets to ensure all POMs in Malaysia to have biogas facilities installed by 2020 (NKEA, 2014).

1.3 Problem Statement

POME has huge amount of essential fatty acids, inorganic nutrients, nitrogenous compound and more which will pollute the water and is particularly harmful to aquatic communities upon discharging POME into waterways (Iskandar et al., 2018; Santosa, 2008). Currently, 80% of Malaysia's POMs employ either anaerobic ponding systems or open digester tanks to treat the POME (Oshegale et al., 2016). These treatment methods generate a large amount of GHGs comprising CO_2 and methane that are not captured but rather, escape into the atmosphere (Khadaroo et al., 2019; Choong et al., 2018). A more environmentally-friendly alternative is the biogas plant. However, only 90 POMs have a complete biogas plant out of 450 POMs in Malaysia (Oshegale et al., 2016). Figure 1.1 shows the current utilisation of the biogas generated from the treatment of POME in POMs in Malaysia. It is clear from the figure that most of the biogas is flared (58%), while the second highest utilisation of biogas is for electricity generation (27%) which is sold to the grid. It is also apparent from the figure that it is critical to encourage sustainable practices in managing POME (Raman et al., 2019). Thus, this study compared two different POME treatment technologies which are: covered lagoon bio-digester (CLB) representing 36 mills employing covered lagoon system (Foo and Aziz, 2019) and continuous stirred tank reactor (CSTR), representing the majority of the 54 mills employing a closed tank system (Oshegale et al., 2016).

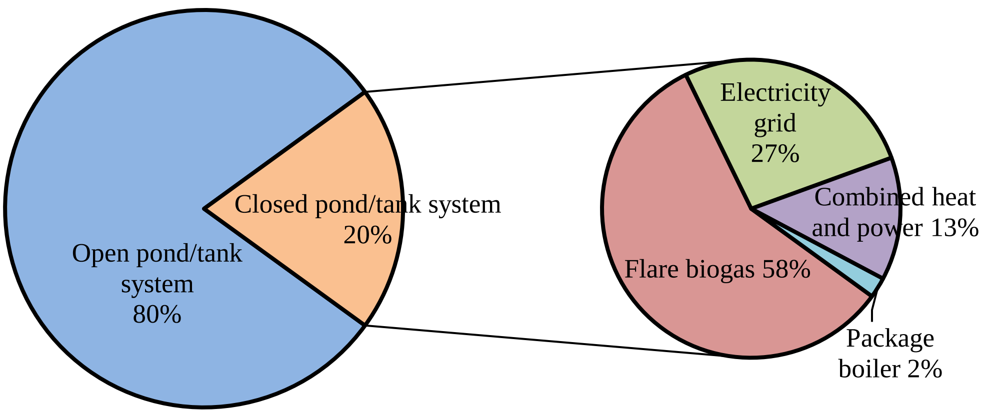

Figure 1.1 Current utilisation of biogas in POMs (Source: Oshegale et al., 2016)

Additionally, lack of support from the relevant authorities and government on related RE technology adoption in the current market has resulted in slow growth of biogas plant development in Malaysia. High risks of implementing new RE technology and a long payback period (PP) have reduced the interest of the stakeholders to finance RE projects, which eventually makes the RE technology not commercially viable in Malaysia (Yien et al., 2015). Thus, it is crucial to encourage a sustainable practise of a closed AD system of converting POME to renewable biogas which is then converted to electricity (Choong et al., 2018).

Malaysia pledged to reduce its GHG emission by 45% in 2030 based on the Nationally Determined Contribution of Malaysia (INDC, 2015). However, there is not any carbon trading to encourage the implementation of RE technologies as the first five-year commitment period for certified emission reductions credit in the Kyoto Protocol ended in 2012 and second international agreement regarding carbon reductions is yet to be implemented (UNFCCC, 2018). Apart from that, the feed-in tariff (FiT) scheme introduced by the Sustainable Energy Development Authority (SEDA), given to the installation of the biogas technology, differs according to the facilities' capacity. In addition, an extra bonus is given to facilities employing local technology, as well as for achieving high efficacy in electricity generation (Wong et al., 2015). Such policy regulations never seem to be attractive to POM owners who expect a high, fixed FiT price. Other than that, natural gas which is the main contributor of primary energy production in Malaysia is given as much as 71-77% subsidy by the Government of Malaysia on its selling price (Chatri et al., 2018). Simultaneously, POM owners expect the Malaysian Government to be able to provide a subsidy in the form of incentives for investment in electricity transmission to grid or to set up the biogas facilities. Currently, there is investment tax allowance (ITA) and an interest subsidy provided for the installation of biogas facilities where the application for ITA seems to be complicated. However, there is not any subsidy or incentives provided for the investment made to encourage the RE generation. This clearly shows that there is a need to enhance the current policy with sufficient evidence on POME treatment for energy generation to attract investors and foster the contribution of renewables in the energy mix.

Building from the policy context outlined above, this study seeks to identify possible solutions that could provide recommendations for the development of a relevant policy on the treatment of POME for energy generation. Policy plays an important role to ensure this study has a positive impact on society. The policy enhancement emerging from the study has the following characteristics:

1. It considers both environmental and economic aspects of the POME treatment process for energy generation;
2. It considers the output of life cycle studies and interviews with POM management who then suggested the possible solutions for policy enhancement based on the current scenario;
3. It considers the opinions of experts who ranked the possible solutions according to current regulations and practices set by the relevant authorities;
4. It acts as an initiative and evidence-based policy enhancement to encourage the implementation of biogas facilities in the remaining POMs with no biogas facilities and upcoming biogas plant projects.

1.4 Research Goal and Scope

The main goal of this study is to provide evidence-based policy suggestions for energy generation from POME. It delivers policy suggestions taking into consideration the output of LCA, life cycle cost-benefit analysis (LCCBA), interviews with POM management and a survey with experts for two types of energy generation POME treatment technologies for energy generation, enabling policy makers to improve the existing policy and encourage investors to implement biogas facilities in all POMs.

1.4.1 Research Objectives

The specific objectives are as follows:

1. To establish an inventory of inputs and outputs for two types of treatment technologies of electricity generation from POME.

2. To assess the potential environmental impacts for two types of treatment technologies of electricity generation from POME using LCA approach.

3. To evaluate the economic feasibility for two types of treatment technologies of electricity generation from POME using LCCBA.

4. To utilise the findings from LCA, LCCBA and conduct interview with the palm oil mill management for the suggestion of possible solutions for policy enhancement.

5. To rank the possible solutions through a survey with experts and assign weights using multi criteria analysis to suggest prioritised solutions towards policy enhancement of electricity generation from POME.

1.4.2 Research Scope

This study covered two different POME treatment technologies from POM 1 and POM 2, respectively for energy generation. The two POME treatment technologies compared are: CLB and CSTR system. Out of the 90 POMs with biogas facilities, 36 mills are employing the CLB system while the remaining 54 mills using the tank system, most commonly the CSTR system. Thus, CLB and CSTR systems would represent the scenarios of POMs employing biogas facilities. As for data inventory, inputs and outputs for two different processing routes are based on the software database and industrial data from POM 1 and POM 2. The boundary of the study is based on gate-to-gate (POME to electricity generation) for two types of processing route.

In order to quantify the potential environmental impacts for different treatment technologies of electricity generation from POME, potential impacts available in CML 2001 method, a life cycle impact assessment (LCIA) methodology was used, with specific and related impacts assessed. The collected inventory data is modelled using LCA software (Gabi 8). The LCIA shows the values possessed for each different impact which enable easy assessment of generating electricity for the life cycle stages including the full gate-to-gate system boundary. The economic feasibility is evaluated using LCCBA approach which consist of both life cycle cost (LCC) and cost benefit analysis (CBA). LCC comprises the capital cost and operational cost while CBA includes additional economic factors such as return on investment, PP, net present value and Break-Even analysis (BA) which is necessary to evaluate the desirability and feasibility of a process.

An interview with eleven POM management from five POMs were conducted where a list of possible solutions was derived using the output of LCA (environmental hotspots) and LCCBA (economic outputs) as an evidence for policy enhancement of POME treatment for energy generation. The limited number of interviewees was one of the limitations of this study as it was difficult to engage with relevant stakeholders due to slow responses (or mostly no response at all). It is also important to note that if a higher number of POMs responded positively to invitations to participate in interviews, a wider range of solutions may have been identified. Then, a survey listing all the possible solutions was conducted with experts. The possible solutions were analysed and assigned weights using an AHP method. Prioritised solutions towards policy enhancement in this study can be used to guide policy makers to take into consideration the aspects which need improving in the existing policy, as well as to encourage investors to implement biogas facilities in remaining POMs with no biogas facilities and upcoming biogas plant projects.

1.5 Research Significance

Global warming issues are having an adverse impact on the environment. Substituting fossil fuels with renewable resources such as biomass will reduce the environmental impacts, which will help to overcome the environmental crisis. Also, growing demand for electricity generation has increased the necessity to further venture into renewable resources to substitute depleting fossil fuel resources. Apart from environmental issues, economic aspects like longer payback period (PP) upon investing into new RE technology reduces the interest of investors to confidently venture into RE sector. Thus, this study used LCA and LCCBA to assess and compare environmental and economic aspects as well as interviews with POM management and surveys with experts considering two major POME treatment technologies applied in the palm oil industry.

The importance of this study is its contribution in providing an evidence-base for a case study of POME treatment for energy generation, in order to enhance policy decision making. It is crucial to improve the existing policy as it currently fails to portray RE (particularly biogas) as an attractive alternative for the country to move forward as it ventures into RE. In this study, the evidence could encourage policy makers to take into account certain elements in the midst of improving the existing policy, as well as encouraging investors to implement biogas technologies for the remaining POMs with no biogas facilities in Malaysia, taking into account environmental and economic dimensions.

1.6 Thesis Layout

Chapter 1 discussed the background and problem statement of this study. Research goal, objectives, scope and significance of this study were also discussed in Chapter 1.

Chapter 2 discusses all the relevant areas of literature covered in this study. In this chapter, a policy review on energy, POME, characteristics of POME, available treatment technologies of POME, LCA, LCCBA, and previous studies on evidence-based policy are discussed. Lastly, the types of sustainability models are discussed where AHP is discussed in depth.

Chapter 3 presents the research methodology of this study. The overall flow of this study is explained followed by the description of the study site. The data collection methods for life cycle studies as well as the equation involved for emission calculations, and costing calculations are discussed in detail. Lastly, the process flow towards setting the list of possible solutions for policy enhancement through interviews with POM management, a survey with experts and the AHP method to assign weighting for the possible solutions are also explained.

As for Chapter 4, the results and discussions of this study are discussed. Under this chapter, the output of LCA for two different POME treatment technologies are compared and evaluated. Lastly, a sensitivity analysis conducted is presented and critically reflected upon in order to overcome the hotspot of environmental impact.

Chapter 5 further considers economic aspects, which include both LCC and CBA (LCCBA) for the two different POME treatment technologies that are compared. A sensitivity analysis to overcome the hotspot of the economic aspects issue is set out. Lastly, BA to determine minimum annual production of electricity to ensure the company operates at gain is presented.

Chapter 6 sets out the list of possible solutions suggested by the POM management based on the output of life cycle studies which were ranked through a survey with experts. The possible solutions are assigned weights using an AHP. This caters to the policy enhancement of this study based on the final output of the AHP analysis. Lastly, based on the results analysed from this study, conclusions and recommendations for future study and limitations of this study are identified and discussed in Chapter 7.

REFERENCES

Abas, R., Abdullah, R. and Hawari, Y. (2013) ‘Economic Feasibility Study on Establishing an Oil Palm Biogas Plant in Malaysia’, *Oil Palm Industry Economic Journal*, 13(1), 14-21.

Abba, A. H., Noor, Z. Z., Yusuf, R. O., Din, M. F. M. D. and Hassan, M. A. A. (2013) ‘Assessing environmental impacts of municipal solid waste of Johor by analytical hierarchy process’, *Resources, Conservation and Recycling*, 73, 188-196.

Abdulrazik, A., Elsholkami, M., Elkamel, A. and Simon, L. (2017) ‘Multi-products productions from Malaysian oil palm empty fruit bunch (EFB): Analyzing economic potentials from the optimal biomass supply chain’, *Journal of Cleaner Production*, 168, 131-148.

ADB (2018). The Korean Emissions Trading Scheme: Challenges and Emerging Opportunities. Manila, Philippines: Asian Development Bank.

Adebiyi. O., Mohamad, N., Murad, M. A., Hafiz, M. I. M. and Cruz, M. D. (2018) ‘Profiling the promotion of green technology in industry through GTFS’, *Journal of Fundamental and Applied Sciences’,* 10(6S), 2572-2581.

Ahmad, A. L., Chong, M. F., Bhatia, S. and Ismail, S. (2006) ‘Drinking water reclamation from palm oil mill effluent (POME) using membrane technology’, *Desalination*, 191(1-3), 35-44.

Ahmad, A. L., Ismail, S. and Bhatia, S. (2003) ‘Water recycling from palm oil mill effluent (POME) using membrane technology’, *Desalination*, 157(1-3), 87-95.

Ahmad, A. L., Sumathi, S. and Hameed, B. H. (2005) ‘Residual oil and suspended solid removal using natural adsorbents chitosan, bentonite and activated carbon: A comparative study’, *Chemical Engineering Journal*, 108(1-2), 179-185.

Ahmed, W., Nazar, M. F., Ali, S. D., Rana, U. A. and Khan, S. U.-D. (2015a) 'Detailed investigation of optimized alkali catalyzed transesterification of Jatropha oil for biodiesel production', *Journal of Energy Chemistry*, 24(3), 331-336.

Ahmed, Y., Yaakob, Z., Akhtar, P. and Sopian, K. (2015b) 'Production of biogas and performance evaluation of existing treatment processes in palm oil mill effluent (POME)', *Renewable and Sustainable Energy Reviews*, 42, 1260-1278.

Akincilar, A. and Dagdeviren, M. (2014) 'A hybrid multi-criteria decision making model to evaluate hotel websites', *International Journal of Hospitality Management*, 36, 263-271.

Alexander, M. (2012) *Decision-Making using the Analytic Hierarchy Process (AHP) and SAS/IML*, at: http://analytics.ncsu.edu/sesug/2012/SD-04.pdf (Accessed: 9 July 2019).

Alhaji, M. H., Sanaullah, K., Lim, S. -F., Khan, A., Hipolito, C. N., Abdullah, M. O. Bhawani, S. A. and Jamil, T. (2016) 'Photocatalytic treatment technology for palm oil mill effluent (POME) – A review', *Process Safety and Environmental Protection*. 102, 673-686.

Alrawi, R. A., Ahmad, A., Ismail, N. and Kadir, M. O. A. (2011) 'Anaerobic co-digestion of palm oil mill effluent with rumen fluid as a co-substrate', *Desalination*, 269(1-3), 50-57.

Andersson, J., Lundgren, J. and Marklund, M. (2014) 'Methanol production via pressurized entrained flow biomass gasification - Techno-economic comparison of integrated vs. stand-alone production', *Biomass and Bioenergy,* 64, 256-268.

Appels, L., Baeyens, J., Degrève, J. and Dewil, R. (2008) 'Principles and potential of the anaerobic digestion of waste-activated sludge', *Progress in Energy and Combustion Science*, 34(6), 755-781.

Associated Press in Tokyo (2014, July 11) At Least One Injured after Earthquake Hits Japan's Coast Near Fukushima. *The Guardian*. Retrieved December 31, 2019, from https://www.theguardian.com/world/2014/jul/11/person-injured-earthquake-tsunami-japan-fukushima.

Aziz, N. I. H. A., Hanafiah, M, M. and Gheewala, S. H. (2019) 'A review on life cycle assessment of biogas production: Challenges and future perspectives in Malaysia', *Biomass and Bioenergy*, 122, 361-374.

Aziz, N. I. H. A. and Hanafiah, M. M. (2020) 'Life cycle analysis of biogas production from anaerobic digestion of palm oil mill effluent', *Renewable Energy*, 145, 847-857.

Baharuddin, A. S., Hock, L. S., Yusof, M. Z., Rahman, N. A. A., Shah, U. K., Hassan, M. A., Wakisaka, M., Sakai, K. and Shirai, Y. (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*, 9(16), 2427-2436.

Basher, S. A. and Raboy, D. G. (2018) 'The misuse of net present value in energy efficiency standards', *Renewable and Sustainable Energy Reviews*, 96, 218-225.

Begum, S. and Saad, M. F. M. (2013) 'Techno-economic analysis of electricity generation from biogas using palm oil waste', *Asian Journal of Scientific Research*, 6(2), 290-298.

Bello, M. M., Nourouzi, M. M., Abdullah, L. C., Choong, T. S. Y., Koay, Y. S. and Keshani, S. (2013) 'POME is treated for removal of color from biologically treated POME in fixed bed column: Applying wavelet neural network (WNN)', *Journal of Hazardous Materials*, 262, 106-113.

Bello, M. M. and Raman, A. A. A. (2017) 'Trend and current practices of palm oil mill effluent polishing: Application of advanced oxidation processes and their future perspectives', *Journal of Environmental Management*, 198(Pt 1), 170-182.

Bernama (2017, February 1) Malaysia's first carbon credit firm to offset CO_2 emissions. *Free Malaysia Today*. Retrieved February 3, 2020, from https://www.freemalaysiatoday.com/category/nation/2017/02/01/malaysias-first-carbon-credit-firm-to-offset-co2-emissions/.

Bernama (2010, July 16) Subsidy Rationalisation A Bold Step for the Future-Najib. Retrieved Jan 10, 2020, from https://www.kln.gov.my/web/sdn_khartoum/home//asset_publisher/8pPT/blog/subsidy-rationalisation-a-bold-step-for-the-future-%E2%80%93 najib?redirect=%2Fweb%2Fsdn_khartoum%2Fhome.

Benmoussa, K., Laaziri, M., Khoulji, S., Kerbeb, M. L. and Yamami, A. E. (2019) 'AHP-based Approach for Evaluating Ergonomic Criteria', *Procedia Manufacturing*, 32, 856-863.

Blaschke, T., Biberacher, M., Gadocha, S. and Schardinger, I. (2013) ''Energy landscapes': Meeting energy demands and human aspirations', *Biomass and Bioenergy*, 55, 3-16.

Borja, R. and Banks, C. J. (1994) 'Treatment of Palm Oil Mill Effluent by Upflow Anaerobic Filtration', *Journal of Chemical Technology and Biotechnology*, 61, 103-109.

Branche, E. (2017) 'The multipurpose water uses of hydropwer reservoir: The SHARE concept', *Physical Reports*, 18(7-8), 469-478.

Brandenburg, M., Govindan, K., Sarkis, J. and Seuring, S. (2014) 'Quantitative models for sustainable supply chain management: Developments and directions', *European Journal of Operational Research*, 233(2), 299-312.

Bouras, C., Filopoulos, A., Kokkinos, V., Michalopoulos, S., Papadopoulos, D. and Tseliou, G. (2014) 'Policy recommendations for public administrators on free and open source software usage', *Telematics and Informatics*, 31(2), 237-252.

Boyd, E., Hultman, N., Roberts, J. T., Corbera, E., Cole, J., Bozmoski, A., Ebeling, J., Tippman, R., Mann, P., Brown, K. and Liverman, D. M. (2009) 'Reforming the CDM for sustainable development: lessons learned and policy futures', *Envrionmental Science and Policy*, 12(7), 820-831.

Carlini, M., Mosconi, E. M., Castellucci, S., Villarini, M. and Colantoni, A. (2017) 'An Economical Evaluation of Anaerobic Digestion Plants Fed with Organic Agro-Industrial Waste', *Energies*, 10(8), 1165.

Carneiro, M. L. N. M., Pradelle, F., Braga, S. L., Gomes, M. S. P., Martins, A. R. F. A., Turkovics, F. and Pradelle, R. N. C. (2017) 'Potential of biofuels from algae: Comparison with fossil fuels, ethanol and biodiesel in Europe and Brazil through life cycle assessment (LCA)', *Renewable and Sustainable Energy Reviews*, 73, 632-653.

Carvalho, D., Rocha, A., Gomez-Gesteira, M. and Santos, C. S. (2017) 'Offshore winds and wind energy production estimates derived from ASCAT, OSCAT, numerical weather prediction models and buoys - A comparative study for the Iberian Peninsula Atlantic coast', *Renewable Energy*, 102, 433-444.

Castellani, V., Sala, S. and Benini, L. (2017) 'Hotspots analysis and critical interpretation of food life cycle assessment studies for selecting eco-innovation options and for policy support', *Journal of Cleaner Production*, 140, 556-568.

CDM (2008) *CDM Project 2336: Felda Serting Hilir Biogas Power Plant Project*. Malaysia: Clean Development Mechanism, at: http://cdm.unfccc.int/Projects/DB/SGS-UKL1227808382.8/view (Accessed: 2 February 2018).

CDM (2014). Study on Grid Connected Electricity Baselines in Malaysia. Malaysia: Clean Development Mechanism.

Chan, Y. J., Chong, M. -F. and Law, C. -L. (2013) 'Optimization of palm oil mill effluent treatment in an integrated anaerobic-aerobic bioreactor', *Sustainable Environment Research*, 23(3), 153-170.

Chan, Y. H., Tan, R. R., Yusup, S., Lam, H. L. and Quitain, A. T. (2016) 'Comparative life cycle assessment (LCA) of bio-oil production from fast pyrolysis and hydrothermal liquefaction of oil palm empty fruit bunch (EFB)', *Clean Technologies and Environmental Policy*, 18(6), 1759-1768.

Chatri, F., and Yahoo, M. (2015) Economic Analysis of Gas - Subsidy reform and FiT Mechanism in the Malaysian Electricity Sector: Based on the CGE Model. *Proceedings of the 33rd International Association for Energy Economics.* 25-28 October. Pittsburgh, US: IAEE.

Chatri, F., Yahoo, M. and Othman, J. (2018) 'The economic effects of renewable energy expansion in the electricity sector: A CGE analysis for Malaysia', *Renewable and Sustainable Energy Reviews,* 95, 203-216.

Chatterjee, R., Sharma, V., Mukherjee, S. and Kumar, S. (2014) 'Life Cycle Assessment of Bio-diesel Production- A Comparative Analysis', *Journal of The Institution of Engineers (India): Series C*, 95(2), 143-49.

Chattopadhyay, D. and Jha, S. (2014) 'The Impact of Energy Subsidies on the Power Sector in Southeast Asia', *The Electricity Journal*, 27(4), 70-83.

Choo, E. U., Schoner, B. and Wedley, W. C. (1999) 'Interpretation of criteria weights in multicriteria decision making', *Computers and Industrial Engineering*, 37, 527-541.

Choong, Y. Y., Chou, K. W. and Norli, I. (2018) 'Strategies for improving biogas production of palm oil mill effluent (POME) anaerobic digestion: A critical review', *Renewable and Sustainable Energy Reviews*, 82, 2993-3006.

Chow, M. C. (1991) *Palm oil mill effluent analysis*. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, pp. 11-18.

Clement, S., Watt, J. and Semple, A. (2016) *The Procura+ Manual : A Guide to Implementing Sustainable Procurement*. (3rd ed.) Freiburg, Germany: Local Governments for Sustainability, European Secretariat.

Connaughton, S., Collins, G. and O'Flaherty, V. (2006) 'Psychrophilic and mesophilic anaerobic digestion of brewery effluent: A comparative study', *Water Research*, 40(13), 2503-2510.

Crawford, R. H., Bontinck, P. -A., Stephan, A., Wiedmann, T. and Yu, M. (2018) 'Hybrid life cycle inventory methods – A review', *Journal of Cleaner Production*, 172, 1273-1288.

Daniel, S. E., Tsoulfas, G. T., Pappis, C. P. and Rachaniotis, N. P. (2004) 'Aggregating and evaluating the results of different Environmental Impact Assessment methods', *Ecological Indicators*, 4(2), 125-138.

Daud, M. K., Rizvi, H., Akram, M. F., Ali, S., Rizwan, M., Nafees, M. and Jin, Z. S. (2018) 'Review of Upflow Anaerobic Sludge Blanket Reactor Technology: Effect of Different Parameters and Developments for Domestic Wastewater Treatment', *Journal of Chemistry*, 1-13.

Davis, L., M. and Cornwell, A., D. (2013) *Introduction to Environmental Engineering*. (5th ed.) New York: Mc-Graw Hill Education.

Dhillon, B. S. (2010) *Life Cycle Costing for Engineers*. New York: CRC Press Taylor & Francis Group.

Dickoff, J., James, P. and Wiedenbach, E. (1968) 'Theory in a practice discipline. Part 1 practice-oriented theory', *Nursing Research*, 17(5), 415-434.

Dissanayake, S., Mahadevan, R. and Asafu-Adjaye, J. (2020) 'Evaluating the efficiency of carbon emissions policies in a large emitting developing country', *Energy Policy*, 136, 111080.

DOE (2010) *Environmental requirements: A guide for investors*. Putrajaya, Malaysia: Department of Environment.

Doorn, M. R. J., Towprayoon, S., Vieira, S. M. M., Irving, W., Palmer, C., Pipatti, R. and Wang, C. (2006) *Wastewater treatment and discharge in IPCC Guidelines for National Greenhouse Gas Inventories.* Hayama, Japan: Institute for Global Environmental Strategies.

DOSH (2016) *Guidelines on Occupational Safety and Health in Construction, Operation and Maintenance of biogas plant*. Malaysia: Department of Occupational Safety and Health Malaysia.

EC (2016) *Malaysia Energy Statistics Handbook*. Putrajaya, Malaysia: Energy Commission.

Eggleston, H. S., Buendia, L., Miwa, K., Ngara, T. and Tanabe, K. (2006) IPCC Guidelines For National Greenhouse Gas Inventories, Japan.

EIA (2012) *Country Brief Analysis: Japan.* Washington, DC: Energy Information Administration.

EPD (2011) *Guidelines for minimising impacts of oil palm plantations and palm oil mills on quality of rivers in Sabah*. Kota Kinabalu, Sabah: Environment Protection Department.

EQA (1974) *Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations* 1977. Malaysia: Environmental Quality Act.

Eshun, J. F., Apori, S. O. and Oppong-Anane, K. (2011) 'Environmental system analysis of tomato production in Ghana', *African Crop Science Journal*, 19(3), 165-172.

Fang, C., O-Thong, S., Boe, K. and Angelidaki, I. (2011) 'Comparison of UASB and EGSB reactors performance, for treatment of raw and deoiled palm oil mill effluent (POME)', *Journal of Hazardous Materials*, 189(1-2), 229-234.

Farjana, S. H., Huda, N., Mahmud, M. A. P. and Saidur, R. (2018) 'Solar process heat in industrial systems - A global review', *Renewable and Sustainable Energy Reviews,* 82, 2270-2286.

Fernández-Tirado, F., Parra-López, C. and Romero-Gámez, M. (2016) 'Life cycle assessment of biodiesel in Spain: Comparing the environmental sustainability of Spanish production versus Argentinean imports', *Energy for Sustainable Development*, 33, 36-52.

Finnveden, G. and Moberg, A. (2005) 'Environmental systems analysis tools – an overview', *Journal of Cleaner Production*, 13(12), 1165–1173.

Foo, D. C. Y. and Aziz, M. K. T. A. (2019) *Green Technologies for the Oil Palm Industry*. Singapore: Springer.

Gan, P. Y. and Li, Z. (2008) 'An econometric study on long-term energy outlook and the implications of renewable energy utilization in Malaysia', *Energy Policy,* 36(2), 890-899.

Garcia-Nunez, J. A., Rodriguez, D. T., Fontanilla, C. A., Ramirez, N. E., Lora, E. E. S., Frear, C. S., Stockle, C., Amonette, J. and Garcia-Perez, M. (2016) 'Evaluation of alternatives for the evolution of palm oil mills into biorefineries', *Biomass and Bioenergy,* 95, 310-329.

Georgatzi, V. V., Stamboulis, Y. and Vetsikas, A. (2020) ' Examining the determinants of CO_2 emissions caused by the transport sector: Empirical evidence from 12 European countries', *Economic Analysis and Policy,* 65, 11-20.

Ghimire, L. P. and Kim, Y. (2018) 'An analysis on barriers to renewable energy development in the context of Nepal using AHP', *Renewable Energy*, 129, 446-456.

Global Energy (2019a) *Total energy consumption,* at: https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html (Accessed: 31 December 2018).

Global Energy (2019b) *Share of renewables in electricity production,* at: https://yearbook.enerdata.net/renewables/renewable-in-electricity-production-share.html (Accessed: 31 December 2018).

Goepel, K. (2014) *BPMSG's AHP Online System. Rational Decision Making Made Easy,* at: https://bpmsg.com/ahp/docs/BPMSG-AHP-OS 2019-11-20.pdf (Accessed: 20 November 2019).

Goh, C. S., Tan, K. T., Lee, K. T. and Bhatia, S. (2010) 'Bio-ethanol from lignocellulose: Status, perspectives and challenges in Malaysia', *Bioresource Technology*, 101(13), 4838-4841.

Habibzadeh-Bigdarvish, O., Yu, X., Lei, G., Li, T. and Puppala, A. J. (2019) 'Life-Cycle cost-benefit analysis of Bridge deck de-icing using geothermal heat pump system: A case study of North Texas', *Sustainable Cities and Society,* 47, 101492.

Hadi, P., Xu, M., Ning, C., Lin, C. S. K. and McKay, G. (2015) 'A critical review on preparation, characterization and utilization of sludge-derived activated carbons for wastewater treatment', *Chemical Engineering Journal*, 260, 895-906.

Hanafiah, M. M., Ali, M. Y. M., Izzatina, A. A. N., Ashraf, M. A., Halim, A. A., Lee, K. E. and Idris, M. (2017) 'Biogas production from goat and chicken manure in Malaysia', *Applied Ecology and Environmental Research*, 15(3), 529–535.

Hanaki, K. and Portugal-Pereira, J. (2018) 'The Effect of Biofuel Production on Greenhouse Gas Emission Reductions: Holistic Perspectives for Policy-making', *Biofuels and Sustainability*. 53-71.

Harahap, F., Silveira, S. and Khatiwada, D. (2019) 'Cost competitiveness of palm oil biodiesel production in Indonesia', *Energy*, 170, 62-72.

Harsono, S. S., Grundmann, P. and Siahaan, D. (2015) Role of biogas and biochar palm oil residues for reduction of greenhouse gas emissions in the biodiesel production. *3rd International Conference on New, Renewable Energy and Energy Conservation*. 4-6 June. Jakarta, Indonesia: EBTKE-ConEx, 344-351.

Hashim, H. and Ho, W. S. (2011) 'Renewable energy policies and initiatives for a sustainable energy future in Malaysia', *Renewable and Sustainable Energy Reviews*, 15(9), 4780-4787.

Hatvani-Kovacs, G., Bush, J., Sharifi, E. and Boland, J. (2018) 'Policy recommendations to increase urban heat stress resilience', *Urban Climate*, 25, 51-63.

Hoogmartens, R., Passel, S. V., Acker, K. V. and Dubois, M. (2014) 'Bridging the gap between LCA, LCC and CBA as sustainability assessment tools', *Environmental Impact Assessment Review*, 48, 27-33.

Hu, Y., Ren, S., Wang, Y. and Chen, X. (2020) 'Can carbon emission trading scheme achieve energy conservation and emission reduction? Evidence from the industrial sector in China', *Energy Economics*, 85, 104590.

Ibrahim, P. and Ali, M. (2014) 'Foreign Direct Investment Affluences in Iskandar Malaysia', *International Journal of Management and Sustainability*, 3(2), 72-83.

IEA (2016) *Energy and air pollution*. Paris, France: International Energy Agency.

Igoni, A. H., Abowei, M. F. N., Ayotamuno, M. J. and Eze, C. L. (2007) 'Effect of total solids concentration of municipal solid waste in anaerobic batch digestion on the biogas produced', *Journal of Food, Agriculture and Environment*, 5(2), 333–337.

Igoni, A. H., Abowei, M. F. N., Ayotamuno, M. J. and Eze, C. L. (2008) 'Comparative Evaluation of Batch and Continuous Anaerobic Digesters in Biogas Production from Municipal Solid Waste using Mathematical Models', *Agricultural Engineering International CIGR Journal*, 10, 1–12.

INDC (2015) *Intended Nationally Determined Contribution of the Government of Malaysia*. Malaysia: Intended Nationally Determined Contribution.

IPCC (2014) *Climate Change 2014: Synthesis Report*. Geneva, Switzerland: Intergovernmental Panel on Climate Change:

Irmak, S. (2019) *Challenges of Biomass Utilization for Biofuels*. Biomass for Bioenergy-Recent Trends and Future Challenges. IntechOpen.

Ishizaka, A. and Nemery, P. (2013) *Multi-criteria decision analysis: methods and software*. United Kingdom: John Wiley & Sons.

Iskandar, M. J., Baharum, A., Anuar, F. H. and Othaman, R. (2018) 'Palm oil industry in South East Asia and the effluent treatment technology—A review', *Environmental Technology & Innovation*, 9, 169-185.

Islam, M. T., Huda, N. and Saidur, R. (2019) 'Current energy mix and techno-economic analysis of concentrating solar power (CSP) technologies in Malaysia', *Renewable Energy*, 140, 789-806.

Jato-Espino, D., Castillo-Lopez, E., Rodriguez-Hernandez, J. and Canteras-Jordana, J. C. (2014) 'A review of application of multi-criteria decision making methods in construction', *Automation in Construction*, 45, 151-162.

Jeon, J. W., Wang, Y. and Yeo, G. T. (2016) 'Ship Safety Policy Recommendations for Korea: Application of System Dynamics', *The Asian Journal of Shipping and Logistics*, 32(2), 73-79.

Jeswani, H. K., Azapagic, A., Schepelmann, P. and Ritthoff, M. (2010) 'Options for broadening and deepening the LCA approaches', *Journal of Cleaner Production*, 18(2), 120-127.

Ji, C. M., Eong, P. P., Ti, T. B., Seng, C. E. and Ling, C. K. (2013) 'Biogas from palm oil mill effluent (POME): Opportunities and challenges from Malaysia's perspective', *Renewable and Sustainable Energy Reviews*, 717-726.

Jiang, J., Xie, D., Ye, B., Shen, B. and Chen, Z. (2016) 'Research on China’s cap-and-trade carbon emission trading scheme: Overview and outlook', *Applied Energy*, 178, 902–917.

JKR (2015) *Schedule of Rates*. Malaysia: Jabatan Kerja Raya.

JKR (2016) *Schedule of Rates for Building Works in Sarawak*. Sarawak, Malaysia: Jabatan Kerja Raya.

Jones, G. A. and Warner, K. J. (2016) 'The 21st century population-energy-climate nexus', *Energy Policy*, 93, 206-212.

Kabir, E., Kumar, P., Kumar, S., Adelodun, A. A. and Kim, K. -H. (2018) 'Solar energy: Potential and future prospects', *Renewable and Sustainable Energy Reviews*, 82, 894-900.

Kameyama, Y., Morita, K. and Kubota, I. (2016) 'Finance for achieving low-carbon development in Asia: the past, present, and prospects for the future', *Journal of Cleaner Production,* 128, 201-208.

Kamyab, H., Chelliapan, S., Din, M. F. M., Rezania, S., Khademi, T. and Kumar, A. (2018) *Palm oil mill effluent as an environmental pollutant* in Palm oil. Malaysia: IntechOpen, pp. 13-28.

Kaplan, Y. A. (2015) 'Overview of wind energy in the world and assessment of current wind energy policies in Turkey', *Renewable and Sustainable Energy Reviews*, 43, 562-568.

Karasick, A. S. and Peik, S. (2017) 'The American College of Preventive Medicine Policy Recommendations on Public Health Funding', *American Journal of Preventive Medicine,* 53(6), 928-930.

Kasivisvanathan, H., Ng, R. T. L., Tay, D. H. S. and Ng, D. K. S. (2012) 'Fuzzy optimisation for retrofitting a palm oil mill into a sustainable palm oil-based integrated biorefinery', *Chemical Engineering Journal*, 200-202, 694-709.

Khadaroo, S. N. B. A., Grassia, P., Gouwanda, D. and Poh, P. E. (2019) 'Is the dewatering of Palm Oil Mill Effluent (POME) feasible? Effect of temperature on POME's rheological properties and compressive behaviour', *Chemical Engineering Science*, 202, 519-528.

Khairuddin, M. N., Zakaria, A. J., Isa, I. Md. Jol, H., Rahman, W. M. N. W. A. and Salleh, M. K. S. (2016) 'The potential of treated palm oil mill effluent (pome) sludge as an organic fertilizer', *AGRIVITA Journal of Agricultural Science,* 38(2), 142-154.

Kheang, L. S., Dazhi, L. L., Sukiran, M. A. and May. C. Y. (2011) A biogas traping facility for handling palm oil mill effluent (POME). *MPOB Information Series*, 491.

Khemkhao, M., Techkarnjanaruk, S. and Phalakornkule, C. (2015) 'Simultaneous treatment of raw palm oil mill effluent and biodegradation of palm fiber in a high-rate CSTR', *Bioresource Technology*, 177, 17-27.

Kumaran, P., Hephzibah, D., Sivasankari, R., Saifuddin, N. and Shamsuddin, A. H. (2016) 'A review on industrial scale anaerobic digestion systems deployment in Malaysia: Opportunities and challenges', *Renewable and Sustainable Energy Reviews*, 56, 929-940.

Lansche, J. and Muller, J. (2017) 'Life cycle assessment (LCA) of biogas versus dung combustion household cooking systems in developing countries- A case study in Ethiopia', *Journal of Cleaner Production*, 165, 828-835.

Lee, Y. -M. and Ding, C. -Y. (2000) 'Life - cycle assessment and production policy: An application to corrugated paperboard manufacture', *Journal of Environmental Management*, 59(2), 157-165.

Lee, Z. S., Chin, S. Y., Lim, J. W., Witoon, T. and Cheng, C. K. (2019) 'Treatment technologies of palm oil mill effluent (POME) and olive mill wastewater (OMW): A brief review', *Environmental Technology & Innovation*, 15, 100377.

Lettinga, G., Rebac, S. and Zeeman, G. (2001) 'Challenge of psychrophilic anaerobic wastewater treatment', *Trends in Biotechnology*, 19(9), 363-370.

Li, K., Bian, H., Liu, C., Zhang, D. and Yang, Y. (2015) 'Comparison of geothermal with solar and wind power generation systems', *Renewable and Sustainable Energy Reviews*, 42, 1464-1474.

Li, Y., Chen, Y. and Wu, J. (2019) 'Enhancement of methane production in anaerobic digestion: A review', *Applied Energy*, 240, 120-137.

Lim, X. -L. and Lam, W. -H. (2014) 'Review on Clean Development Mechanism (CDM) implementation in Malaysia', *Renewable and Sustainable Energy Reviews*, 29, 276-285.

Liu, X., Zhou, D., Zhou, P. and Wang, Q. (2018) 'Factors driving energy consumption in China: A joint decomposition approach', *Journal of Cleaner Production*, 172, 724-734.

Locks, M. O. (1978) Maintainability and life cycle costing. *Proceeding of the Annual Reliability and Maintainability Symposium*. 17-19 January. Los Angeles, California: IEEE, 251-253.

Loh, S. K., Nasrin, A. B., Mohamad, A. S., Nurul, A. B., Muzzammil, N., Daryl, J. T. and Stasha, E. R. A. (2017a) Biogas Capture - A Means of Reducing Greenhouse Gas Emissions from Palm Oil Mill Effluent. *Oil Palm Bulletin*, 75, 27-36.

Loh, S. K. (2017b) 'The potential of the Malaysian oil palm biomass as a renewable energy source', *Energy Conversion and Management*, 141, 285-298.

Lopez-Behar, D., Tran, M., Froese, T., Mayaud, J. R., Herrera, O. E. and Merida, W. (2019) 'Charging infrastructure for electric vehicles in Multi-Unit Residential Buildings: Mapping feedbacks and policy recommendations', *Energy Policy*, 126, 444-451.

Lorenzi, G., Gorgoroni, M., Silva, C. and Santarelli, M. (2018) Life Cycle Assessment of biogas upgrading routes. *10th International Conference on Applied Energy*. 22-25 August. Hong Kong, China: ICAE, 2012-2018.

Ma, Q. and Wang, P. (2020) 'Underground solar energy storage via energy piles', *Applied Energy*, 261, 114361.

Marchionni, C. and Reijula, S. (2019) 'What is mechanistic evidence, and why do we need it for evidence-based policy?', *Studies in History and Philosophy of Science Part A*, 73, 54-63.

Marcia, C. S. d. M., Hugo, G. D'. V., André, F. Y., Fernando, L. P. P. and Andrea, M. S. (2017) 'Life cycle assessment of biodiesel produced by the methylic-alkaline and ethylic-enzymatic routes', *Fuel*, 208, 329-336.

Martins, F., Felgueiras, C. and Smitková, M. (2017) 'Mathematical modelling of Portuguese hydroelectric energy system', *Energy Procedia*, 136, 213-218.

Martiskainen, M. and Kivimaa, P. (2018) 'Creating innovative zero carbon homes in the United Kingdom—Intermediaries and champions in building projects', *Environmental Innovation and Societal Transitions*, 26, 15-31.

Marquardt, J. (2014) 'A Struggle of Multi-level Governance: Promoting Renewable Energy in Indonesia', *Energy Procedia*, 58, 87-94.

McGowan, J. E., Naranian, T. and Johnston, L. (2017) 'Kangaroo Care in the high-technology neonatal unit: Exploring evidence-based practice, policy recommendations and education priorities in Northern Ireland', *Journal of Neonatal Nursing*, 23(4), 174-179.

MGTC (2019) *Guidelines for Green Technology Tax Incentive*. Malaysia: Malaysian Green Technology Corporation.

MoF (2014) *The 2014 Budget*. Putrajaya, Malaysia: Ministry of Finance Malaysia.

MoF (2019) *2019 Budget*. Putrajaya, Malaysia: Ministry of Finance Malaysia.

Monson, K. D., Esteves, S. R., Guwy, A. J. and Dinsdale, R. M. (2007) 'Anaerobic Digestion of Biodegradable Municipal Wastes: A Review', University of Glamorgan: Sustainable Envrionment Research Centre, pp. 1-131.

MPOB (2014) *Oil Palm & The Environment*. Selangor, Malaysia: Malaysian Palm Oil Board at: http://www.mpob.gov.my/palm-info/environment/520-achievements#Mill (Accessed: 3 February 2018).

MPOB (2018a) *Malaysian oil palm statistics 2017*. (37th ed). Bangi, Malaysia: Malaysian Palm Oil Board, pp. 205.

MPOB (2018b) *Criteria and Guidelines on MPOB License Application*. Selangor, Malaysia: Malaysian Palm Oil Board at: https://elesen.mpob.gov.my/document/CRITERIA%20AND%20GUIDELINES%20ON%20MPOB%20LICENSE%20APPLICATION%20cetakan%202018%20ENGLISH.pdf (Accessed: 17 December 2019).

Najafpour, G. D., Zinatizadeh, A. A. L., Mohamed, A. R., Isa, M. H. and Nasrollahzadeh, H. (2006) 'High-rate anaerobic digestion of palm oil mill effluent in an upflow anaerobic sludge-fixed film bioreactor', *Process Biochemistry*, 41(2), 370-379.

Nasution, M. A., Wibawa, D. S., Ahamed, T. and Noguchi, R. (2018a) 'Selection of palm oil mill effluent treatment for biogas generation or compost production using an analytical hierarchy process', *Journal of Material Cycles and Waste Management*, 20(2), 789–799.

Nasution M. A., Wibawa, D. S., Ahamed, T. and Noguchi, R. (2018b) 'Comparative environmental impact evaluation of palm oil mill effluent treatment using a life cycle assessment approach: A case study based on composting and a combination for biogas technologies in North Sumatera of Indonesia', *Journal of Cleaner Production*, 184, 1028-1040.

Nazari-Heris, M., Mohammadi-Ivatloo, B. and Gharehpetian, G. B. (2017) 'Short-term scheduling of hydro-based power plants considering application of heuristic algorithms: A comprehensive review', *Renewable and Sustainable Energy Reviews*, 74, 116-129.

Nelson, T., Nelson, J., Ariyaratnam, J. and Camroux, S. (2013) 'An analysis of Australia's large scale renewable energy target: Restoring market confidence', *Energy Policy*, 62, 386–400.

Ngyuyen, D. H., Chapman, A. and Farabi-Asl, H. (2019) 'Nation-wide emission trading model for economically feasible carbon reduction in Japan', *Applied Energy*, 255, 113869.

NKEA (2014) Biogas Capture and CDM Project Implementation for Palm Oil Mills. Malaysia: National Key Economic Areas.

Norfadilah, N., Raheem, A., Harun, R. and Ahmadun, F. R. (2016) 'Bio-hydrogen production from palm oil mill effluent (POME): A preliminary study', *International Journal of Hydrogen Energy*, 41(28), 11960-11964.

NRE (2005) Clean Development mechanism process in Malaysia. Putrajaya, Malaysia: Conservation and Environmental Management Division, Ministry of Natural Resources and Environment.

Oh, T. H., Hasanuzzaman, Md., Selvaraj, J., Teo, S. C. and Chua, S. C. (2018) 'Energy policy and alternative energy in Malaysia: Issues and challenges for sustainable growth – An update', *Renewable and Sustainable Energy Reviews*, 81, 3021-3031.

Ohimain, E. I. and Izah, S. C. (2014a) 'Potential of biogas production from palm oil mills' effluent in Nigeria', *Sky Journal of Soil Science and Environmental Management*, 3(5), 50–58.

Ohimain, E. I. and Izah, S. C. (2014b) 'Estimation of potential electrical energy and currency equivalent from un-tapped palm oil mill effluents in Nigeria', *International Journal of Farming and Allied Sciences*, 3(8), 855–862.

Ohimain, E. I. and Izah, S. C. (2017) 'A review of biogas production from palm oil mill effluents using different configurations of bioreactors', *Renewable and Sustainable Energy Reviews*, 70, 242-253.

Ong, H. C., Mahlia, T. M. I., Masjuki, H. H. and Honnery, D. (2012) 'Life cycle cost and sensitivity analysis of palm biodiesel production', *Fuel*, 98, 131-139.

Oshegale, S. D., Mohamed, A. F. and Chikere, A. O. (2017) 'Status Evaluation of Palm Oil Waste Management Sustainability in Malaysia', *OIDA International Journal of Sustainable Development*, 10(12), 41-48.

Ou, X., Zhang, X. and Chang, S. (2010) 'Alternative fuel buses currently in use in China: Life-cycle fossil energy use, GHG emissions and policy recommendations', *Energy Policy*, 38(1), 406-418.

Oyenuga, A. (2016). *Economic and Environmental Impact Assessment of Construction and Demolition Waste Recycling and Reuse using LCA and MCDA Management Tools*. PhD Thesis, London South Bank University.

Ozcan, M. (2019) 'Factors influencing the electricity generation preferences of turkish citizens: Citizens' attitudes and policy recommendations in the context of climate change and environmental impact', *Renewable Energy,* 132, 381-393.

Ozkan, C. and Mayo, T. (2019) 'The renewable wave energy resource in coastal regions of the Florida peninsula', *Renewable Energy,* 139, 530-537.

Ozturk, M., Saba, N., Altay, V., Iqbal, R., Hakeem, K. R., Jawaid, M. and Ibrahim, F. H. (2017) 'Biomass and bioenergy: An overview of the development potential in Turkey and Malaysia', *Renewable and Sustainable Energy Reviews*, 79, 1285-1302.

Pan, W. and Pan, M. (2019) 'Opportunities and risks of implementing zero-carbon building policy for cities: Hong Kong case', *Applied Energy,* 256, 113835.

Park, C. S., Kumar, P. and Kumar, N. (2004) *Fundamentals of Engineering Economics*, US: Pearson/Prentice Hall.

Parliament of Malaysia (2001) *Energy Commission Act 2001.* Act 610.

Parliament of Malaysia (2011) *Renewable Energy Act 2011.* National Renewable Energy Policy, Act 725.

Parliament of Malaysia (2017) *Income Tax Act 1967.* Act 53.

Payán, D. D. and Lewis, L. B. (2019) 'Use of research evidence in state health policymaking: Menu labeling policy in California', *Preventive Medicine Reports*, 16, 101004.

Peche, R. and Rodríguez, E. (2009) 'Environmental impact assessment procedure: A new approach based on fuzzy logic', *Environmental Impact Assessment Review,* 29(5), 275-283.

Perez, M., Romero, L. I. and Sales, D. (2001) 'Organic Matter Degradation Kinetics in an Anaerobic Thermophilic Fluidised Bed Bioreactor', *Anaerobe,* 7(1), 25-35.

Petinrin, J. O. and Shaaban, M. (2015) 'Renewable energy for continuous energy sustainability in Malaysia', *Renewable and Sustainable Energy Reviews*, 50, 967-981.

Petrillo, A., Felice, F. D., Jannelli, E., Autorino, C., Minutillo, M. and Lavadera, A. L. (2016) 'Life cycle assessment (LCA) and life cycle cost (LCC) analysis model for a stand-alone hybrid renewable energy system', *Renewable Energy*, 95, 337-355.

Pizzol, M., Laurent, A., Sala, S., Weidema, B., Verones, F. and Koffler, C. (2017) 'Normalisation and weighting in life cycle assessment: *qou vadis*?', *International Journal of Life Cycle Assessment,* 22, 853-866.

Poh, P. E. and Chong, M. F. (2009) 'Development of anaerobic digestion methods for palm oil mill effluent (POME) treatment', *Bioresource Technology*, 100(1), 1-9.

Poh, P. E. and Chong, M. F. (2014) 'Upflow anaerobic sludge blanket-hollow centered packed bed (UASB-HCPB) reactor for thermophilic palm oil mill effluent (POME) treatment', *Biomass and Bioenergy*, 67, 231-242.

PTM (2002) *Malaysia's energy scenario*. Malaysia: Pusat Tenaga Malaysia, pp. 1-64.

PWC (2019) *TaXavvy Budget 2020* (ed. Part 1). Malaysia: PricewaterhouseCoopers.

Rahim, K. A. and Liwan, A. (2012) 'Oil and gas trends and implications in Malaysia', *Energy Policy*, 50, 262-271.

Raman, S. S., Noor, Z. Z., Narolhisa, S. S. S., Chong, C. S. and Stringer, L. C. (2019) 'Energy Generation from Palm Oil Mill Effluent (POME): The Environmental Impact Perspective', *Chemical Engineering Transactions*, 72, 25-30.

Rathi, R., Prakash, C., Singh, S., Krolczyk, G. and Pruncu, C. I. (2020) 'Measurement and analysis of wind energy potential using fuzzy based hybrid MADM approach', *Energy Reports*, 6, 228-237.

Reiche, H. (1980) 'Life cycle cost' in Arsenault, J. E., and Roberts, J. A. (Ed.) *Reliability and maintanability of electronic systems* (pp. 3-23). Potomac, MD: Computer Science Press.

Ripley, W., Ogura, J. and Griffiths, J (2016, March 11) Fukushima: Five Years after Japan's Worst Nuclear Disaster. *CNN*. Retrieved Jan 31, 2019, from https://edition.cnn.com/2016/03/08/asia/fukushima-five-year-anniversary/index.html.

Rooyen, R. M. v., Pretorius, B., Tembani, N. M. and Ham-Baloyi, W. t. (2017) 'Evidence-based recommendations to facilitate professional collaboration between allopathic and traditional health practitioners', *Health SA Gesondheid,* 22, 291-299.

RSPO (2018) Principles and Criteria for the Production of Sustainable Palm Oil. Malaysia: Roundtable on Sustainable Palm Oil.

Saaty, R. W. (1987) 'The analytic hierarchy process-what it is and how it is used', *Mathematical Modelling,* 9(3-5), 161-176.

Saaty, T. L. (2000) *Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process*. New York: RWS Publications.

Saavedra, M. R. M., Fontes, C. H. d. O. and Freires, F. G. M. (2018) 'Sustainable and renewable energy supply chain: A system dynamics overview', *Renewable and Sustainable Energy Reviews*, 82, 247-259.

Sabeen, A. H., Noor, Z. Z., Ngadi, N., Almuraisy, S. and Raheem, A. B. (2018) 'Quantification of Environmental Impacts of Domestic Wastewater Treatment using Life Cycle Assessment: A Review', *Journal of Cleaner Production*, 190, 221-233.

Sahu, B. K. (2018) 'Wind energy developments and policies in China: A short review', *Renewable and Sustainable Energy Reviews*, 81, 1393-1405.

Santosa, S. J. (2008) 'Palm Oil Boom in Indonesia: From Plantation to Downstream Products and Biodiesel', *CLEAN - Soil, Air, Water*, 36(5-6), 453-465.

Saydut, A., Erdogan, S., Kafadar, A. B., Kaya, C., Aydin, F. and Hamamci, C. (2016) 'Process optimization for production of biodiesel from hazelnut oil, sunflower oil and their hybrid feedstock', *Fuel*, 183, 512-517.

Schmidt, M. and Crawford, R. H. (2017) 'Developing an Integrated Framework for Assessing the Life Cycle Greenhouse Gas Emissions and Life Cycle Cost of Buildings', *Procedia Engineering*, 196, 988-995.

SEDA (2018) *FiT Rates for Biogas*. Malaysia: Sustainable Energy Development Authority, at: http://www.seda.gov.my (Accessed: 11 December 2018).

SEDA (2019) *The Net Energy Metering*. Malaysia: Sustainable Energy Development Authority, at: http://www.seda.gov.my/reportal/nem/ (Accessed: 23 November 2019).

Seider, D., W, Seader, J. D., Lewin, R., D. and Widagdo, S. (2010) *Product and Process Design Principle*. (3rd ed.) United States: John Wiley & Sons, Inc.

Shafie, S. M., Mahlia, T. M. I., Masjuki, H. H. and Andriyana, A. (2011) 'Current energy usage and sustainable energy in Malaysia: A review', *Renewable and Sustainable Energy Reviews*, 15(9), 4370-4377.

Shomali, A. and Pinkse, J. (2016) 'The consequences of smart grids for the business model of electricity firms', *Journal of Cleaner Production*, 112, 3830-3841.

Singh, A. K. and Parida, S. K. (2013) 'Evaluation of current status and future directions of wind energy in India. *Clean Technologies and Environmental Policies*, 15(4), 643-655.

Sinha, K. C. and Labi, S. (2007). *Transportation Decision Making: Principles of Project Evaluation and Programming*. Wiley.

Song, Q., Li, J., Duan, H., Yu, D. and Wang, Z. (2017) 'Towards to sustainable energy-efficient city: A case study of Macau', *Renewable and Sustainable Energy Reviews*, 75, 504-514.

Stichnothe, H. and Schuchardt, F. (2010) 'Comparison of different treatment options for palm oil production waste on a life cycle basis', *The International Journal of Life Cycle Assessment*, 15(9), 907-915.

Stordahl, N. C. and Short, J. L. (1968) The impact and structure of life cycle costing. *Proceedings of the Annual Symposium on Reliability*. 16-18 January. Boston, Massachusetts: IEEE, 509-515.

Sue, T. T. and Pantzaris, T.P. (2017) *Energy from oil palm biomass.* Pocketbook of oil palm uses. Malaysia: Malaysian Palm Oil Board. pp. 139.

Sun, X., Huang, D. and Wu, G. (2012) 'The current state of offshore wind energy technology development', *Energy*, 41(1), 298-312.

Svatoňová, T., Herák, D. and Kabutey, A. (2015) 'Financial Profitability and Sensitivity Analysis of Palm Oil Plantation in Indonesia', *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 63(4), 1365-1373.

Tabassum, S., Zhang, Y. and Zhang, Z. (2015) 'An integrated method for palm oil mill effluent (POME) treatment for achieving zero liquid discharge – A pilot study', *Journal of Cleaner Production*, 95, 148-155.

Talaat, M., Farahat, M. A. and Elkholy, M. H. (2019) 'Renewable power integration: Experimental and simulation study to investigate the ability of integrating wave, solar and wind energies', *Energy,* 170, 668-682.

Tan, Y and Lim, J. S. (2019) ' Feasibility of palm oil mill effluent elimination towards sustainable Malaysian palm oil industry', *Renewable and Sustainable Energy Reviews*, 111, 507-522.

Theo, W. L., Lim, J. S., Ho, W. S., Hashim, H. and Lee, C. T. (2017) 'Review of distributed generation (DG) system planning and optimisation techniques: Comparison of numerical and mathematical modelling methods', *Renewable and Sustainable Energy Reviews*, 67, 531-573.

TNB (2014) Electricity tariff schedule. Malaysia: Tenaga Nasional Berhad. Retrieved July 13, 2019, from https://www.tnb.com.my/assets/files/Tariff_Rate_Final_01.Jan.2014.pdf.

TNB (2019) *Renewable Energy Fund*. Malaysia: Tenaga Nasional Berhad. Retrieved December 17, 2019, from https://www.tnb.com.my/kumpulan-wang-tenaga-boleh-baharu-kwtbb.

Toklu, E. (2017) 'Biomass energy potential and utilization in Turkey', *Renewable Energy*, 107, 235-244.

Tong, S. L. and Jaafar, A. B. (2004) *Waste to Energy: Methane Recovery from Anaerobic Digestion of Palm Oil Mill Effluent*. Selangor, Malaysia: Malaysia Energy Centre.

Tsorakidis, N., Papadopoulos, S., Zerres, M., and Zerres, C. (2011) *Break-Even Analysis*. Kenyatta University Library: Bookboon.

TSP (2014) *Breakdown of Energy Production Statistics*. The Shift Project, at: http://www.tsp-data-portal.org/Breakdown-of-Energy-Production-Statistics#tspQvChart (Accessed: 20 May 2018).

Uemura, Y., Sellappah, V., Trinh, T. H., Hassan, S. and Tanoue, K. -i. (2017) 'Torrefaction of empty fruit bunches under biomass combustion gas atmosphere', *Bioresource Technology*, 243, 107-117.

Umar, M. S., Urmee, T. and Jennings, P. (2018) ' A policy framework and industry roadmap model for sustainable oil palm biomass electricity generation in Malaysia', *Renewable Energy*, 128, 275-284.

UNFCCC (2015) *Adoption of the Paris Agreement*. Geneva, Switzerland: United Nations Framework Convention on Climate Change.

UNFCCC (2017) *CDM Methodology Booklet*. United Nations Framework Convention on Climate Change. Retrieved June 20, 2018, from https://cdm.unfccc.int/methodologies/documentation/meth_booklet.pdf.

UNFCCC (2018) *Clean Development Mechanism Passes New Milestone*. *UN Climate Change News*. Bangkok, Thailand: United Nations Framework Convention on Climate Change. Retrieved June 21, 2018, from https://unfccc.int/news/clean-development-mechanism-passes-new-milestone.

Vaidya, O. S. and Kumar, S. (2006) 'Analytic hierarchy process: An overview of applications', *European Journal of Operational Research*, 169(1), 1-29.

Vidadili, N., Suleymanov, E., Bulut, C. and Mahmudlu, C. (2017) 'Transition to renewable energy and sustainable energy development in Azerbaijan', *Renewable and Sustainable Energy Reviews*, 80, 1153-1161.

Voss, A. and Madlener, R. (2017) 'Auction Schemes, Bidding Strategies and the Cost-Optimal Level of Promoting Renewable Electricity in Germany', *Energy Journal*, 38, 229–264.

Wang, Y., Li, L., Kubota, J., Zhu, X. and Lu, G. (2016) 'Are fluctuations in Japan's consumption of non-fossil energy permanent or transitory?', *Applied Energy*, 169, 187-196.

Wang, X. -H., Wang, X., Huppes, G., Heijungs, R. and Ren, N. -Q. (2015) 'Environmental implications of increasingly stringent sewage discharge standards in municipal wastewater treatment plants: case study of a cool area of China', *Journal of Cleaner Production*, 94, 278-283.

Wind, Y. and Saaty, T. L. (1980) 'Marketing Applications of the Analytic Hierarchy Process', *Management Science*, 26(7), 641-658.

Wong, S. L., Ngadi, N., Abdullah, T. A. T. and Inuwa, I. M. (2015) 'Recent advances of feed-in tariff in Malaysia', *Renewable and Sustainable Energy Reviews*, 41, 42-52.

Woon, K. S., Lo, I. M. C., Chiu, S. L. H. and Yan, D. Y. S. (2016) 'Environmental assessment of food waste valorization in producing biogas for various types of energy use based on LCA approach', *Waste Management*, 50, 290-299.

Wu, Q., Qiang, T. C., Zeng, G., Zhang, H., Huang, Y. and Wang, Y. (2017) 'Sustainable and renewable energy from biomass wastes in palm oil industry: A case study in Malaysia', *International Journal of Hydrogen Energy*, 42(37), 23871-23877.

Wu, S. -Y., Chu, C. -Y. and Shen, Y. -C. (2012) 'Effect of calcium ions on biohydrogen production performance in a fluidized bed bioreactor with activated carbon-immobilized cells', *International Journal of Hydrogen Energy*, 37(20), 15496-15502.

Wu, X. F. and Chen, G. Q. (2017) 'Global primary energy use associated with production, consumption and international trade', *Energy Policy*, 111, 85-94.

Wu, Y., Zhu, Q. and Zhu, B. (2018) ' Comparisons of decoupling trends of global economic growth and energy consumption between developed and developing countries', *Energy Policy*, 116, 30-38.

Yacob, S., Hassan, M. A., Shirai, Y., Wakisaka, M. and Subash, S. (2006) 'Baseline study of methane emission from anaerobic ponds of palm oil mill effluent treatment', *Science of the Total Environment*, 366(1), 187-196.

Yasin, M. H. M., Mamat, R., Najafi, G., Ali, O. M., Yusop, A. F. and Ali, M. H. (2017) 'Potentials of palm oil as new feedstock oil for a global alternative fuel: A review', *Renewable and Sustainable Energy Reviews*, 79, 1034-1049.

Yeoh, B. G. (2005) 'A Technical and Economic Analysis of Heat and Power Generation from Biomethanation of Palm Oil Mill Effluent', *International Energy Journal*, 6(1), 3-15.

Yien, W. S., Sharaai, A. H., Kusin, F. M. and Ismail, M. M. (2015) 'Renewable Energy Policy Status and Challenges of POME-Biogas Industry in Malaysia', *Pertanika Journal of Scholarly Research Reviews*, 1(1), 33-39.

Yip, C. H. and Chua, K. H. (2008) An overview on the feasibility of harvesting landfill gas from MSW to recover energy. *Proceedings of the International Conference on Construction and Building Technology*. 16-20 June. Kuala Lumpur, Malaysia: ICCBT, 303-310.

Younas, M., Awan, I., Kryvinska, N., Strauss, C., and Thanh, D. v. (2016) Mobile Web and Intelligent Information Systems. *Proceedings of the 13th International Conference on Mobile Web and Information Systems.* 22-24 August. Vienna, Austria: MobiWIS.

Yuan. J., Luo, D., Xia, L. and Feng, L. (2015) 'Policy recommendations to promote shale gas development in China based on a technical and economic evaluation', *Energy Policy*, 85, 194-206.

Yusoff, S. and Loh, T. S. (2013) 'The Application of Clean Development Mechanism as a Driver for Renewable Energy Projects in Malaysia', *Advances in Environmental Technologies*, 726-731, 3189-3199.

Zamfir, M., Manea, M. D. and Ionescu, L. (2016) 'Return on Investment - Indicator for Measuring the Profitability of Invested Capital', *Valahian Journal of Economic Studies*, 7(21), 79-86.

Zamparas, M., Kapsalis, V. C., Kyriakopoulos, G. L., Aravossis, K. G., Kanteraki, A. E., Vantarakis, A. and Kalavrouziotis, I. K. (2019) 'Medical waste management and environmental assessment in the Rio University Hospital, Western Greece', *Sustainable Chemistry and Pharmacy*, 13, 100163.

Zechter, R., Kossoy, A., Oppermann, K., Ramstein, C., Klein, N., Wong, L., Lam, L., Zhang, J., Quant, M., Neelis, M., Nierop, S., Ward, J., Kansy, T., Evans, S., and Child, A. (2017) *State and Trends of Carbon Pricing 2017*. Washington, DC: World Bank.

Zhang, C., Wang, Q., Shi, D., Li, P. and Cai, W. (2016) 'Scenario-based potential effects of carbon trading in China: An integrated approach', *Applied Energy*, 182, 177–190.

Zhang, T., Xie, X. and Huang, Z. (2017) 'The policy recommendations on cassava ethanol in China: Analyzed from the perspective of life cycle “2E &W”', *Resources, Conservation & Recycling*, 126, 12-24.

Zhang, Y., Yan, L., Chi, L., Long, X., Mei, Z. and Zhang, Z. (2008) 'Startup and operation of anaerobic EGSB reactor treating palm oil mill effluent', *Journal of Environmental Sciences*, 20(6), 658-663.

Zhang, Y. -J., Sun, Y. -F. and Huang, J. (2018) ' Energy efficiency, carbon emission performance, and technology gaps: Evidence from CDM project investment', *Energy Policy*, 115, 119-130.

Zore, Ž., Čuček, L., Širovnik, D., Pintarič, Z. N. and Kravanja, Z. (2018) 'Maximizing the sustainability net present value of renewable energy supply networks', *Chemical Engineering Research and Design*, 131, 245-265.