UNIVERSITY OF TWENTE.

MASTER THESIS

Optimising the Utilisation of Palm Oil Mill Effluent (POME) for Biogas Power Plants to Achieve Indonesian Target of Bioenergy Power Plants in 2025

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ABSTRACT

The liquid waste in Crude Palm Oil production process, namely Palm Oil Mill Effluent (POME), can be utilized not only as animal feedstocks or fertilizers, but also in electricity generation by convert them into biogas. Biogas power plants that use POME as energy feedstock may give economic benefits for palm oil producers, not only used in the internal process but also by selling the electrical potential to the electricity company. This research will focus on the utilization of POME in biogas power plants, stakeholder roles and cross-sectoral problems. The objectives of this research are to analyse the options in utilising POME, the roles of stakeholders and barriers that may become bottlenecks and to give recommendations on how to overcome the barriers and to optimize the cross-sectoral coordination for the development of POME as feedstock in biogas PPs in Indonesia, particularly in order to achieve the national target of bioenergy power plants in 2025 as stated in the Indonesian National Energy Policy.

Keywords: POME, Biogas Power Plant

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This thesis is dedicated to my beloved Father and my son, Siraj Aldebaran Salvia

Believe that you can and have courage are the keys to reach your dreams

Leeuwarden, the Netherlands, 2019

CONTENTS

LIST OF ABBREVIATIONS

AANE	: Austindo Aufwind New Energy
AD	: Anaerobic Digestion
APLIBI	: Indonesian Bioenergy Power Producer Association (Asosiasi Produsen Listrik Bioenergi Indonesia)
BMS	: Behavioural, Management and Social Sciences
BOD	: Biochemical Oxygen Demand
BOO	: Build, Own, Operate
BOOT	: Build, Own, Operate and Transfer
BPDPKS	: Indonesian Oil Palm Estate Fund Agency (Badan Pengelola Dana Perkebunan Kelapa Sawit)
BPP	: Power Generation Cost (Biaya Pokok Penyediaan)
CDM	: Clean Development Mechanism
CF	: Capacity Factor
CIRCLE	: Capacity for Indonesian Reduction Carbon in Land Use and Energy
COD	: Chemical Oxygen Demand
CPO	: Crude Palm Oil
CSTR	: Continously Stirred Tank Reactors
DCLG	: Department for Communities and Local Government
DGNREEC	: Directorate General of New and Renewable Energy and Energy Conservation
EFB	: Empty Fruit Bunch
EGSB	: Expanded Granular Sludge Bed
EoDB	: Ease of Doing Business
FFB	: Fresh Fruit Bunch
FIT	: Feed-in Tariff
GAPKI	: Indonesian Palm Oil Association (Gabungan Pengusaha Kelapa Sawit Indonesia)
GHG	: Greenhouse gas
GMI	: Global Methane Initiative
GOI	: Government of Indonesia
GW	: Gigawatt
Ha	: Hectare
HGU	: Land cultivation rights or business land use permits (Hak Guna Usaha)
ICP	: Indonesian Crude Oil Price
INDC	: Intended Nationally Determined Contribution
Inofice	: Indonesian Organic Farming Certification
IPP	: Independent Power Producer
IRR	: Internal rate of return
ISCC	: International Sustainability and Carbon Certification
ISPO	: Indonesia Sustainable Palm Oil
KPBU	: Cooperation between Government and Business entitites (Kerjasama Pemerintah dan Badan Usaha)
kV	: kilovolts
kWh	: kilo-watt hour
MCA	: Multi Criteria Analysis
MEF	: Ministry of Environment and Forestry
MEMR	: Ministry of Energy and Mineral Resources
MOA	: Ministry of Agriculture

MOF	: Ministry of Finance
MOI	: Ministry of Industry
MOT	: Ministry of Trade
MSOE	: Ministry of State-owned Enterprise
MSW	: Municipal Solid Waste
MtCO2	: Million tonnes of carbon dioxide
MTOE	: Million Tonnes of Oil Equivalent
MW	: Megawatt
MWe	: Megawatt electric
N	: Nitrogen
NEP	: National Energy Policy
NPV	: Net Present Value
PKO	: Palm Kernel Oil
PLN	: Indonesian State-owned Electricity Company (Perusahaan Listrik Negara)
POC	: Palm Oil Company
POME	: Palm Oil Mill Effluent
PP	: Power Plant
PPA	: Power Purchase Agreement
REF	: Renewable Energy Fund
RQ	: Research question
RSPO	: Roundtable on Sustainable Palm Oil
RUED	: Regional Energy General Plan (Rencana Umum Energi Daerah)
RUEN	: National Energy General Plan (Rencana Umum Energi Nasional)
RUPTL	: Electricity Supply Business Plan (Rencana Umum Penyediaan Tenaga Listrik)
SDG	: Sustainable Development Goals
SEM	: Sustainable Energy Management
SME	: Small and Medium Enterprise
SRQ	: Sub-research question
TBL	: Triple Bottom Line
TKDN	: Local content (Tingkat Komponen Dalam Negeri)
UASB	: Up-flow Anaerobic Sludge Blanket
UK	: United Kingdom
UN	: United Nations
UNFCCC	: United Nations Framework Convention on Climate Change
VA	: Volt-Ampere
VAT	: Value Added Tax
WIPO	: World Intellectual Property Organization

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I. Introduction

The background information about the study and problem statement are presented in this chapter. General information about Palm Oil Mill Effluent (POME) and its process into energy, together with the research objectives and research questions are presented.

1.1 Background of the Study

Indonesia, Malaysia and Thailand are the top largest producers of palm oil in the world (World Atlas, 2018; Index Mundi, 2019). Oil palm plantation is considered as the biggest agricultural commodities that contribute to the economic development and rural poverty reduction of a country or has impacts on the socio-economic (CIFOR, 2017). Unfortunately, over the past decade, the palm oil industry has been criticised because of the impacts on the environment, such as deforestation and habitat loss (RSPO, 2018), forest fires, thus it is considered contributing to the greenhouse gas (GHG) emissions (Asian Agri, 2018).

Based on data from Indonesian Statistics in 2017, Indonesia has palm plantations distributed in 25 provinces. Riau, North Sumatera, South Sumatera, East Kalimantan and Central Kalimantan are provinces with the largest area of palm plantations (Figure 1).

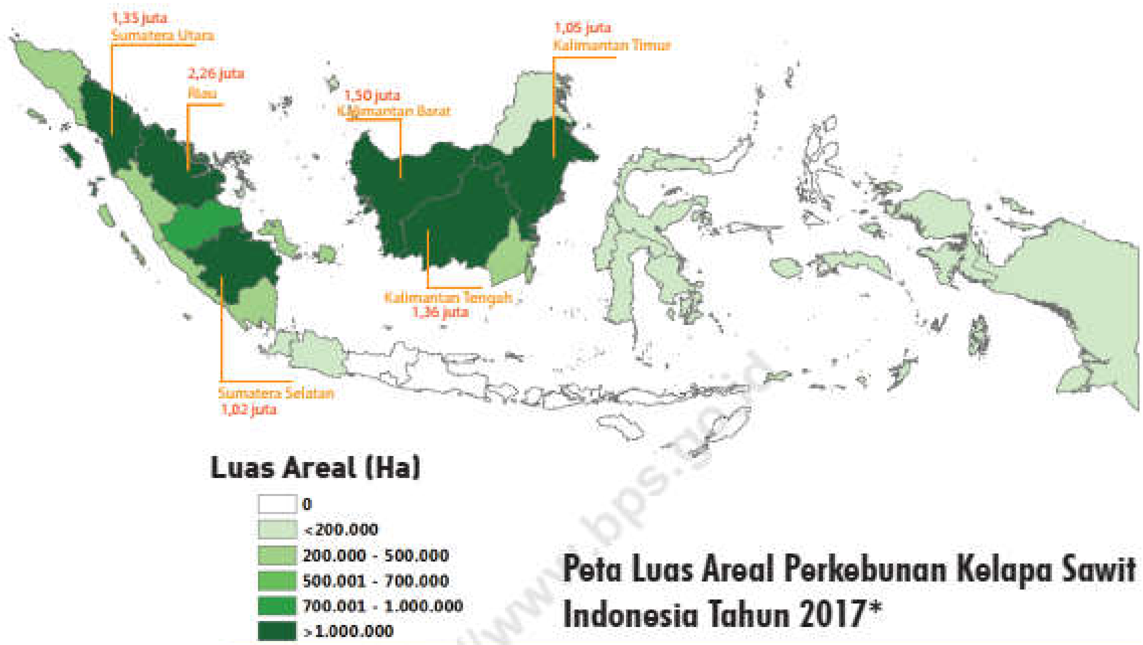

Figure 1 Regions of Oil Palm Plantations in Indonesia 2017 (hectare) (BPS, 2018b)

Number of palm oil companies (POCs) in Indonesia is about 1,779 (BPS, 2018a). Based on their business status, the plantation owners are divided into private companies (6.05 million Ha or 49.17%), by smallholders (5.61 million Ha or 45.64%) and 0.64 million Ha or 5.19% by government estates as shown in Table 1. Riau Province which has 2.26 million Ha (18.38% of total area) with 200 POCs (11.24% of total POCs) was estimated as the province with highest Crude Palm Oil (CPO) production in Indonesia (22.4% of total production) (BPS 2018a; BPS 2018b).

Table 1 Oil Palm Plantation Area in 2013-2017

Year	Category of Producers			Total Area (Ha)
	Government estates (Ha)	Private estates (Ha)	Smallholders (Ha)	
2013	727,767	5,381,166	4,356,087	10,465,020
2014	729,022	5,603,414	4,422,365	10,754,801
2015	743,894	5,980,982	4,535,400	11,260,276
2016	707,428	5,754,719	4,739,318	11,201,465
2017	638,143	6,047,066	5,613,241*	12,298,450

Notes: *totals are not final (BPS, 2018b)

Based on data in Indonesian Oil Palm Statistics 2017, the production growth continues to increase as shown in Figure 2. In 2016 there was only slightly decreasing, because of the process to implement moratorium policy[1] (BPS, 2018b). The moratorium is released following the forest fire damages in 2015 and to improve the management of oil palm plantations, farmers and increase productivity. The massive forest fire happened in provinces where most of the peatlands and oil palm concessions located considerably because of land clearing (WRI Indonesia, 2017).

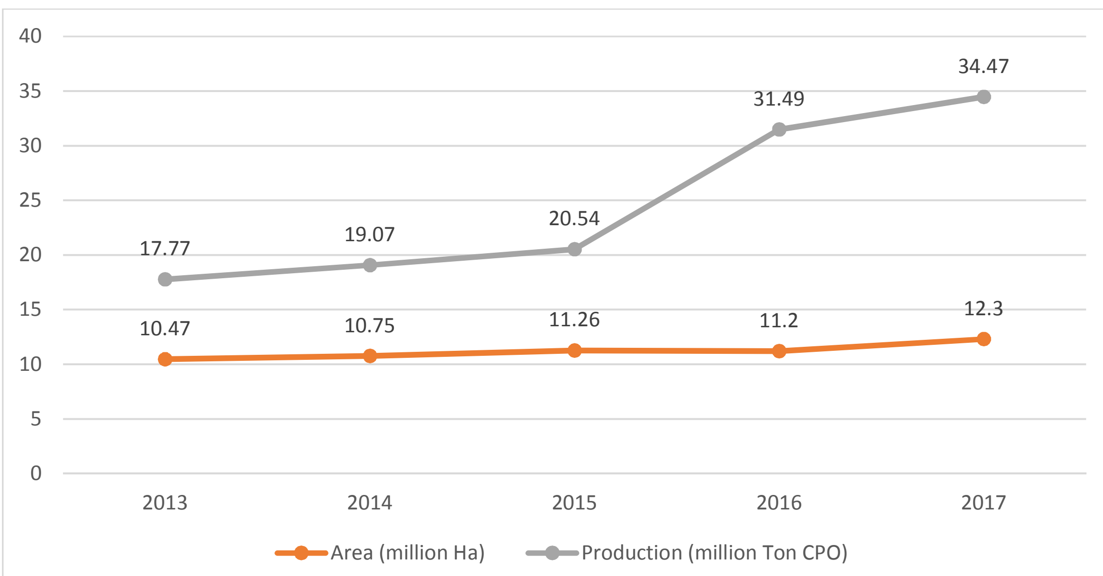

Figure 2 Oil palm plantation areas and production in 2013-2017 (Statistics Indonesia, 2017)

Hence, to reduce the negative impacts on the environment and communities or to promote the sustainability of palm oil cultivation is considerably important. In Indonesia, an Indonesia Sustainable Palm Oil (ISPO) scheme is applied. The scheme review and evaluate whole production process, social responsibility, labour, waste processing, legal aspect and ecosystem/the environment management (BPDP, 2019) and it is either a mandatory or

[1] Presidential Instruction Number 8 of 2018 on land use extension for oil palm plantations (September 2018 to 2021)

voluntary regulation for all companies (MOA, 2015)[2]. Also, palm oil producers that wish to enter the industry and international trade must fulfil several sustainability certificates, such as International Sustainability and Carbon Certification (ISCC)[3] for biodiesel in Europe and sustainability criteria which are defined by Roundtable on Sustainable Palm Oil (RSPO)[4].

One of the efforts to scaling up a sustainable palm oil is done by palm producers by building biogas power plants (PPs) from their effluent, which is known as Palm Oil Mill Effluent (POME).

POME as liquid waste in CPO Production

In the production of CPO, fresh fruit bunches (FFBs) are processed into two types of oil: Crude Palm Oil (CPO), which is extracted from mesocarps, and Palm Kernel Oil (PKO), which is extracted from kernels (Asian Biomass Handbook, 2008). As palm oil industry uses lots of water and energy, it also generates wastes. Wastes could be classified into solid, liquid (wastewater) and gas (air pollution). The solid wastes such as empty fruit bunches (EFB), mesocarp fruit fibres, shells and palm kernel cakes, while the primary liquid waste is POME (WIPO, 2016). A flow diagram of the process of FFBs into CPO and PKO by Hambali and Rivai (2017) is attached in Appendix 1. The low amount of CPO production is affected the volume of POME produced. In the CPO production of 1 ton of FFBs, it was estimated that it could produce 583 kg of POME (58.3%) as shown in Figure 3.

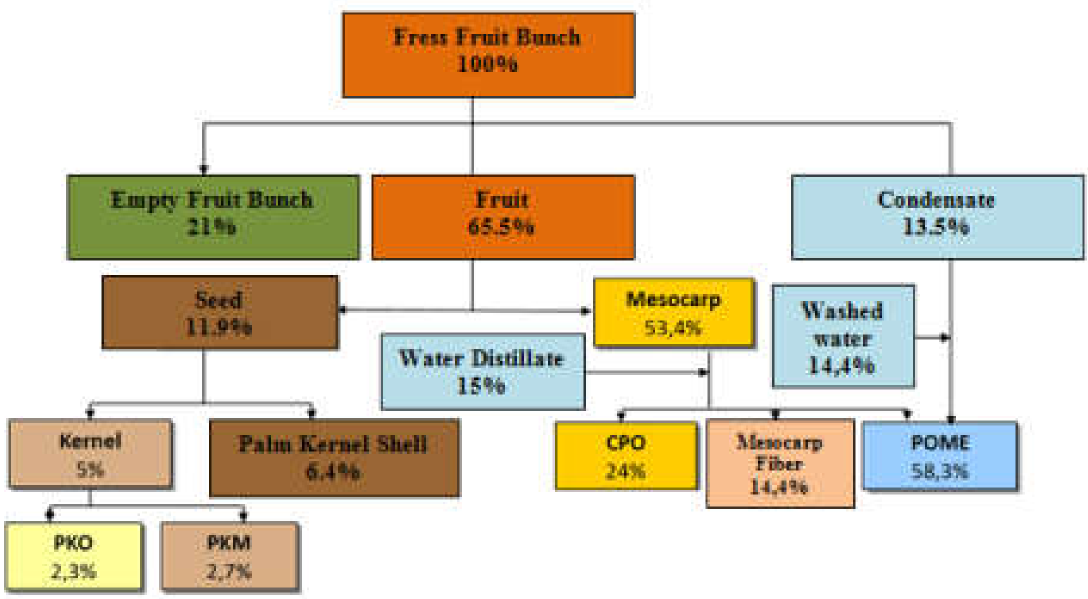

Figure 3 Mass balance in Palm Oil Production Process (Hambali, E., 2010)

The research by Global Methane Initiative (GMI) in 2015 states that in general process of CPO production it is also produced about 60-65% of POME. But, the findings from Capacity for Indonesian Reduction of Carbon in Land Use and Energy (CIRCLE) project studies showed that the rate of effluent production in Indonesian palm mills could reach more than 80% (GMI,

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2 Regulation of the Minister of Agriculture Number 11 of 2015 on ISPO

3 https://www.iscc-system.org/

4 https://rspo.org/resources/certification/rspo-principles-criteria-certification

2015), mainly because of inefficient process. Nevertheless, a more effective process in CPO production could potentially reduce the type and amount of wastes (WIPO, 2016).

POME contains chemical elements, such as nitrogen, phosphate, potassium, magnesium and calcium, hence it is good as fertilizer (Winrock International, 2015; Ugoji E., 1997). Furthermore, POME can be mixed with other solid biomass for the production of organic fertilizer (WIPO, 2016). When considering using POME as a fertilizer should be treated before application to crops, since applying POME directly could kill the vegetation. It may contribute significantly to the water surface pollution (Winrock International, 2015; Chavalparit, O., 2006). A research of physicochemical characteristics has been conducted by Khairuddin et al. (2016) in the treated POME sludge. The study identified the present of anaerobic bacteria that were important to help the decomposition process and recommended the POME sludge from treatment pond is safe and can be used as an organic fertilizer.

The maximum level of allowance to discharge wastes into water required by environmental standards are set by government (MEF, 2018)[5]. In Indonesia, generally, POME is treated by using ponds, 6-10 series of aerobic and anaerobic open lagoons as shown in Figure 4.

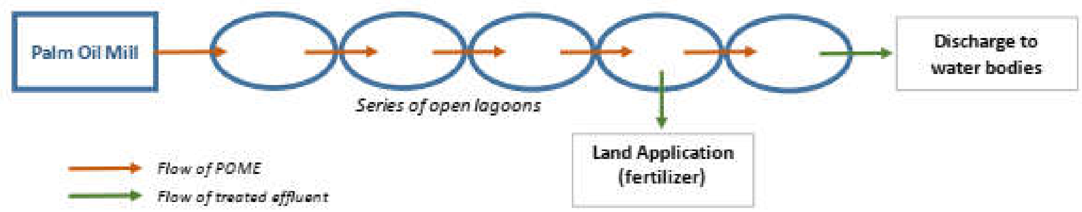


Figure 4 Ponding system of POME treatments in CIRCLE project (GMI, 2015)

The ponding system was chosen because it is relatively low in cost and easy or uses simple operations. The system consists of several stages and type of ponds: fat pit, cooling pond, anaerobic pond and aerobic pond (Winrock International, 2015) that are used by typical palm oil mills is shown in the Appendix 2. Although it is more economical, the system that uses many ponds has drawbacks, such as land-use problems or require a large and open land extension area. Particularly to the people who live in surrounding area, they suffered with the smells. The open ponds also have low ability to reduce the organic contents, increase potential risk of methane releases to the atmosphere and time consumptive (Zahari et al., 2018; Cahyanto, R., n.a.). In addition, it is estimated that 70% of total greenhouse gas (GHG) emissions in CPO production are released from the treatment system of POME (Winrock International, 2015). Although there are research methods resulted in better methods of ponding systems (Zahari et al., 2018), there is another option that can be chosen by palm oil mills managers. That is, to convert the POME into biogas and use it in an electricity generation by applying an Anaerobic Digestion (AD) in the waste treatment (GMI, 2015).

POME conversion to biogas and electricity generation

[5] Regulation of the Minister of Environment and Forestry Number 5 of 2014 (jo. No 1/2018) on Quality Standard of Wastewater (Appendix III in palm oil industry)

As a biodegradable organic waste, POME has the characteristics of biogas content[6] through an AD process that can be used in electricity generation (Winrock International, 2015; Kusrini et al., 2016). There are several technologies used in AD, namely continuously stirred tank reactors (CSTR), covered lagoons, anaerobic filters, fluidized and expanded beds, up-flow anaerobic sludge blanket (UASB) and expanded granular sludge bed (EGSB). The most common technology used is CSTR or covered lagoons (Figure 5), because the methods could manage a high density of oil and solids content in the POME, use simple operations and less expensive compared with other technologies (Winrock International, 2015).

Figure 5 Covered Lagoons PT Austindo Aufwind New Energy (AANE) (ANJ, 2018)[7]

In the conversion of POME into biogas, the Indonesian Palm Oil Association[8] states that the from 147 million tonnes of POME could produce about 4,127 million cubic-metre of biogas (GAPKI, 2016). Biogas can be used in many sectors, such as household, transportation and electricity as shown in Figure 6.

[6] Biogas contains methane (50-75%), carbon dioxide (25-45%), water vapour (2-7%) and other gases such as oxygen, nitrogen, hydrogen sulfide, hydrogen and ammonia (less than 2%). Moreover, biogas has no odour and colour, it burns with a clear blue flame and has the efficiency of about 60% in a conventional biogas stove (Winrock International, 2015)

[7] https://anj-group.com/en/renewable-energy

[8] Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI)

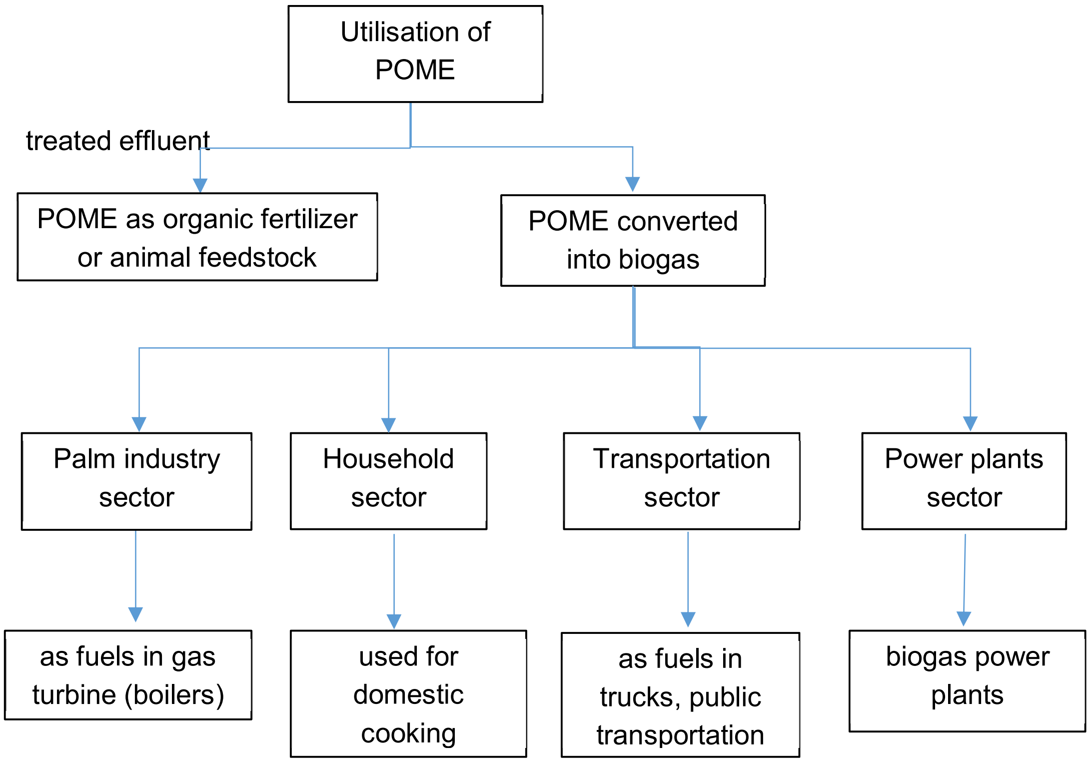


Figure 6 Options in Utilisation of POME

In household sector, biogas can be used for domestic cooking (IRENA, 2017), in transportations sector, biogas is used as transportation fuels (FVEE, 2013), and in power sector biogas is used to generate electricity (Winrock International, 2015). In palm oil industry, the mill's operator could choose several options to use biogas:

- Internally, to replace fuels used in gas turbine or boilers (usually use biomass fuels such as palm fibres and shells) and to fulfil the electricity needs for the facility
- Externally, by selling the excess power to the grid (Figure 7) or build a dedicated biogas PP to improve electrification ratio in the community or region.

Figure 7 Biogas PP of PT Inti Indosawit Subur (Asian Agri, 2015)[9]

The formula used to calculate the potential power based on the characteristics of the wastewater is attached in the Appendix 3 (Winrock International, 2015). The benefit of PPs for palm oil producers is also to support clean technology in CPO production (Chavalparit O., 2006) or waste treatment technologies (WIPO, 2016).

The biogas PPs are also part of the plan to achieve the national target[10]. That is in 2025, the role of new energy and renewable energy is expected at least 23%, or 92.2 million tonnes of oil equivalent (MTOE). The renewables could be from direct usage (23 MTOE) and electricity generations (69.2 MTOE or 45.2 GW). For electricity generations, bioenergy PPs are expected to contribute about 5.5 GW[11] as shown in Figure 8:

[9] https://www.asianagri.com/en/about-us/about-us/our-milestones
[10] Government Regulation Number 79 of 2014 on National Energy Policy (NEP)
[11] Presidential Regulation Number 22 of 2017 on National Energy General Plan (RUEN)

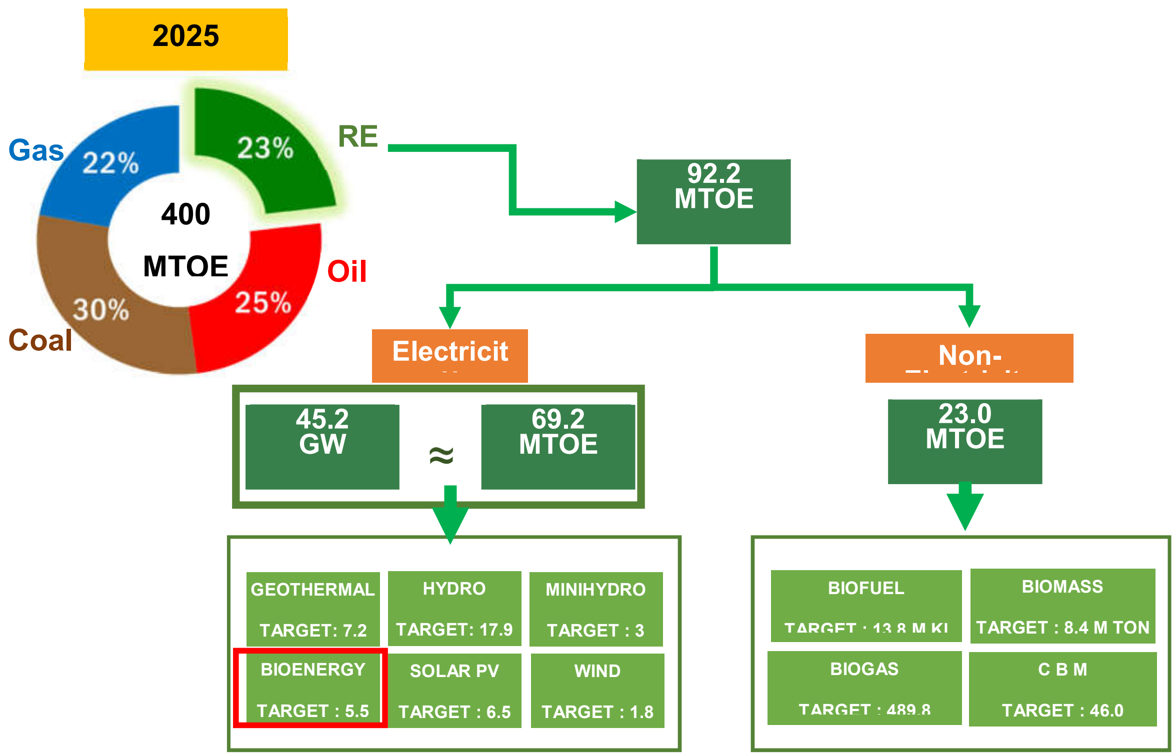


Figure 8 Indonesian Primary Energy Mix Target in 2025 (MEMR, 2019)

Based on Survey in 2011-2012 by the Ministry of Energy and Mineral Resources (MEMR), as also stated in RUEN, Indonesia has resources potential of bioenergy about 32,654 MWe or 32.7 GW. The estimation of electrical potential that can be generated from palms is about 12,654 MWe as shown in Table 2. The palms, CPO and their wastes can be used directly as feedstock in biomass PPs or converted into biogas and applied in biogas PPs.

Table 2 Type and Potential of Bioenergy Resources

Type of Resources	Sumatera	Kalimantan	Java-Madura-Bali	NTT - NTB	Sulawesi	Maluku	Papua	Total (Mwe)
Palm Oil	8,812	3,384	60	-	323	-	75	12,654
Sugar Cane	399	-	854	-	42	-	-	1,295
Rubber	1,918	862	-	-	-	-	-	2,780
Coconut	53	10	37	7	38	19	14	178
Rice Husk	2,255	642	5,353	405	1,111	22	20	9,808
Corn	408	30	954	85	251	4	1	1,733

Type of Resources	Sumatera	Kalimantan	Java-Madura-Bali	NTT - NTB	Sulawesi	Maluku	Papua	Total (Mwe)
Cassava	110	7	120	18	12	2	1	270
Wood	1,212	44	14	19	21	4	21	1,335
Cow Manure	96	16	296	53	65	5	4	535
MSW	326	66	1,527	48	74	11	14	2,066
Total Potential (MWe)	15,589	5,061	9,215	635	1,937	67	150	32,654

Source: MEMR (based on survey 2011-2012)

In Indonesia, the pilot project of biogas PPs that use POME as raw materials has been started since 2013 in Riau Province. The project was built under the supervision of Directorate General of New and Renewable Energy and Energy Conservation (DGNREEC). With a capacity of 1 MW, it can be used to electrify about 2,000 households (DGNREEC, 2016). Some POC have the initiatives to develop methane released from POME to biogas in electricity generation in Sumatera and Kalimantan islands (Asian Agri, 2015). Usually, the electric power that is generated from the PPs or its capacity is more than enough than the company's electricity needs. The excess power generated from the PPs could be connected to the grid (on-grid) and sell to the Indonesian State-owned Electricity Company (PT PLN (Persero)) by signing a contract agreement as an excess power or as an independent power producer (IPP). Until now, only a few companies have contract agreements as shown in Table 3:

Table 3 Installed Capacity of Biogas PPs-POME based (on-grid connection)

No	Companies	Type of Contract	Location	Capacity (MW)
1	PT Austindo Aufwind New Energy	IPP	Pangkal Pinang, Bangka Belitung	1.2
2	PT Bangka Biogas Synergy	IPP	Bangka Belitung	2
3	Maju Aneka Sawit	Excess Power	South Kalimantan	1
4	Sukajadi Sawit	Excess Power	South Kalimantan	2.4
5	Mutiara Bunda	Excess Power	South Sumatera	2
6	Sampurna	Excess Power	South Sumatera	2

No	Companies	Type of Contract	Location	Capacity (MW)
7	Siringo-ringo	Excess Power	North Sumatera	1
8	PT Gunung Pelawan Lestari	Excess Power	Bangka Belitung	1.2
9	PT United Kingdom	Excess Power	North Sumatera	0.8
10	PT Mitra Puding Mas	Excess Power	Bengkulu	2
11	PT Saudara Sejati Luhur	Excess Power	North Sumatera	1.4
12	PT Hari Sawit Jaya	Excess Power	North Sumatera	1.4
13	PT Bahana Nusa Interindo	Excess Power	Riau	1
14	PT Sinar Agro Raya	Excess Power	Riau	1
15	PT Indomakmur Sawit Berjaya	Excess Power	Riau	1
16	PT Inti Indosawit Subur (Buatan-1)	Excess Power	Riau	0.4
17	PT Inti Indosawit Subur (Ukui-1)	Excess Power	Riau	1
18	PT Sawit Graha Manunggal	Excess Power	South Kalimantan	1
T O T A L (MW)				23.8

The oil palm producers, that also have the benefit as electricity seller shown in the Table above (as an IPP or excess power), they have to comply with the regulation of Feed-in-Tariff (FIT) and Excess Power Policy of power purchase price as follow:

a. FIT Policy

In order to add market attractiveness for the interest of the national electricity from bioenergy and other renewable resources, MEMR has regulated the mechanism and power purchase price in Regulation Number 50 of 2017 on Utilization of Renewable Energy Sources for Power Supply (jo. Number 53/2018). The Power Generation Cost (Biaya Pokok Penyediaan Pembangkitan or BPP Pembangkitan), which means the cost of power supply by PT PLN (Persero) in Power Generation excluding the cost of power distribution, is calculated based on local grid system BPP and the average national BPP for each Province. Then, the costs are compared to each other on which has the greater value. For biogas PPs (Article 9), the rules of power purchase from biogas PPs by PT PLN (Persero) as the following:

Buying mechanism	Power purchase price from Biogas PPs	
	BPP Pembangkitan of the local grid system > the average national BPP Pembangkitan	BPP Pembangkitan of the local grid system ≤ the average national BPP Pembangkitan
a direct selection	at a maximum of 85% of BPP Pembangkitan of the local grid system	determined based on the agreement of the parties

In addition, the power purchase from biogas PPs uses the cooperative model of Build, Own, Operate and Transfer (BOOT). The construction of power grid for transferring power from biogas PPs to PT PLN (Persero) interconnection point may be done by IPP based on business-to-business mechanism.

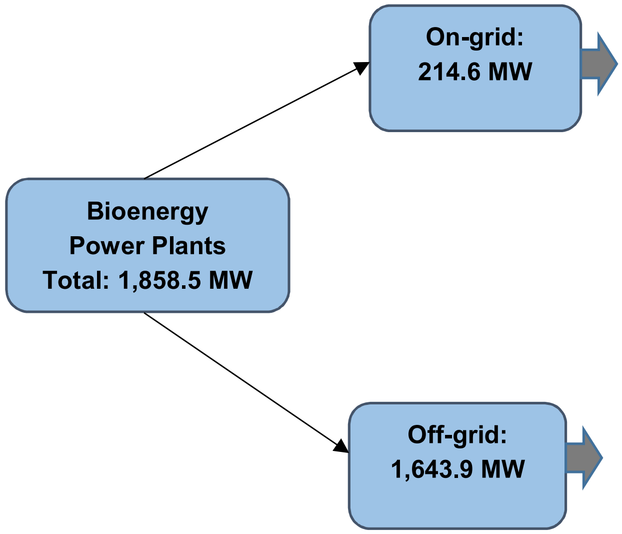
b. Buying of Excess Power Policy

As stated in the Regulation of the MEMR Number 19 of 2017, Article 12, that PT PLN (Persero) could buy an excess power from the operational permit holder in order to strengthen the local electricity supply, and the operational power plants (excess power) must comply with the Grid Code Rules in the local system. The power purchase price is determined at the maximum of 90% of BPP Pembangkitan of the local grid system in accordance to the condition of the grid system, i.e. maximum 70% if the grid is not in a deficit condition and maximum 90% when the grid suffered from electricity deficit. An agreement is signed between the power plant developer and PT PLN (Persero) in the short term (1 year). The agreement can be renewed based on the local condition and PT PLN (Persero) will evaluate the power purchase price annually.

1.2 Problem Statement

From the 1.1, it can be concluded that Indonesia has the interest to improve the sustainable palm oil, and the conversion of POME into energy could be one of the options. Indonesia also has a high electrical potential that can be generated from palm oil (up to 12,654 MWe or 12 GW), so with the potential resources of POME. The technology in POME conversion to biogas and to apply them in biogas PPs is also already known, Indonesia has several regulations to support the value-added of POME as renewable energy resources and has policy ambition to achieve the NEP's target. But, in current conditions, the utilisation of POME as raw materials in biogas PPs is still very minimal (Table 4), that is 23.8 MW on-grid (11.09%) and 9 MW off-grid (0.54%) of total bioenergy PPs installed capacity. Overall, the total capacity of POME-based biogas PPs is very minimal compared to the total installed capacity of bioenergy PPs (less than 2%) and the installed capacity of bioenergy PPs itself is only 32.72% than 2025 target of 5.5 GW. Thus, it is also still very far from the 2025 target. Whereas, the potential of POME in CPO production as biogas feedstock is estimated up to 60% (Hambali and Rivai, 2017), hence the potential electricity generation in biogas PPs from POME could also be estimated and included into account.

Table 4 The current installed capacity of POME-based Biogas PPs (2018)



No.	Materials/Industry	Capacity (MW)
1	Palm waste	129
2	POME	23.8
3	MSW	17.6
4	Others	44.2
TOTAL		214.6

No.	Materials/Industry	Capacity (MW)
1	Palm waste	460.9
2	POME	9
3	Sugar cane Industry	219
4	Pulp and paper Industry	955
TOTAL		1,643.9

Source: MEMR, 2019

The on-grid and off-grid terms refer to connected or not connected with the grid system or network distribution provided by PT PLN (Persero).

This wide gap problem will be the focus of this research, by finding the barriers and cross-sectoral problems regarding with the roles of stakeholders. Figure 9 shows the process of electricity generation of biogas PPs from POME which involving palm oil plantations, CPO production and waste management as the entities of an integrated process. Hence, many sectors are involved and may create cross-sectoral problems and challenges.

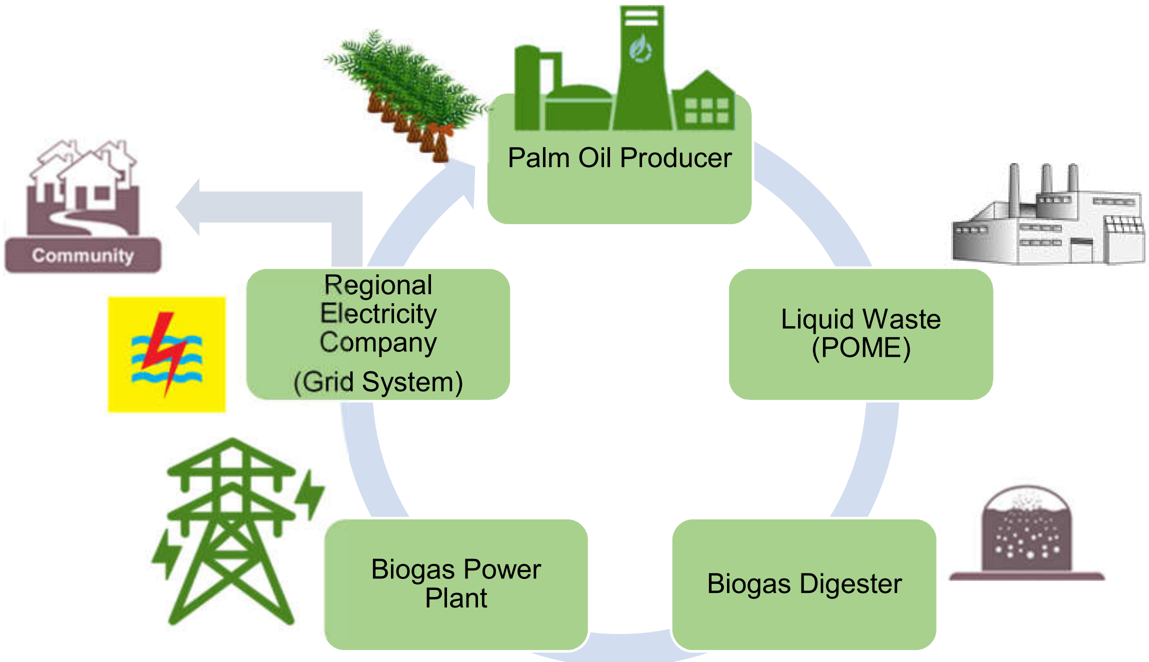


Figure 9 Process in POME Waste to Energy

One of the challenges is about the awareness of palm producers on the benefits to reuse their wastes in CPO production. That they could convert them into biogas to generate electricity or apply for the incentives/subsidies. In general, the cross-sectoral problems and challenges based on the information from Directorate Bioenergy, DGNREEC-MEMR is shown in Table 5:

Table 5 Challenges in Bioenergy Development

Sectors	Challenges
Financial	high initial investments, perception of high risk and not profitable business makes it difficult to get a loan with low interest
Technology	the dependency of some technology on foreign countries
Infrastructure	needs development on-grid systems
Resources	guarantee of the supply for raw materials, the accuracy of the database for resource potential
Spatial Planning	conflict on land use for food, agriculture and energy
Price	guarantee on the stability of price (biomass)
Partnership	weak interaction among stakeholders

Source: MEMR, 2019

In order to overcome the challenges, the MEMR has taken several actions to support the utilisation of bioenergy resources into electricity such as: to guarantee the sustainability of feedstock by improving cross-sectoral coordination and cooperation with stakeholders; implement fiscal and non-fiscal incentives, create the market and determined the price in order to encourage the investments; renew the specification standards and the use of advanced technology; improve the research on local potential; planning the conversion of diesel PPs into CPO as fuels and encourage POCs to utilize their waste into energy (MEMR, 2019). The latest action that is mentioned above will be the focus of this study. Therefore, the problem in this research is how to encourage the optimal utilisation of POME into energy (i.e. electricity generation) by identifying the barriers and considering all stakeholders that are involved in the cross-sectoral problems.

1.3 Research Objectives

The objectives of this research are (i) to analyse the options in utilising POME, the roles of stakeholders and barriers that may become bottlenecks in order to achieve the national target of bioenergy PPs in 2025; and (ii) to give recommendations on how to overcome the barriers and to optimize the cross-sectoral coordination for the development of POME as feedstock in biogas PPs in Indonesia.

1.4 Research Questions

The main research question in this thesis is:
How to contribute to achieve the Indonesian national target of bioenergy PPs in 2025 by optimising the utilisation of POME as biogas PPs feedstock?

The main question is elaborated into sub-research questions (SRQs) as follow:

a. What are the advantages to utilise POME into electricity rather than to be used as other by-products?
b. What are the barriers and roles of stakeholders when a policy to build a POME-based Biogas PP in palm mills is implemented?
c. What recommended policy instruments can be used to overcome the barriers?

1.5 Structure of Thesis

This thesis is structured into 6 chapters, including Introduction. Chapter II presents Theoretical Background, Chapter III explains Research Methodology, Chapter IV discuss the comparison analysis of the utilisation of POME to answer sub-research question 1, Chapter V discuss the analysis to identify barriers in answering sub-research question 2 and recommendations to answer the third sub-research questions. Chapter VI is the Conclusion and Recommendations for future research.

II. Theoretical Background

This chapter will describe the two theories that are used in the study: sustainable energy management (section 2.1) and stakeholders in multi-level, multi-actor governance networks (section 2.2).

2.1 Theory in Sustainable Energy Management

Sustainability, or sustainable development, is not only related with environmental impacts (UN, 1972) but also in economic and social effects. The sustainable development has been introduced in the report of United Nations' Brundlant Commission, and is defined as "the development to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 1987: p.16). The three pillars of sustainability are economic development, social equity and environmental protection (UN, 1992) or known as People, Profit and Planet (3P's) or Triple Bottom Line (TBL) (Barbier, 1987; Purvis, Mao and Robinson, 2018) as shown in Figure 10.

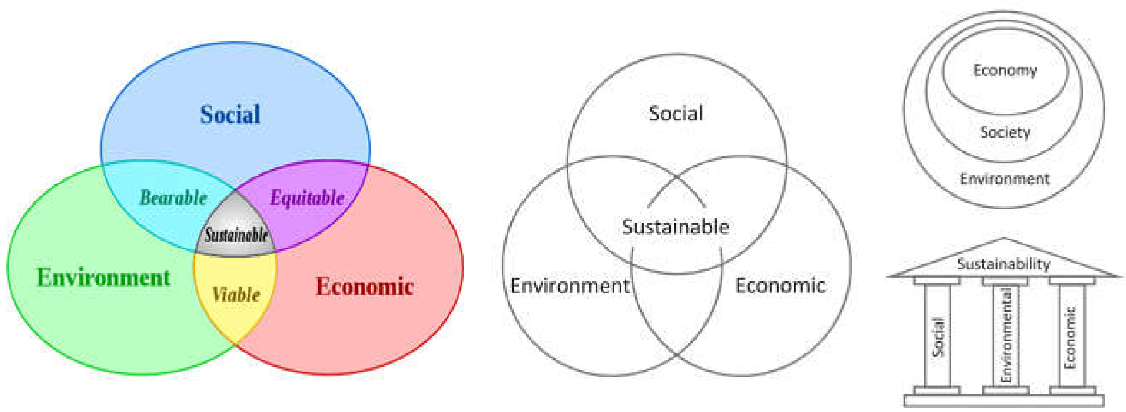


Figure 10 Visualisation of Sustainability Principles

The concept of sustainable development is also implemented in energy sector. The study of Golusin, Dodic and Popov (2013) discussed sustainable development in terms of Sustainable Energy Management (SEM). The SEM is designed to be an effective mechanism in managing problems related energy, with consideration on the need for economic development, to keep energy resources and reduce pollution. It states that an efficient strategic implementation of SEM requires the design of organizational structure, the allocation of resources and related procedures, the creation of an effective coordination system and system of information, the selection of people for important positions and the creation of a reward system that encourage or motivate people to take actions.

In Indonesia, the complex problems of palm oil industry have forced decision makers to encourage the motivation of all players in the industry to implement the sustainable palm oil thoroughly. The implementation of SEM may require not only intensive changes in internal process of the company, but also the attitude of all employees or the community. For example, the policy of land clearing without burning it. The process of changes may cause reactions from the community to reject the policies. Hence, an effective coordination and efficient management is needed. The strategy of SEM can be applied by making more effort in the communication, education, active involvement in proposing changes, or add the attractiveness by the systems of rewards (Golusin, Dodic and Popov, 2013). In this research, the framework of thinking of SEM is be applied in the analysis that apply the sustainability principles to encourage the motivation in optimising the utilisation of POME into energy.

2.2 Theory of Stakeholders

In Indonesia, cross-sectoral coordination is very problematic, because of the unclear roles and responsibilities of stakeholders. The stakeholders in this thesis are defined as any group or individual who can affect or is affected by the implementation of a policy or to achieve the policy's objective. Hence, the identification of stakeholders does matter and should be well-structured, to meet different perspectives or perceptions of individual or group interests and misunderstandings, and to minimize the conflict of cross-sectoral alignment among stakeholders.

In the agricultural industry, an integrative approach to governance is needed to improve cross-sectoral alignment and lighten the negative impact, particularly to the environment (Ozerol, Bressers and Coenen, 2012). The cross-sectoral alignment or problems are happened when there is an intersection of policy sectors within a system of governance. The governance structure in this research use the definition by Bressers and Kuks (2003) that explained the conceptual model in their publication "What does governance mean? From conception to elaboration". Their conceptual model is shown in the Figure 11:

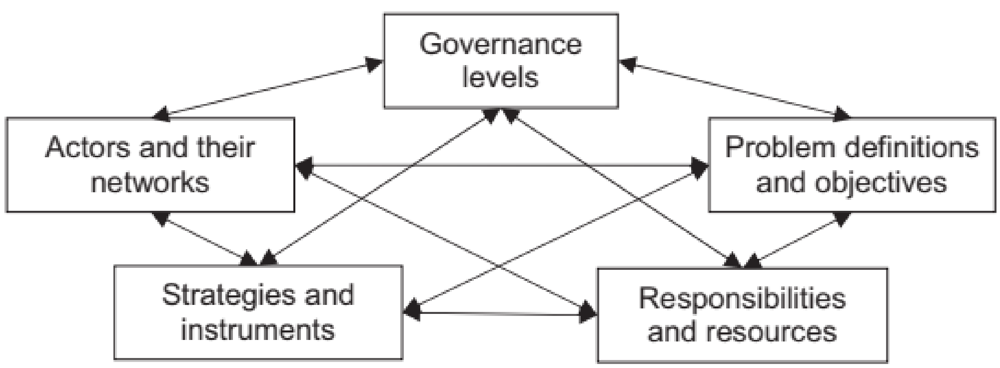


Figure 11 The conceptual model of governance (Bressers and Kuks, 2003)

The model in the figure shows five interrelated dimensions which provide a comprehensive framework that can help researcher in assessing the problems in multiple policy sectors. The concept answers the questions of Where? Who? What? How? and With what?

1. Governance levels
   Where? Multilevel
   It should be known on which levels of governance that hold the dominance roles or has the influence in making the decisions of the policy, and how is the interaction among other administrative levels of government.
2. Actors and their networks
   Who? Multi-actor

It describes on how open the policy arena in theory and practice, and to whom. It should be known who are actually involved, their position or whether they have same capacity in implementing the policy within organisations.

3. Problem definitions and objectives
   What? Multifaceted
   It sees the core of problems and how serious it can be, what is the perception of people to the causes of problems, is it considered as a problem for individuals or whole society. It also should be known on the levels of policy makers aspire the policy ambition (local or national).
4. Strategies and instruments
   How? Multi-instrumental
   It explains the types and characteristics of policy instruments, the target groups, the timing of the application of strategy. It should be known whether the instruments provide the flexibility, including the distribution costs and benefits of the policy implementation.
5. Responsibilities and resources for implementation
   With what? Multi-resource-based
   It describes the responsibilities of organisations (government and non-government institutions) in implementing the policy, what are their authorities, resources and the restrictions by the policy.

In this research, the framework of thinking of the governance model is used in the analysis to identify the barriers and to give recommendations in optimising the utilisation of POME into energy.

III. Research Methodology

This chapter explains the research design and methodology used in the thesis: the contents on what, why and how deep is the study (research boundary), followed by a description of the research methods and how the analysis was conducted.

3.1 Research Framework

The step-by-step approach in a scheme or visualized interpretation to achieve research objectives (Verschuren and Dooreward, 2010), or research framework, of this research is as follows:

- Step 1: Characterizing briefly the research objectives
  This research is aimed to analyse the options in utilising POME, stakeholders' roles and barriers that may become bottlenecks of the gap between realisation and target. It also aims to give recommendations on how to overcome the barriers and how the cross-sectoral coordination can be optimised for the development of POME as feedstock in biogas PPs in Indonesia.
- Step 2: Determining the research objects
  The objects of this research are the stakeholders and barriers in implementing biogas PPs-POME based.
- Step 3: Establishing the nature of the research perspective
  Firstly, the problem-analysing is conducted at the preliminary stage to describe the current condition and targeted situation and problems in the interaction among stakeholders (see Introduction Chapter).
  Second, this research will analyse market attractiveness of POME, such as comparing the options to be used as fertilizer or converted into biogas, and the possibility of making use of biogas in power plant sectors. The method used to make the comparison is by Multi-Criteria Analysis (MCA). The MCA uses the implementation of sustainability criteria as required in the theory of sustainable energy management. MCA techniques are generally used to help decision makers in thinking and decision-making situation, not to take the decision, as explained in the Manual of MCA for making government policy by Department for Communities and Local Government (DCLG), government of the UK (2009). Steps that need to be taken in MCA are:
  - Establishing the aims, who are the decision makers or other players
  - Identifying the options
  - Identifying the objectives and criteria of each option
  - Developing the expected performance of each option versus criteria and make the scoring
  - Assigning the weights according to perceived importance to the decision
  - Combining the weights and scores and calculate the overall value
  - Examining the results
  - Conducting a sensitivity analysis of the results

  Third, the analysis on the barriers and cross-sectoral problems faced by POCs that run biogas facility is also being discussed. The method used in this step is by doing interviews.
  Lastly, it will use an intervention research method to give recommendations needed to remove the bottlenecks in achieving the national target. The method that is used by

analysing the conceptual model of governance as explained in theory in the interaction of stakeholders.

- Step 4: Determining the sources of the research perspective
  This research uses scientific works of literature, such as published journals about the utilisation of POME, feasibility studies and technology to convert biogas from POME into electricity. It also reviews existing documentation, such as regulation documents, national electricity planning and reports of the organisation.

  The key concept and relevant theories to be used in this research are shown in Table 6:

Table 6 Key concepts and theoretical frameworks

Key concepts	Theoretical frameworks
sustainable energy management and stakeholders	• theory on sustainable energy management • theory in the interaction of stakeholders

- Step 5: Making a schematic presentation and formulation
  The framework of this research is schematically illustrated in Figure 12:

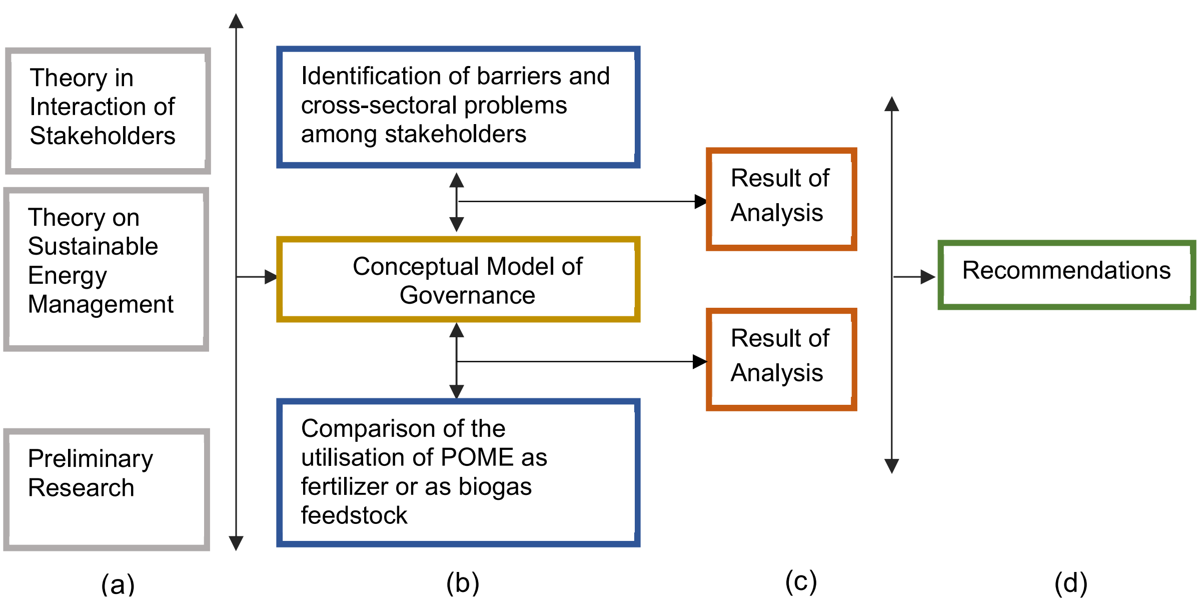


Figure 12 A Schematic Presentation of Research Framework

- Step 6: Formulating the research framework in the form of arguments which are elaborated
  The steps to be taken as illustrated in a scheme of Figure 12:
  (a) The theoretical basis of the concepts in sustainable energy management, stakeholders and preliminary research is carried out based on the study literature
  (b) Means by which research objects will be evaluated
  (c) The results of each analysis
  (d) Recommendations concerning solve the problems

- Step 7: Checking whether the model requires any change
  During the research, researcher checked whether it needs any change to the research design and research objectives.

3.2 Defining Concept

For the purpose of this research, the following concepts are defined:

a. Electricity grid connection: a connection into the grid system from the power providers (PT PLN (Persero)) to consumers by using 150 kV transmission lines or 20 kV distribution lines. In the Provincial level, the grid distributor or control centre is the Regional electricity company (PT PLN Wilayah).
b. On-grid connection: there is an established connection into the grid system with a scheme that is approved by the biogas developer and electricity company.
c. Off-grid connection: there is no connection to the grid system. The power plants developer should develop the transmission lines.
d. IPP: a business entity in power supply in cooperation with PT PLN (Persero) through the signing of power purchase/lease agreement
e. Excess power: selling of excess power capacity to the PT PLN (Persero), that is produced by power plant developers who hold operational permits and comply with the Grid Code Rules in the local system
f. Stakeholder: any group or individual who can affect or is affected by the implementation of a policy or to achieve the policy's objective
g. Governance: the system of organizations, including government organizations, which has five elements in its structure: multi-level, multi-actor, multi-faceted, multi-instrumental, multi-resource based (Bressers and Kuks, 2003)
h. Mandatory regulation: a regulation that obliges every stakeholder to comply with and is enforced by law
i. Voluntary initiative: an action that is not driven by regulatory requirement (Gibson, R.B., 1999)

3.3 Research Strategy

This research project is not only desk research concerning academic journals or reports, but also an in-depth study, which collects information from interviews. In the first analysis, researcher identify and analyse the options in utilising POME, the conversion into biogas and electricity, by using the framework of thinking in MCA. In the second analysis, researcher tries to identify barriers to the adoption of the desired technology, including cross-sectoral coordination and interaction among stakeholders, by interviews. Hence, researcher focused on interviewing the POCs that also have biogas facility or develop biogas PPs.

3.3.1. Research Unit

The research unit of this research is the oil palm producers who are developing biogas PPs from POME.

3.3.2. Selection of Research Unit

The selection of POCs or palm oil mills is based on the following criteria:

a. The company is currently an active producer in CPO production
b. The company has an installed capacity of biogas PPs that use POME as biogas feedstock
c. The company has signed a contract agreement with PT PLN (Persero): as an excess power or as an IPP

3.3.3. Research Boundary

Considering time frame limitations to achieve the objectives of this research, the following boundary is applied:

a. The utilisation of POME will focus primarily on palm oil industry sector and electricity generation or power plants sector
b. For the purpose of this thesis, the number of companies to be explored is limited into two, one that represents as an excess power producer, and one that represents as an IPP.
   As stated in Introduction Chapter, that there are 18 companies (2 of them are IPPs) and some of them are subsidiary companies (part of big POCs). In this research, the company chosen is the mother company that has several mills which also run biogas PPs facilities.

3.3.4. Research Material and Accessing Method

The required data and information to answer research questions is collected through study literature, such as to review and analyse documents of regulations, company's reports, previous research in POME, including cases in other palm oil producer countries (e.g. Thailand, Malaysia) and interviews.

The data and information required are shown in Table 7 below:

Table 7 Data and Information Required for the Research and Accessing Method

Research Questions	**Data/Information Required**	**Data Sources**	**Data Access**
How to contribute to achieve the Indonesian national target of bioenergy PPs in 2025 by optimising the utilisation of POME as biogas PPs feedstock?			
A. what are the advantages to utilise POME into electricity rather than to be used as other by-products?	• information about the process in CPO production and waste treatment • description on the utilisation of POME as animal feedstock, fertilizer and biogas feedstock • published research in feasibility studies of biogas PP-POME based	Primary Data Secondary Data	Literature Study • Statistics Indonesia (BPS) • Statistics of Tree Crop Estates <u>Interviews/Questionnaires</u> • MEMR, Directorate Bioenergy Methods: Analysis of MCA
B. what are the barriers and roles of stakeholders when a policy to build a POME-based Biogas PP in palm mills is implemented?	• observation about stakeholder interaction, roles and responsibilities • information about benefits as excess power producers or IPP	Primary Data Secondary Data	Literature Study <u>Interviews/Questionnaires</u> • MEMR, Directorate Bioenergy • 2 POCs

Research Questions	Data/Information Required	Data Sources	Data Access
C. what recommended policy instruments can be used to overcome the barriers?	• information about policy which have been tried or exist in municipalities or local governments	Primary Data Secondary Data	Literature Study Interviews/Questionnaires • MEMR, Directorate Bioenergy • 2 POCs

3.3.5. Ethical Statement

Considering the issues in palm oil industry, this research may involve sensitive data from the respondents, such as individuals, groups or organisations. Thus, according to Ethics Committee of Faculty of Behavioural, Management and Social Sciences (BMS) University of Twente, the issue on data ethics was informed to the respondents at the beginning in conducting research as stated in ethical assessment. The signed Informed Consent Forms are attached in this thesis. For the data management, researcher also aware on responsibilities for the proper handling of data, regarding working with personal data, data storage, sharing and presentation/publication according to the University of Twente's rules of Data Policy[12].

3.4 Data Analysis

3.4.1. Methods of Data Analysis

Both quantitative and qualitative methods are being used in this research as shown in the following Table 8:

Table 8 Data and Method of Data Analysis

Data/Information Required	Method of Analysis
information about the process in CPO production and waste treatment	Quantitative: as an input to estimate the potential resource of waste in one production process of CPO Qualitative: to analyse the technology needed and technology awareness among producers
description on utilisation of POME as fertilizer or biogas feedstock	Quantitative: as an input to estimate the potential market of POME Qualitative: to analyse and compare the benefits in utilising POME
information about feasibility studies of certain project of biogas PP-POME based	Quantitative: as an input of analysis on potential regions of POME resources in Indonesia, the application of technology and the costs of infrastructure Qualitative: to analyse problems related with possible options or the advantages in utilising POME
information about current policy in the implementation of biogas PP from POME	Qualitative: to analyse problems related with regulations

[12] https://www.utwente.nl/en/bms/research/ethics/

Data/Information Required	Method of Analysis
information about the roles of association of producers in community	Qualitative: to analyse problems related with roles of stakeholders
information about benefits as excess power producers or IPP	Qualitative: to analyse the market opportunities and challenges of CPO producers to become power plant developers
information about stakeholders and their roles and responsibilities	Qualitative: to analyse problems related with interaction of stakeholders

3.4.2. Validation of Data Analysis

Data validation is important in order to prevent bias definitions, to ensure the data is accurate and from trustworthy resources, so that it can be useful in the analysis. In the quantitative phase, the data was from the database of Indonesian Statistics. The data was checked with the database of MEMR. In the qualitative phase, data from interviews is checked by cross-validation from other resources, such as published reports or news. Cross-validation methods is mainly used to estimate the performance of a predictive model that is used in a case where the goal of research itself is a prediction (Georgios Drakos, 2018).

3.4.3. Analytical Framework

In answering SRQs, the analytical framework of this research is schematically illustrated in Figure 13.

a. First step of data analysis was reviewing theoretical basis and empirical background of the study about the characteristics of POME, the technology proses in POME conversion to energy, initial barriers/challenges and the cross-sectoral problems among stakeholders.
b. Second step was conducting the comparison between the utilisation of POME in palm oil industry sector and power plant sector and answering SRQs-1. The comparison was done by using the framework of thinking of MCA.
c. Third step was about identifying the barriers and cross-sectoral problems among key stakeholders in answering SRQs-2. The information was collected from the interviews.
d. The last step was to discuss the findings of analysis in order to answer SRQs-3. However, for the future research, the recommendations can be analyzed again in order to identify the barriers or cross-sectoral problems which involve the stakeholders in its implementation.

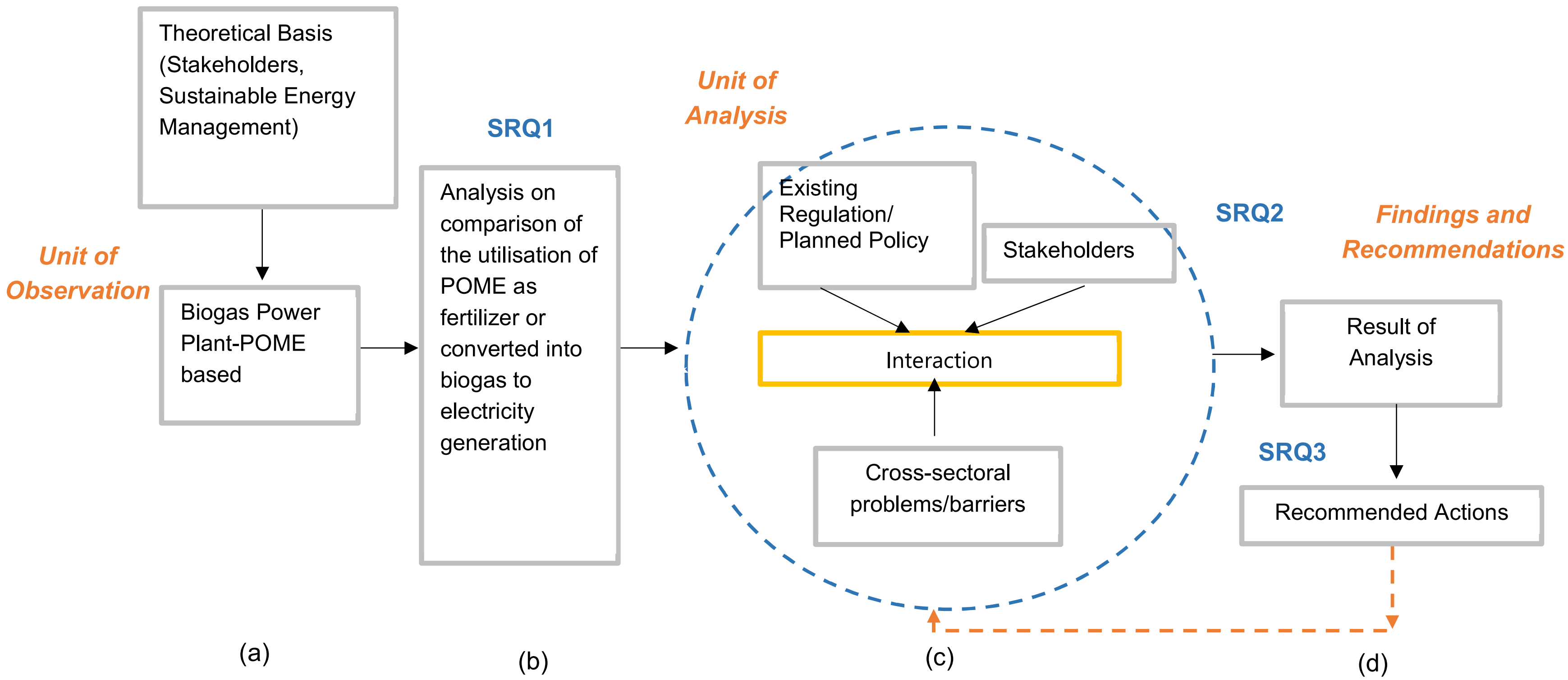


Figure 13 A Schematic Presentation of Analytical Framework

IV. Multi Criteria and Stakeholder Analysis on POME into Energy

This chapter will try to answer the first SRQs by using the framework of thinking in MCA methods. This chapter is structured as follows: The MCA, is discussed based on the steps and guidance on application of criteria, and roles of stakeholders in each of possible options.

4.1 Multi-Criteria Analysis (MCA)

As already explained briefly in Chapter 3, by doing MCA means that many options are considered carefully based on several criteria. The criteria are defined by decision makers to achieve their objectives. MCA can be applied to many complex problems, not only the one that use monetary valuation (financial analysis, cost-effectiveness, cost-benefits analysis), but also non-monetary valuation, such as in making a short-list of options, the ranking of options or appraisal of certain quality (DCLG, 2009).

4.1.1. Steps in MCA

In this research, the approach will be divided into 3 (three) levels. The first level, in establishing the utilisation of POME, whether as organic fertilizer or animal feedstock, or organic waste that can be converted into energy. At the second level, that define the sectors for the utilisation of POME as biogas feedstock, such as in industry, or electricity sector. Finally the third level, the options for decision makers that use POME in biogas power plants, such as type of connection, the on-grid or off-grid connection. Furthermore, in the on-grid connection, there are also type of agreements with electricity company in order to give impacts to the environment and local community. The scope of discussion on MCA of those options is illustrated as shown in Figure 14.

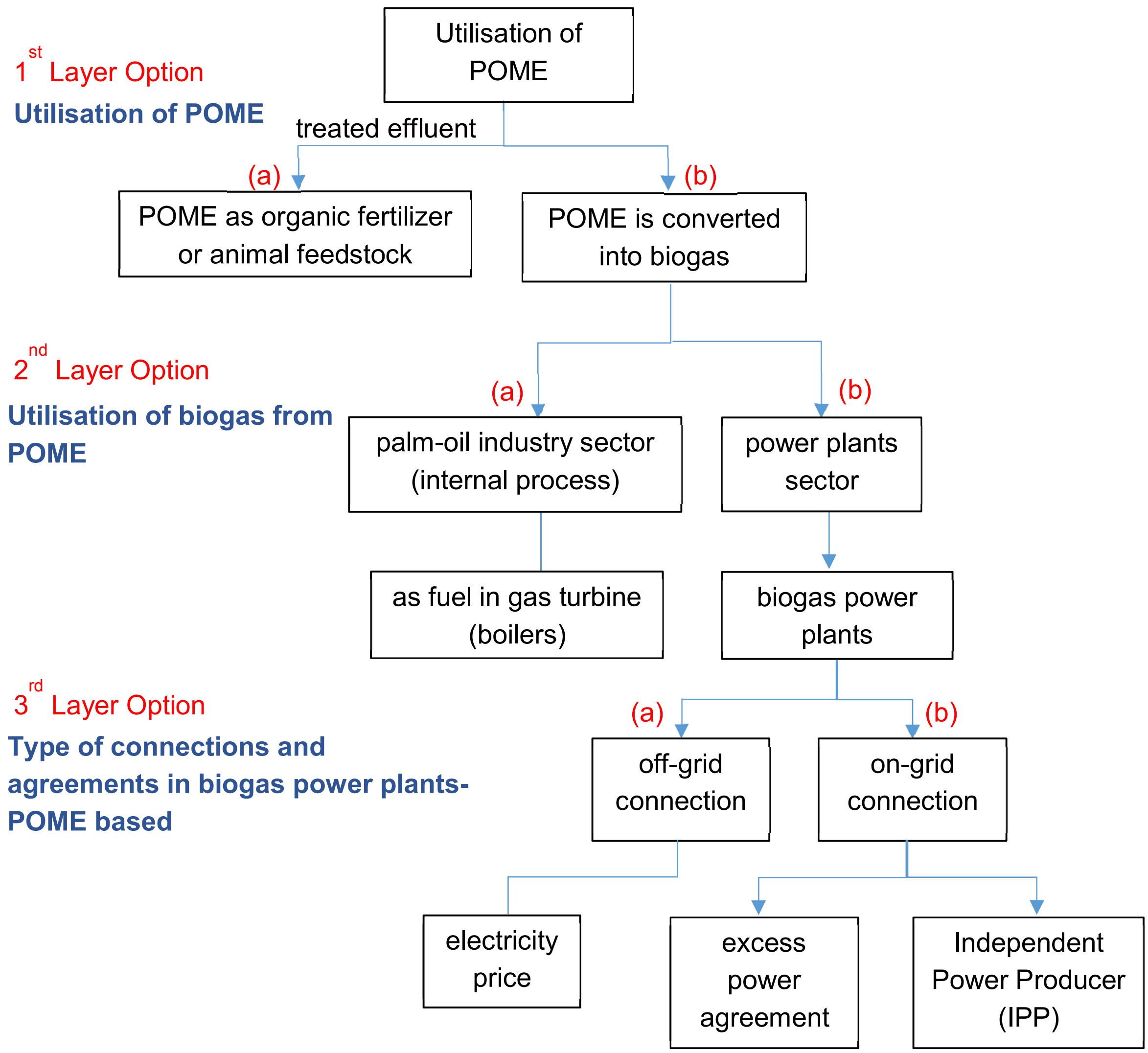


Figure 14 Options in Utilising POME into Energy

Step 1: Establishing the aims, decision makers or other players

The aim in the first layer option is to make benefit of POME after being treated based on environmental standard as regulated by MEF[13]. As mentioned in Chapter 2 that POME could be used either as organic fertilizer, animal feedstock or converted into biogas. In this process, the decision maker is oil palm producers. In option 1(a), other actors involved such as oil palm farmers, fertilizer sellers and stock farmers. In option 1(b), the companies need to cooperate with engineers, investors or financial institutions, electricity company and local government. Meanwhile, the aim in the second layer option is to make benefit of POME as biogas feedstock. The decision maker in this process is also oil palm producers. Lastly, the aim in the third layer option is to know which agreement is suitable between the options or has more benefits to be implemented (depend on the location, availability of grid connection infrastructure, etc.). In this option layer, the decision makers are the Government and oil palm producers. The other

[13] Regulation of the Minister of Environment and Forestry Number 5 of 2014 (jo. No 1/2018) on Quality Standard of Wastewater (Appendix III in palm oil industry)

actors involved are national state-owned or regional electricity company (PT PLN (Persero) and PLN Wilayah), Provincial government and local community.

Step 2: Identifying the options
Option 1(a) can be chosen by oil palm producers that do not convert the effluent into biogas or capture the methane yet, but still seek an economic opportunity of POME. Option 1(b) is mostly chosen by companies that not only seeking the economic benefits, but also aware on reducing GHG emissions in CPO production process. Option 2(a) is for companies that want to use biogas in their production process internally, for example to use biogas as fuels in their boilers. Option 2(b) is for companies that want to be both palm oil and electricity producers. Option 3(a) and 3(b) can be chosen by the Government or palm producers after considering the geographical location and infrastructure facility, for instance, whether in the location already has grid connection or not. Moreover, the option to be both palm and electricity producer could be considered as one attractive choice in optimising the utilisation of POME as biogas feedstock in palm oil industry.

Step 3: Identifying the objectives and criteria of each option
In general, the objective is not only to make benefit, but also to develop positive impacts on the utilisation of POME in order to support the sustainable palm oil. Hence, the management or SEM is important to apply in this matter. The criteria used are based on the three principles of sustainability (economic, social, environmental) as follow:

A. Economic
    - Criterion A1: Profit
      The world's change or transitions, into a sustainable and low-carbon products or services, forces businesses to change the paradigm of traditional growth and profit-maximization model (Wilson, M., 2003). Profit is important, but it is not the only objective. In this research, the profitability of each option is accounted by looking at general attractiveness in the market or the value-added of products. For example, the potential of savings in government's expenditure by using POME as organic fertilizers or the revenue for company in using biogas to replace other fuels, and profit from selling electricity.
    - Criterion A2: Compliance with standard or regulations
      As the project needs some amount of funds (middle to high) from investors (domestic or a joint-venture with foreign companies) and involve several stakeholders, so it is important to comply with regulations, has effective mechanisms in planning so it is enable to get feedback and to do revision, provide access in monitoring the implementation, has good documentation so that the project's objective and effectiveness could be reviewed.
    - Criterion A3: Apply good corporate governance and risk management
      A corporation that apply a good corporate governance gives precise and accurate information, become more transparent to the stakeholders and general public. For example, an accurate project's structure of costs, clear revenue streams and financial resources. In general, the project should consider the potential risks in the environmental, health, safety, economic and legal (Winrock International, 2015).

B. Social

- Criterion B1: support and approval from the employees, stakeholders and the community where it is located
  As palm oil industry is seen as an industry that has a large negative impacts, such as land-use change, threatening biodiversity, issue on plantation workers (child labour), etc., then it is important to implement a good mechanism in communication and information among community, government, non-government organization and other institutions, particularly in surroundings location.
- Criterion B2: positive social impacts to local or regional community
  Palm oil industry is hoped to have multiplier effect, not only to the economy (commodity exports), but also to social and the environment. In Indonesia, where the electrification ratio is still below 100% (see Appendix 4), the power plants project could also open new employment. As the methane-capture in the anaerobic process of organic material digestion needs careful handling in operation and maintenance, it requires knowledge and expertise in civil, process, mechanical, and electrical engineering (Winrock International, 2015). The example of indicators in this criterion such as availability or access to electricity for local community, job creation and knowledge or capacity building activities.

C. Environment

- Criterion C1: carbon reduction
  The human activities such as creating, using or transporting products and land clearing in agriculture, will emit some carbon and other GHG. The main sources of emissions in CPO production are plantation, transportation and the mills (Winrock International, 2015). Hence, whether there exists a link that connects between the activity and effort to reduce the impacts on climate change (i.e carbon emissions reduction) locally or nationally, is an indicator of this criterion.
- Criterion C2: water usage
  Similar with carbon reduction criterion, water is also a sensitive issue in CPO production and palm oil industry chain. The production of the effluent, or wastewater, the treatment process and reuse in palm oil industry is discussed in this criterion.
- Criterion C3: positive environmental impacts
  Nevertheless, whole process in palm oil industry chain is aimed to have positive impacts to the environment. So, the result of has a good impact is important in this criterion.

The sustainability principles and criteria of each option used in this research is shown in the following Table 9.

Table 9 Principles and Criteria

Principles	**Economic (Profit)**	**Social (People)**	**Environment (Planet)**
Criteria	profitable for the company and government (i.e. interesting selling price)	support and approval from the employees, stakeholders and the community where it is located	carbon reduction
	compliance with standard or regulations	positive social impacts to local or regional community	water usage
	apply good corporate governance and risk management		positive environmental impacts
	↓ Guidance on Application of Criteria	↓ Guidance on Application of Criteria	↓ Guidance on Application of Criteria

Step 4: Scoring
As mentioned in Chapter 2, the MCA methods used in this research is not to take the decision (DCLG, 2009), rather it is used to provide guidance to the decision makers in identifying the areas which already sufficient with the objective in policy implementation or needs further improvement. Thus, the proposed scoring is as follow:

A =	all of the requirements are fully met
B =	all of the requirements are satisfactorily met, although some further improvements are desirable
C =	some requirements have been satisfactorily or fully met, but others have not yet been satisfactorily met
D =	few of the requirements have, as yet, been satisfactorily met

(Source: IDPM, 2001)

Step 5: Weighting
As the three principles has the same relative importance to the decisions and considering the time limitation as research boundary to get enough number in assessing input data, hence, the criteria in this research are not explicitly weighted. The analysis will follow the methods approach of without weighting based on the Manual of MCA (DCLG, 2009).

Step 6: Combining the weights and scores and calculate the overall value
Although this research does not show numerical value of expected performance in scoring and weighting, in order to make comparison among the options in each layer, the results are shown in a performance matrix. The matrix which will be used by decision maker to study and analyse the problems are based on qualitative description. Moreover, the descriptive analysis

is chosen in this research, because researcher is aware that numerical scales without exact measurement could lead to incorrect message of the result of research (DCLG, 2009).

Step 7: Examining the results
The results in the performance matrix are examined again.

Step 8: Sensitivity Analysis
This step will look again of overall selected options and the comparison of each other, particularly dealing with uncertainties during the assessment in this research. Furthermore, if it is possible to create a new and better model of options.

The application of criteria based on the sustainability principles are explained in the following:

4.1.2. Guidance on Application of Criteria

The interpretation of criteria is seen based on the analysis of literature research and interviews. The assessment in this research, whether the option is met satisfactorily condition or only partly met, will look at the overall values that integrates the three principles: economic, social and the environment. For example, if Option 1(a) has good performance dominantly by economic consideration, then the result shows only part of requirements are met.

4.1.2.1. Economic Advantage

Considering production activity of palm oil plantations is expected to continue growing, so with the needs of fertilizer. Farmers could choose to apply organic fertilizer, inorganic or the combination of both ([14], Chong et al., 2017). In addition, the knowledge on dosage and timing, type of soil, land contour, climate, age of plants (growth stage) or the health of roots, leaves, etc. (Darmosarkoro, Sutarta and Winarna, 2003; Panggabean and Purwono, 2011; [15]) are needed to get a good quality of crops.

In Option 1(a), by considering the content of nutrients in POME, most palm oil mills in Indonesia use the final treated POME as a direct land application only, to restore the nutrients in the soil. However, they still use additional fertilizers. In Indonesia, the organic fertilizer should be tested and registered before circulating to the consumers as regulated in the regulation[16] (MOA, 2019). As POME can be mixed to produce an organic fertilizer (Chong et al., 2017) so the research is needed to find the appropriate composition of the mix. One example of an organic fertilizer in Indonesia that use the mix of EFB and POME, is known as "ImproBio", which has been accredited and meets an Indonesian National Standard and certification from Indonesian Organic Farming Certification (Inofice)[17] (Agronet, 2017). The price of this fertilizer is about 15,000 IDR/kg[18].

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[14] https://sentrabudidaya.com/pupuk-sawit-jenis-dosis-dan-cara-memberikannya/
[15] https://sawitnotif.pkt-group.com/2018/02/01/cara-menghitung-kebutuhan-pupuk-pada-tanaman-kelapa-sawit/
[16] Regulation of Minister of Agriculture Number 1 of 2019 on Registration of Organic Fertilizer, Bio-Fertilizer and Soil Enhancer
[17] http://inofice.com/
[18] https://www.bukalapak.com/p/hobi-koleksi/berkebun/pupuk-nutrisi-tanaman/55yaxn-jual-pupuk-organik-improbio-meningkatkan-panen-28-35-tidak-gagal-panen

In Indonesia, the production and distribution of fertilizers, particularly subsidized fertilizers, are managed by several government policies. Firstly, Ministry of Agriculture (MOA) has responsibility to define the allocation and the highest retail price of subsidized fertilizer. Then, PT Pupuk Indonesia (Persero) that is under the supervision of Ministry of State-owned Enterprise (MSOE), as a holding company of 10 subsidiary companies, has responsibilities to manage the production and distribution of Urea, SP-36 (superphosphate, 36% P_2O_5), ZA/AS, NPK, ZK (K_2SO_4)[19]. In the case of high demand or operational disruption which caused PT Pupuk Indonesia (Persero) cannot fulfill the stock, then reallocation among producers or imports can be done, as stated in the regulation of Ministry of Trade (MOT)[20]. Based on the Indonesian regulation of Based on Data from Indonesian Fertilizer Producers Association[21], most of the fertilizers are imports and only Urea is being exported (15.4% of total urea production in 2018). The other fertilizers are imported because of a lack of domestic sources of raw materials (FAO, 2005). In other hand, based on research of palm-based fertilizer in Malaysia by Chong et al. (2017), the 15 million tonnes of POME can be quantified to the fertilizers as shown in the following Table 10:

Table 10 The representation 15 million tonnes of POME to the fertilizer (Wu et al., 2009)

Fertilizer	Tonnes (×1000)
Ammonium sulphate*	75.5
Rock phosphate (phosphorite)	19.5
Muriate of potash (potassium chloride)	68.6
Kieserite (magnesium sulphate)	59.6

*Amount of ammonium sulphate (21% N) is translated to urea (46% N) based on N content

So, there is an opportunity of the POME nutrient contents to replace the percentage of proportion needed in the compounded fertilizers.Then, to estimate the value-added of POME used in fertilizer production, the corresponding amount can be calculated based on the current price of fertilizer and the percentage of each type of fertilizers in Indonesia. The highest retail price for subsidised fertilizer 2019 in agricultural sector based on the regulation[22] is shown in Table 11:

Table 11 The highest retail price for subsidised fertilizers 2019

Fertilizer	Highest retail price
Urea	IDR 1,800/kg
SP-36/phosphate	IDR 2,000/kg
ZA/AS	IDR 1,400/kg
NPK	IDR 2,300/kg
Organic	IDR 500/kg

[19] http://pupuk-indonesia.co.id/en/produk#
[20] Regulation of Minister of Trade Number 13 of 2013 on Procurement and Distribution of Subsidized Fertilizer in Agricultural Sector
[21] Asosiasi Produsen Pupuk Indonesia (APPI)
[22] Regulation of Minister of Agriculture Number 47 of 2018 on Allocation and highest retail price of subsidised fertilizers 2019

So far, the price for non-subsidised fertilizers is not regulated by the Government. In a conclusion of Option 1(a), firstly there is the economic potential to develop the conversion of POME into organic fertilizer (palm-based), hence it is also can be proposed to get the subsidies or considered as subsidized fertilizers. Secondly, there are economic opportunities: to reduce the fertilising costs in palm plantations (as POME is used as land application), to reduce the imports of other inorganic fertilizer (the percentage of POME can be quantified to replace or fill the gap of the composition in the mix), or, to add the government revenue from the exports of organic fertilizers (fertilizers from POME are commercially produced for domestic needs and exports).

Whereas, in Option 1(b), the economic advantage of using POME as biogas can be used internally or to give economic impacts to the local community. In internal process, it can replace the use of fossil fuels or solid wastes, such as palm shells (Natashia, K., 2013; Kamal, N., 2012). Research by Kamal (2012) states that palm shells still have caloric value of 3,500-4,100 kcal/kg. Moreover, the shells have high export values. The Indonesian Palm Kernel Shell Association[23] states that the shells are mainly exported to Japan, Korea, Thailand, China, as the countries have biomass target in their Energy Policy. In 2017, the export of shells reaches up to 1.8 million ton (19.6% of total shells production), where 1.2 million were exported to Japan. The price of palm kernel shell in 2018 is shown in Figure 15.

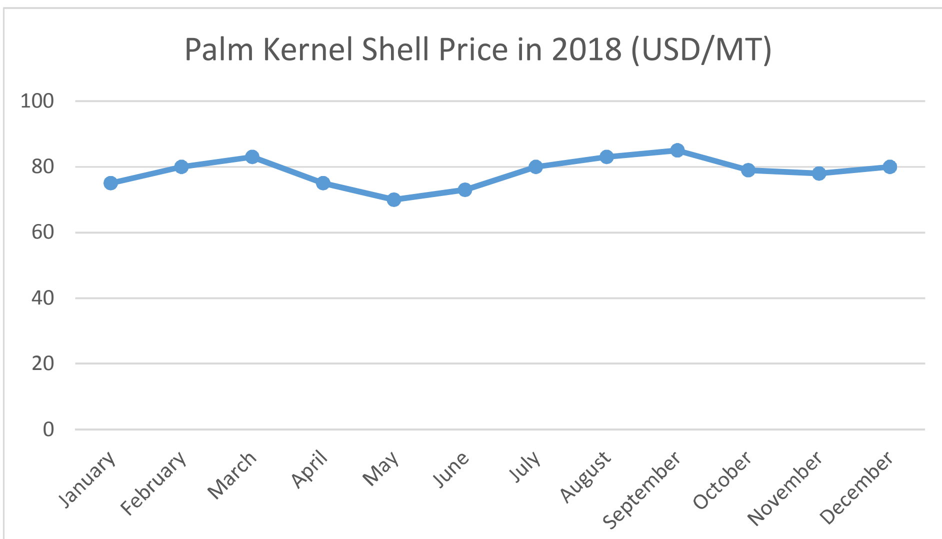

Figure 15 The Price of Palm Kernel Shell 2018[24]

A research study that was conducted an energy audit of a palm oil mill in North Sumatera calculates that there was a waste of biomass energy in the boiler. The research states that the difference between real fuel consumption and theoretical fuel consumption in the mill was about 2,730 kg/day (Natashia, K., 2013). This is quite a large amount from the perspective of a loss of potential revenue if the biomass shells were exported.

For economic benefits in Option 2 and 3, the value-added of POME conversion into biogas and electricity are that it can be used in the mills' facility, such as for a combined heat

[23] Asosiasi Pengusaha Cangkang Sawit Indonesia (APCASI): https://palmkernelshell.id/
[24] https://palmkernelshell.id/

and power of steam generator in the CPO production process, electricity supply in the facility and workers' housing (GMI, 2015). In addition, to the biogas facility should be built to a high-quality standard of health, safety and environmental protection, and it also needs quite large amount of investments (the requirements to have a 'good' or well performance in Criterion A2 and A3). Palm oil producers that also develop biogas power plants will get the benefit from selling electricity by having the agreements with Provincial government (off-grid connection), or with PT PLN (Persero) in on-grid connection based on the FIT regulation[25]. For example, a palm oil mill of Asian Agri needs only about 700 kW for the operation of their facility, while the biogas power plant (Option 2(b)) capacity could reach up to 2.2 MW (Asian Agri, 2018). Since the company has an on-grid connection, thus, the mill could give the remaining to the local communities or signed the excess power or IPP agreement and sell the electricity to PT PLN (Persero) as in the 3rd layer options. Hence, the economic benefit is not only for internal usage, but also could have multiplier effect to the economy of local community and the regions/provinces.

4.1.2.2. Environmental Benefits

In order to support a sustainable palm oil, Option 1(a) is considered has the least impact to the environment, because in the process to reduce the chemical oxygen demand (COD) and biochemical oxygen demand (BOD)[26] so that it is safe for water discharge, it still uses 6-10 open ponds as the aerobic and anaerobic digestion and release methane into atmosphere. Whereas in Option 1(b), POME is converted into biogas by using anaerobic digestion process and using covered lagoons to capture the methane, so that the methane will not go directly into atmosphere (GMI, 2015; Winrock International 2015). The type of material and thickness of lagoon cover also has a standard to prevent the leakage. Moreover, the use of smaller land area for lagoons will reduce the impacts of land use change.

Several palm oil mills also have the potential in contributing to the Clean Development Mechanism (CDM) projects[27], although later on the projects not all operating, but it was estimated to reduce a total CDM volume about 125 Mt CO_2 in 2012 (The World Bank, 2001). The partnership of CDM projects could also attract new businesses in developing the sustainable palm oil (Hassan et al., 2009). However, a biogas facility needs a flare, for the safety reason in case there is excess in biogas production because of over-capacity while processing FFBs. This excess is flammable and the release into atmosphere means the release of GHG emissions, so it needs to develop a methane-capture installation. The project is financially feasible through carbon credit incentive from CDM (Winrock International, 2015). Thus, in the World Bank Report (2001) of CDM projects the utilisation of flared gas was considered as high priority with medium cost. In order to reduce the risk of excess in biogas production, the mill operators should consider stability of FFB supply and the ratio of POME volume to FFB. Actually, the excess of biogas can be stored, compressed or injected to the existing natural gas infrastructure by upgrading of the biogas into the form called as biomethane (UNIDO, 2017). Although, the biogas storage is seen as not really necessary

[25] Regulation of the Minister of Energy and Mineral Resources No 50 Year 2017 (jo. 53/2018) on Utilisation of Renewable Energy Sources for Power Supply
[26] COD and BOD are measurement of the amount of oxygen and organic matter required by bacteria and organic material in the decomposition process (Winrock International, 2015)
[27] https://cdm.unfccc.int/ProgrammeOfActivities/poa_db/A6KOBD5XH7P4IUZMEQ0JY1CT2WGRF9/view

because most of biogas will be used and it is only “a temporary nature, when production exceeds consumption or during maintenance of digester equipment” (Krich et al., 2005: Chapter 4, p.72), as in the case study of renewable natural gas in California, USA. The topic is not going to be a discussion in this thesis (research boundary).

In the 2nd and 3rd layer options, where POME is considered as a renewable energy source for electricity generation, the emissions reductions can be calculated by using the methods in CDM of AMS.I-D Version 18 by the United Nations Framework Convention on Climate Change (UNFCCC) entitled “Small-scale Methodology Grid connected renewable electricity generation”[28]. One example of carbon reduction by a biogas PP that has been demonstrated by PT AANE in Bangka Belitung Province. The company could get the benefits of carbon reduction up to 25,000 tCO_2e/year, or >25 $MtCO_2$, and received a sustainability certification (SDG Action Awards, 2019).

4.1.2.3. Social Impacts

The utilisation of POME as organic fertilizer which means the reduction in amount of waste and the cost for removal has several benefits for farmers in palm oil plantation, such as: more income to farmers since the treated POME can be used as land application in revitalizing the land, minimize the expenses of using other inorganic fertilizers, have better quality of harvested crops so with better quality of CPO for palm oil producers and will improve their income (IEE, 2010). Farmers that have interest to develop the organic fertilizer will also gain more knowledge, not only about the mixture of waste used as fertilizer, but also the creation and sense of good business to develop new products and products diversification.

In the conversion of POME into biogas, the construction process of biogas facility will create new jobs (jobs creation) and affected the social economy of local society. The waste treatment process also will improve the quality of air and water pollution. For palm oil producers or the mills manager, the cost reduction of using biogas to replace the use of fossil or biomass fuels and more profit in biomass exports will improve the livelihood of the company, as well as skills, knowledge or capacity building of their employees.

Furthermore, by using biogas for electricity generation, it will benefit to a larger community. Considering Indonesia has many remote villages and islands, the pilot project of biogas PPs of 1 MW in Rantau Sakti Village, Kecamatan Tambusai Utara, Rokan Hulu, Riau Province can be used to electrify about 1,050 households. Previously, that area has no access to electricity (MEMR, 2014). Similarly, with the first IPP of biogas power plant that is developed by PT AANE. The power plant of 1.8 MW is connected to the grid and could electrify about 2,000 households (capacity of 900 VA/home) (SDG Action Awards, 2019). With electricity, people can have more activities during the night, creating more additional income to the family, children could study in a better condition that will not risk their eyesight or health because of the smoke from kerosene lamp, etc.

[28] https://cdm.unfccc.int/methodologies/DB/W3TINZ7KKWCK7L8WTXFQQOFQQH4SBK

4.2 Roles of Stakeholders

In order to succeed, strong commitment and planned actions or programmes from key stakeholders are needed in order to optimize the utilisation of POME that could contribute to energy and national energy target:

- First layer options of Option 1(a), the utilisation of treated POME could make benefit to the fertilizer industry in Indonesia, particularly organic fertilizers. As already mentioned above, the coordination among ministries, namely MOA, MOT, MSOE, are needed in order to develop the policies in production and distribution, highest retail prices of fertilizers and subsidies for farmers. The actors and networks, such as researchers and research institutions are also involved, in order to formulate the optimal mix of POME and other waste into palm-based fertilizers, educate and make socialisation to the farmers; local governments (Provincial or Regional government) and financial institutions are needed so that palm oil farmers could cooperate with fertilizer producers in promoting the products, etc.
- In Option 1(b), the board of management, engineers and investors have major role in the decision to build biogas facility in the mills. In Indonesia, number of big palm oil companies are not too many compared to the smallholders. However, stimulating big companies to adopt the technology is potentially easier as they need to improve the sustainability performance in an active international trade to comply with RSPO. Regulations and policies of Ministry of the Environment and Forestry (MEF) and Ministry of Industry (MOI), for example, about the health and safety environment rules, national certification standards and the local contents, should support the development of the project.
- In the 2nd and 3rd layer options, the MEMR regulates the policies such as electricity price, FITs, easiness for permits; Ministry of Finance (MOF) regulates type incentives or subsidies for palm oil companies that support the renewable energy development. Lately, there is also Indonesian Oil Palm Estate Fund Agency (Badan Pengelola Dana Perkebunan Kelapa Sawit or BPDPKS)[29]. BPDPKS has tasks to collect and manage palm oil funds[30]. The fund is a levy imposed on commodity exports of CPO. The funds are used for many purposes, such as to encourage human resource development, research and development, promotion, replanting and facilities and infrastructure of oil palm plantations that support the development of sustainable palm oil. The implementation of regulations by the governments should create an interesting market attractiveness not only for the big companies, but also to smallholders, electricity company (PT PLN (Persero) and their regional offices). Furthermore, the associations with an interest in biogas[31] should have stronger networks among others to provide information on actions needed in addressing the issue of low palm oil prices and sustainable palm oil. Since the Regional Government also has responsibilities to develop renewable energy resources as mandated in the Presidential Regulation on RUEN, so the regions or provinces are expected to give contributions to support the projects, in terms of the ease of permits and administrative

[29] BPDPKS is a non-echelon organizational unit in the Ministry of Finance that are under and accountable to the Minister of Finance through the Director General of the Treasury

[30] Presidential Regulation No 61 of 2015 (jo. No 66/2018) on Collection and Disbursement of Oil Palm Estate Fund

[31] Indonesian Palm Oil Association (Gabungan Pengusaha Kelapa Sawit Indonesia or GAPKI), Indonesian Bioenergy Power Producer Association (Asosiasi Produsen Listrik Bioenergi Indonesia or APLIBI), Indonesian Biogas Association (Asosiasi Biogas Indonesia)

procedure requirements/bureaucracy. In addition, the regulation on Regional Energy General Plan (Rencana Umum Energi Daerah or RUED) is being developed by each Province. Lastly, the community itself as actors that their livelihood and living standards may be affected by the projects. The community benefit sharing programme (Wang, C., 2012) seems appropriate to be proposed to the financial institutions because it ensures the social and economic benefits to the local communities affected by power plants projects.

V. Discussion

This chapter will try to answer the sub-research questions 2 and 3 based on analysis used in Chapter IV and interview results based on the data given by the palm oil mill key informants about current conditions to utilize biogas for internal process in palm oil industry. The result of MCA performance matrix, the identification of barriers, including cross-sectoral alignment among stakeholders are presented in this chapter.

5.1 MCA Performance Matrix

Based on the guidance of application criteria that is used in this research, the overall scores are shown in the Table 12. The fulfillment of three sustainability principles and scope of impacts become the main consideration in the scoring.

According to the result as shown in the Matrix, the option by using POME as feedstock in biogas power plants gets the higher score than to be used as fertilizers that only use aerobic treatment ponds. The conversion by using AD process in biogas is considered better to the environment, because it prevents the methane release into atmosphere than using the open ponds in general POME treatment. In addition, if it is only for land application, the effluent from sedimentation pond in a bio-digester system can be used as a fertilizer (see figure in Appendix 5 and the information from a respondent). The biogas PP project itself has been demonstrated to reduce GHG emissions based on the calculation by POCs (SDG Action Awards, 2019). Moreover, the impacts on social and economy also promising, not only for the mills in internal usage (fuels and electricity), but also for the local community. Provincial government also has the benefits in achieving the target of electrification ratio and the utilisation of renewable energy resources.

Table 12 MCA Performance Matrix

Criteria	Economic (Profit)			Social (People)		Environment (Planet)			Scoring*)
	profitable	compliance with standard and regulation	apply good corporate governance and risk management	has support and approval from the employees, stakeholders and the community where it is located	positive social impacts to local or regional community	carbon reduction	water usage	positive environmental impacts	
1st layer options: Utilisation of POME as animal feedstock or fertilizer, or converted into biogas									
Option 1(a)	there is market opportunity to develop the palm-based (organic) fertilizer, to reduce the fertilizer costs in cultivation/land revitalization, and opportunity to add exports or reduce imports in fertilizers	following the standard used in fertilizer industry, although it needs more research on the percentage in the mix of POME and other waste and converted into proportion of nutrient contents in fertilizers		add additional income for farmers and improve livelihoods		it still uses 'traditional waste treatment' in open ponding systems (6-10 ponds), release the methane into atmosphere and high possibility of land use change area			D (few of the requirements have, as yet, been satisfactorily met)
Option 1(b)	biogas can be used in many sectors, to reduce the fuels costs, or generate income by selling electricity	high quality standard is an important requirement in biogas facility		add additional income for mills and improve livelihoods (mills operator, employees and local community/regions)		the anaerobic digestion processes prevent the methane release into atmosphere, use smaller land area for lagoons			C (some requirements have been satisfactorily or fully met, but others have not yet been satisfactorily met)
* Notes: A = all of the requirements are fully met; B = all of the requirements are satisfactorily met, although some further improvements are desirable; C = some requirements have been satisfactorily or fully met, but others have not yet been satisfactorily met; D = few of the requirements have, as yet, been satisfactorily met (IDPM, 2001)									
2nd layer options: Utilisation of biogas from POME in palm-oil industry sector (internal process), or power plant sector									

Criteria	**Economic (Profit)**			**Social (People)**		**Environment (Planet)**			**Scoring*)**
	profitable	compliance with standard and regulation	apply good corporate governance and risk management	has support and approval from the employees, stakeholders and the community where it is located	positive social impacts to local or regional community	carbon reduction	water usage	positive environmental impacts	
Option 2(a)	biogas could replace the use of palm shells as biomass fuels used in boilers and make benefit from palm shells exports	health and safety, environmental standard, comply with national certification standard are obligatory requirements in biogas power plants facility		add additional income for mills and improve livelihoods (mills operator, employees that live in surrounding facility)		the main objective is to reduce GHG emissions (PT AANE was built 1.8 MW of biogas power plant capacity with POME-based and reduce >25 $MtCO_2e$)[32]. The palm oil mills could also get the benefit for sustainability certification. It also reduces water and air pollution (waste treatment).			B (all of the requirements are satisfactorily met, although some further improvements are desirable)
Option 2(b)	electricity from biogas could reduce the operational costs and make profit from selling electricity			add access of people to electricity (regional/Provincial electrification rate), improve livelihoods of local community					B
3rd layer options: Type of connections (off-grid or on-grid) and agreements in biogas power plants-POME based									
Option 3(a)	electricity from biogas could reduce the operational costs and make profit from selling electricity, whether as an IPP or excess power producer			suitable for remote areas (villages or islands) and small-scale generation		same as above			B
Option 3(b)				could contribute to the reliability of grid connection (regionally or nationally)					B
* Notes: A = all of the requirements are fully met; B = all of the requirements are satisfactorily met, although some further improvements are desirable; C = some requirements have been satisfactorily or fully met, but others have not yet been satisfactorily met; D = few of the requirements have, as yet, been satisfactorily met (IDPM, 2001)									

[32] https://sdgactionawards.org/initiative/1375

5.2 Sensitivity Analysis (Step 8th of the MCA)

Buchholz et al. (2009) showed that the uncertainty treatment can be applied in the criteria weighting or in assessing the performance of the alternative options (scoring). In the decision making by MCA, stakeholders can be involved and contribute in the process, such as to give inputs in building the model and selection of criteria, criteria weighting and to assess rankings on scenario options (Buchholz et al., 2009; Cinelli, Coles and Kirwan, 2014).

The model in this research is presented in a general context with simplified scenarios based on possible options in the utilisation of biogas in industry and power plants sectors. Hence, the scenario options are limited into the utilisation of biogas from POME in internal process, such as to replace fuels in boilers, and the implementation of biogas power plants, such as to fulfill electricity needs in the mills, or to the local community by connection into grid systems. In this research, researcher got the information from the palm oil mills as follow: Firstly, in the mill which only uses the output of electricity generation connected to the grid (IPP), they gave an idea to use biogas to replace the biomass fuels in the boilers and make additional revenue benefits from the selling of biomass (palm shells) feedstock for fuels. Secondly, in the mill which sells part of the output power generated by biogas power plants (excess power), the respondent stated that the electricity output can be used for their additional machineries, hence it will improve their productivity. Considering the project of biogas to energy needs a high amount of investment, so it can be done by big companies which has a strong capital. Nevertheless, it is expected that the project could also be done by all players in palm oil industry (government estates, private estates and smallholders). Because, number of smallholders are quite many and could give large potential in electricity generation. These criteria have not been shown in the model. Furthermore, lack of quantitative data, since the data are confidential, become the challenges in this research to account the uncertainty applications in more detail.

5.3 Interview Results and Analysis

As planned in the research framework, interviews have been conducted with companies that built and developed biogas power plants that is also a subsidiary of major palm oil company. Both companies have good awareness on sustainable palm oil. They apply Principles and Criteria of RSPO and ISPO, and also got the ISCC certification. The Company A has contract agreement with PT PLN (Persero) as an IPP for 15 years since 2013, and Company B has contract agreement as excess power. The main purposes of the interviews are to find the motivation in building the biogas PPs facility, the reasons to choose type of contract agreements and to identify the barriers in project implementation. The results of interviews are as follow:

Topic and Questions	Organisation: Independent Power Producer (IPP)
Motivation to develop biogas power plant from POME	To reduce GHG emissions and to produce energy for internal and/or external usage in the plantation.
Previous waste treatment	By using open ponds (7-10 ponds) to decrease the BOD and COD level biologically as regulated in the emission standard so it is safe to be used in land application or discharged into water.

Topic and Questions	Organisation: Independent Power Producer (IPP)
Barriers in implementation of the project	The project had full supports from regional government and state-owned electricity company, because the area has no electricity at all (east Belitung). However, nowadays the electricity tariff of IDR 975/kWh (7 cent USD) for electricity from renewable energy is no longer fit to economic conditions. Particularly for the operational costs, because for the maintenance and spare part mostly are imports so that the increasing price are quite significant. This matter may affect the continuity of operations.
Problems in cross-sectoral coordination	The coordination is quite good. The project usually become a comparative study place or visits for the government and associations. The payment from PLN, in average, are paid less than 60 days.
Roles of associations and suggestion	The associations should look deeply about potential of waste as renewable energy as an integrated part of palm oil mills, not just its derivative products, such as biofuels. Because, the potential of waste in not only to reduce GHG emissions, but also to meet energy needs at the plantation itself.
Reasons in choosing an agreement as an IPP instead of excess power	IPP has the certainty of long-term cooperation, instead of excess power contract that only lasts for 1 year although can be renewed depends on the PLN needs. So, from the investment perspective, IPP is considered more certain and safer.
Capacity of power plant and development planning	Capacity of 1.8 MW are connected to the PLN's grid with annual rate of capacity factor (CF) > 80%. The electricity generation from biogas power plant could electrify about 2,000 households with capacity of 900 VA per home. The parent company has plan to develop biogas power plants in all subsidiary of palm oil mills, with main objective to fulfill the mills' own energy needs. The development of a second biogas facility is planned to be located at North Sumatra I Plantation.
Opinion about mandatory regulation for all palm oil mills to build their own biogas power plant	Strongly disagree. At least, there are 3 barriers: • a mandatory regulation could mean that palm oil mills will only build in order to meet the minimum standards of the regulation. They will look for the cheapest options and quality is not the priority (a good standard of 2 MW biogas power plant, from 60 tonnes per hour of mills' capacity, needs investment about USD 2.7 – 3 million). • as condition above, then the business will not become sustainable. The project needs serious expertise and skillful workforce (administratively and technically). • since biogas power plants are fire-prone (methane gas)[33], so if the quality of equipment and operations are not good, then accidents that could endanger workers and plantations are possibly to happen. This can cause a negative image of the business and weakened the trust of investors.

[33] Biogas contains flammable gases (50-75% methane, 20 to 50% CO_2, hydrogen sulphide (0.01 to 0.4% vol.), and traces of ammonia, hydrogen, nitrogen, and carbon monoxide), an explosion is possible to happen if the concentration of biogas exceeds the lower explosive limit (German Agricultural Occupational Health and Safety Agency, 2008)

Topic and Questions	Organisation: Independent Power Producer (IPP)
Partnership cooperation with smallholders	It is possible and it is already been done by developing plasma plantations[34].
Suggestions for the government or other institutions (policy makers)	Palm oil mills is a long-term business (30 years of production of oil palm trees), so POME as raw material of renewable energy is expected to be sustainable. The number of palm oil mills in Indonesia is many, and the technology for biogas power plant is not new and has been proven to have good performance. Hence, the problems that seek for solutions are how to get the revenue to return the investment and develop other biogas power plants. The problems are: 1. at this moment, there is no reward (or price) on the value of GHG emissions reduction from renewable energy. Only can be added as part of the RSPO in order to get a premium CPO selling price, which lately has been very difficult to get because of various environmental issues of Indonesian palm oil. 2. high costs, because most of the main equipment (gas engine, control panel, etc.) are imported. Products with local content are limited and not as cheap as imported products, for example compared to products from China or other countries. 3. electricity tariff (from renewable energy) is not yet attractive. Current tariffs, as stated in the regulation[35] is capped at the maximum of 85% of the cost of generation (BPP Pembangkitan) of the local grid system, as if renewable energy is forced to compete against the BPP from fossil fuels. 4. the option in buying mechanism of direct and the cooperative model of BOOT are not flexible for IPPs. Because the companies prefer their own partners (joint venture or contract), and, because most of oil palm plantations only has land cultivation rights title or business land use permits (hak guna usaha (HGU)).
Planning to develop the utilisation of biogas in other sector (i.e. transportation)	The potential is still open although it is not feasible if only for internal use, because of high investment and challenge in infrastructure.
Expectation to improve sustainable palm oil in Indonesia	Low CPO price because of negative image/perspective on palm plantation is the main priority at this moment, hence the progress development of biogas power plants become very slow. However, the presence of biogas power plants to answer environmental issues and the implementation of sustainable palm oil are also important. Government's policy to support the development of biogas power plant is needed.

The response from companies A and B to several questions are quite the same, such as the motivations to develop biogas power plant from POME are the company's commitment

[34] The plasma estate is a plasma area (a residential and farming area developed by participating farmers in the context of the implementation of the project of the People's Core Company (PIR), which includes yards, housing, and plasma plantations) which is built by a core company with plantation crops (Sawit, 2018)
[35] Regulation of the Minister of Energy and Mineral Resources No 50 Year 2017 on Utilization of Renewable Energy Sources for Power Supply (jo. No 53 Year 2018)

to environmental sustainability and to support renewable energy, and the type of waste treatment traditionally. However, company B gave some different answers or provided additional information which are given in the following table:

Topic and Questions	Organisation: Excess Power Producer
Barriers in implementation of the project	the barriers when the project is being developed are making the decisions for the biogas plant system to be used, the construction team, so that the quality of work and schedule in accordance with the plan. After the project is done, the barrier is in the maintenance of power plants. Because it is not easy to find experts for repairing and the availability of spare parts in the market.
Reasons in choosing an agreement as an excess power instead of IPP	because the output power of electricity generation from the mill is only enough for the mill itself. The mill uses the electricity to develop and run additional facilities of Kernel Crushing Plant (KCP) dan Empty Bunch Press (EBP). Then, the excess power is sold to PLN.
Capacity of power plant and development planning	the capacity of biogas PP is up to 2 MW[36] (the mill uses about 700 KW, the excess is sold to the local grid operator, and the company has plans to build 20 power plants in every mill by 2020). So far, 7 biogas power plants from POME[37] have been operated and 3 are in the progress of projects.
Opinion about mandatory regulation for all palm oil mills to build their own biogas power plant	agree that the palm oil mill must have access or build its own power plant to meet its electricity needs, but as a mandatory it will be difficult because the investment costs are high/expensive. The barriers, such as for small companies is to find the investors, and it needs support from PLN in terms of the ease of selling electricity.
Suggestions for the government or other institutions (policy makers)	PLN to prioritize the electricity sales from biogas power plants, because it is more environmentally friendly. So that the electricity from excess power is used 100%.
Expectation to improve sustainable palm oil in Indonesia	To obtain superior seeds with higher quantity and the yield of production/hectare. And, the awareness to implement sustainable palm oil from its own, not make damage to the environment.

From the answered questions, the companies receive benefits from the conversion of POME into biogas and energy (electricity generation) and give impacts not only to the company itself, but also to the local community. A high investment cost is the challenge by decision makers in the company to find investors at the beginning of project. Company A has a joint venture with a German company, while Company B is self-funding. But, with strong commitment and cooperation with PLN, as electricity company, and government, as policy maker, they could solve the cross-sectoral problems, and the coordination needs to continuously improved.

Both companies have found difficulties in the maintenance stage. Lack of 'local' knowledgeable-skills and spare parts are one of the issues, because biogas energy systems need high quality of knowledge, skills, careful treatment and safety. And most of the spare parts are not available in the local market, so they need to import them. By this means, there

[36] In the real contract agreement, it was only less than 1 MW that has been sold to the PLN
[37] The subsidiary companies are also in the list of POCs that have the installation of PPs (Table 3 in Chapter I)

are gaps between the suppliers have and the industry needs, but also an opportunity to develop the industry locally and the services industry.

Both companies suggested that it will be difficult in the implementation if a mandatory regulation for every palm oil mill to build biogas power plants is going to be applied, particularly for small companies. A mandatory requirement to treat the palm wastes has been introduced according to regulatory discharge limits[38], and biogas power plant is only one option to treat the wastes. However, to achieve renewable energy target[39] and to reduce GHG emissions as become the main motivation and commitment of the companies in supporting sustainable palm oil, then the effort should be valued. For example, as it has been applied in Malaysia (Chong et al., 2017), by giving them incentives or tax exemption. As mentioned in Chapter 4, the CPO fund that is managed by BPDPKS are distributed to give incentives on biodiesel, as affirmed in Article 18 on the Presidential regulation (BPDPKSa, 2018), in order to support a mandatory regulation on fuels blending of B-20[40]. Since biogas from POME are also renewables and could reduce the GHG emissions, hence it is possible for the development of biogas power plants-POME based to receive incentives from the CPO fund too.

Both companies have good experience in partnership cooperation with smallholders. The cooperation is expected to be developed in order to assist the smallholders in managing the waste treatment or to become actively involved in sustainability commitments. Suggested improvement such as to define benefit-sharing to the community (Community Benefit Sharing) as it has been implemented in several project of renewable power plants and financed by World Bank (Wang, C., 2012).

5.4 Identification on Barriers and Cross-sectoral Alignment among Stakeholders

Based on literature study and interviews, the barriers that cause slow progress in the development of biogas power plants from POME are explained as follow:

- High initial investment costs

  PT Asian Agri estimated the costs to build 20 biogas PPs by 2020 is about USD 120 million (Kompas, 2018). Furthermore, some research on the feasibility of biogas PPs-POME based showed that the projects are feasible to be implemented. Nuaini, N., Hamdani, H., and Rizal, T.A. (2018) calculated that the mills with a capacity of 50 tons FFB/hour and POME generation of 0.6 m^3 / ton FFB will be able to produce electricity of 1.3 MW in Aceh Province. The internal rate of return (IRR) = 19.2%, positive net present value (NPV) and the payback period about 7 to 8 years. Nuryadi, A.P., et al. (2019) recommended the project's duration of 15 years with IRR = 17.47%, and payback period for 5 to 6 years in Riau Province. The research also show that alternative options of 5 years period is still feasible. The Nuryadi's research uses electricity selling price of IDR 975/kWh as regulated in the 2012 regulation. Thus, it depends on the investors to choose the shorter or longer periods. Moreover, with their risk assessments it can be analysed which type of agreements (IPP or excess power) which are more feasible to be implemented in the POCs. Higher electricity selling price will make the project become more attractive because it will lessen the payback periods.

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[38] Regulation of the Minister of Environment and Forestry Number 5 of 2014 (jo. No 1/2018) on Quality Standard of Wastewater (Appendix III in palm oil industry)

[39] Government Regulation Number 79 of 2014 on National Energy Policy

[40] Regulation of the Minister of Energy and Mineral Resources Number 12 of 2015 on Biofuel Supply, Utilisation and Trading as an Alternative Fuels

- High maintenance costs because most of main equipment and spare parts are import products, or limited availability in local market
  The GOI always strives to strengthen the industrial sector[41]. The MOI regulates tax allowance for industries that have high investment, high employment and apply 20% of the level of domestic components (Tingkat Komponen Dalam Negeri or TKDN)[42] and support the use of domestic products in electricity infrastructure[43]. Although the regulations are not specific for electricity generation from renewable energy of waste resources, but domestic products should be improved and need to be competitive in quality and price with import products.
- No value or reward on effort to reduce GHG emissions and support the utilisation from renewable energy
  Considering the commitment of Indonesia to reduce GHG emissions as stated in the Intended Nationally Determined Contribution (INDC)[44], such as to utilise waste into energy. Hence, the utilisation of POME in biogas PPs can be proposed to get certain value or reward that could become the benefits for palm oil mills.
- Electricity selling price is no longer economically feasible in the current economic conditions
  The company that had the PPA in 2013 were using electricity selling price of IDR 975/kWh based on the regulation[45] which is no longer valid[46]. While the electricity tariff to the consumer had the adjustment since 2014. The fluctuation of tariff adjustment[47] are caused by exchange rate, inflation and the Indonesian Crude Oil Price (ICP). The electricity selling price nowadays are not suitable anymore to cover the maintenance costs, because the price of spare part and equipment are decreasing significantly than the price in 2012/2013. So, the electricity selling price should be evaluated to make the market become more attractive.
- Buying mechanism of direct and the cooperative model of BOOT are not flexible
  Directorate General of Estate Crops said the problems related to the plantation, other than productivity is not maximal, are because most of the plantation area only has the right of HGU (Republika, 2018). HGU is the right to cultivate land directly controlled by the state for agricultural, fishery or livestock companies. HGU can be given for a maximum period of 35 years and can be extended for a maximum of 25 years[48]. According to the regulation,

[41] Government Regulation No 29 Year 2018 on Industrial Empowerment
[42] Regulation of the Minister of Industry Number 1 of 2018 on Criteria or requirements in the implementation of utilization of income tax facilities for investment in certain business fields and / or in certain areas of the industrial sector
[43] Regulation of the Minister of Industry Number 48 of 2010 on Guidelines for the use of domestic products for electricity infrastructure development
[44] https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Indonesia/1/INDC_REPUBLIC%20OF%20INDONESIA.pdf
[45] Regulation of the Minister of Energy and Mineral Resources Number 4 of 2012 on Purchase price of electricity by PT PLN (Persero) from small and medium scale of renewable energy power plants or excess power
[46] Regulation of the Minister of Energy and Mineral Resources Number 7 of 2018 on Revocation of the regulation of the Minister of Energy and Mineral Resources and regulation of the Minister of Mining and Energy related to electricity business activities
[47] Regulation of the Minister of Energy and Mineral Resources Number 28 of 2016 (jo. 41/2017) on Tariff of electricity provided by PT PLN (Persero)
[48] Law Number 5 of 1960 on Basic Agrarian Principles (Undang-undang Pokok Agraria or UUPA)

with the status of HGU, the farmers can do business activities, but the owner of the land is the state. If the Transfer in BOOT scheme is done, then it will stop the business activities. So, it is not possible to transfer of the assets because the land does not belong to the oil palm producers. Other than that, the farmers may not want to sell the land because it is family's heritage as assets or cannot sell it because the land is used as collateral in the bank. Thus, the option to revise the regulation or change the BOOT scheme into BOO can be considered as a solution in this matter.

- The ease of selling electricity business by PT PLN (Persero)
  Based on the survey of World Bank in Ease of Doing Business (EoDB), access to electricity is one of the indicators [49]. Based on the report, Indonesia has the rank of 33 in the ease of getting electricity performance. PT PLN (Persero) has the planning on the Reformation of Electricity in 2020, such as to simplify the procedure (one-door-service and the change of business perspective from downstream to upstream), time (the process to add electricity connection become not more than 18 days), tariff and reliability (automatization in system and special teams) (PLN, 2019). Hence, the ease of electricity business or business to business agreements with IPP or excess power should be improved too.
- The priority to buy electricity from biogas PPs
  Several regulations have been applied to support the utilisation of renewable energy sources for power supply (Regulation of the MEMR Number 12 of 2017 as it has been changed into Number 50 of 2017 (jo. Number 53 of 2018)). Until now, the realization of primary energy mix target in renewable energy resources is about 17.55 MTOE (8.55% of total energy mix) (MEMR, 2019). So, as long as the dominance of the PPs is still from fossil fuels (where the price is lower and receive subsidy), so it is hard for renewable energy PPs to compete with.
- Fiscal or non-fiscal incentives
  Based on Indonesia Clean Energy Outlook 2019, the projects of renewable energy are seen risky by local banks, so they implement high interest rates. A high collateral that makes small-scale developers become more difficult to get financial supports and face challenge to meet a creditworthy project sponsor (IESR, 2018). The government has introduced several regulations to support the utilization of renewable energy resources, such as tax allowance, exception of income tax collection 22 imports, exemption of value added tax (VAT) imports, exemption from import duty on import of goods and machineries, facility of tax borne by the government[50]. Unfortunately, the tax incentives have not been utilized optimally by developers/investors, due to a lack of familiarisation, so the prospective investors are not aware/know with the type of incentives, and there are still obstacles at the technical level of implementation (BKF, 2019). Moreover, the electricity, steam, fuel substitution, and/or biogas, which are produced from processing of organic waste (sludge and POME) in palm oil mill are clearly stated to receive income tax allowance facility[51]. The Government also has regulated the infrastructure projects that are provided by the Government through cooperation with Business Entities (Kerjasama

[49] https://www.worldbank.org/content/dam/doingBusiness/media/Annual-Reports/English/DB2019-report_web-version.pdf
[50] Regulation of the Minister of Finance Number 21 of 2010 on Granting of taxation and customs facilities for renewable energy resources activities (PMK No.21/PMK.011/2010)
[51] Government Regulation Number 18 of 2015 (jo. 9/2016) on Income tax facilities for capital investment in certain businesses and/or in certain regions (Appendix II)

Pemerintah dan Badan Usaha or KPBU) where infrastructures on energy and electricity are included in it[52]. The government will continue the incentives and add new incentives, namely subsidy on interests, VAT exemption of construction services, and emission reduction incentives (BKF, 2019). In addition, to solve the problems in profit margins because of low electricity selling price, high transaction costs and the risks in project development, and the perception of risks by financial institution as mentioned above, the government also has plans to introduce the Renewable Energy Fund (REF)[53], this concept will be synergized in the platform of Sustainable Development Goals (SDG) Indonesia One.

The recommendation of strategies or instruments needed to overcome the barriers above are discussed in the following section.

5.5 Recommended Actions

The recommended actions needed are explained in the following:

a. To increase awareness about sustainable palm oil

The POME treatment that uses anaerobic digestion process in biogas facility is proven to reduce the GHG emissions (environment), to add the company's profit (economy) and to improve livelihoods of the local community (social). The information and education of the value-added creation of POME should be implemented to all POCs, including smallholders. For example, the big POCs and smallholders to implement a joint-cooperation or partnership between build biogas facility or biogas PPs; the local government, POCs, PT PLN (Persero) and local community to design and develop Community Benefit Sharing programme. In this matter, the associations of palm oil producers, biogas developer or bioenergy power producers should strengthen their roles in giving the inputs to the government and helping the socialization of policies and the importance to reduce the emissions to all players. Because of the emergence problem in the oil palm industry, so the comprehensive actions from associations are needed as organisations that united all stakeholders.

b. To improve the socialization of the incentives and financial solutions

The MOF, MOI and MEMR to communicate and socialize the regulation of incentives that support renewable energy development to all prospective investors to attract their interest, to implement and monitor the new incentives that have been planned: subsidy on interests, VAT exemption of construction services, and emission reduction incentives (BKF, 2019), to clearly define type of infrastructure projects and procedures that can be provided through cooperation between Government and Business Entities. In addition, the MOF and MSOE to assign a state-owned company or develop a new financial institution, with similar function of BPDPKS, to manage the renewable energy fund or to deal with the financial matter in renewable energy power plants development. The government could also give the incentives of CPO price that is used as biofuels to attract

[52] Regulation of the Minister of PPN/Head of National Development Planning Agency Number 4 of 2015 on Procedures for Implementing Cooperation Government with Business Entity

[53] REF has main objective to distribute incentives in accelerating the investment in renewable energy by reducing the risk of renewable energy projects

palm producers in increasing their productivity, so then it will increase the resources of POME too.

c. To improve the local content in the production of spare parts needed

The MOI to identify the main equipment or spare parts that are used in biogas power plant facility and cooperate with MOT and Small and Medium Enterprises (SMEs) in managing the production, distribution and price in the local market. The government could give incentives for industries of power plants that could increase the local contents in their products, and to electricity producers which use the products, such as by giving an additional or higher electricity selling price.

d. To educate, train and develop skills and knowledge in technology transfer

The MOI, Ministry of Education and Culture and Ministry of Cooperatives and SMEs to support new innovative products or business incubators in product development by training to improve the skills of the operator in renewable energy power plants, particularly biogas operator. Although the activities may also be seen as a threat to the companies if their employees choose to resign and work with their competitors. Or, by education, in a long-term plan, to introduce the technology of renewable energy power plants in the subject of the curriculum in vocational schools.

e. To develop the ease of business

The MEMR to review the Regulation of the Minister Number 50 of 2017 (jo. 53/2018) about the scheme of BOOT is changed into Build Own Operate (BOO), and the buying mechanism of direct selection is changed into a direct assignment for local partnership cooperation. The government also can review the mechanism of FIT, or, if it is necessary to give the subsidy for renewable energy fuels price that is higher than non-subsidized fossil fuels price. PT PLN (Persero) also to improve their performance by implementing their plan on the Reformation of Electricity.

f. To accelerate energy policy targets

All ministries related, as also mentioned in Chapter IV, should cooperate and work together in achieving the target of the NEP. Because the target of bioenergy power plants of 5.5 GW in 2025 has not planned in details percentage on which will give the highest contribution and has large potential resources, whereas POME also has the potential to be developed. The commitment from key stakeholders and the programme implementation that works in line with policy and regulatory framework are important in accelerating renewable energy development in Indonesia.

In summary, by using the framework of thinking of the conceptual model of governance of Bressers and Kuks (2003), the five interrelated dimensions of the model are shown in Table 13.

Table 13 Cross-alignment in the Conceptual Model of Governance

Governance levels	**Actors and their networks**	**Problem definitions and objectives**	**Strategies and instruments**	**Responsibilities and resources**
Main problems: lack of motivation to utilize POME into energy Objectives: to increase awareness about sustainable palm oil; to accelerate the utilization of POME into energy in achieving the national target in renewable energy				
The government as policy makers and POCs as decision makers to improve the optimal utilization of POME into energy	The governments (ministries related), POCs, smallholders, the associations of palm oil producers, biogas developer or bioenergy power producers, PT PLN (Persero), financial institutions and the local community	High maintenance costs because most of main equipment and spare parts are import products, or limited availability in local market	To improve the local content in the production of spare parts needed	Ministry of Industry, Ministry of Trade and Ministry of Cooperatives and SMEs in managing the production, distribution and price in the local market
			incentives for industries of power plants that could increase the local contents in their products	
			To educate, train and develop skills and knowledge in technology transfer	Ministry of Industry, Ministry of Education and Culture and Ministry of Cooperatives and SMEs to support new innovative products or business incubators in product development by trainings for mill operators or add curriculum about the technologies in vocational schools
			the design and development of the	local government, POCs, PT PLN (Persero) and local community

Governance levels	Actors and their networks	Problem definitions and objectives	Strategies and instruments	Responsibilities and resources
			Community Benefit Sharing programme	
		High initial investment costs	To improve the socialization of the incentives and financial solutions, including the government's plan to give the subsidy on interests, VAT exemption of construction services, and emission reduction incentives	POCs to implement a joint-cooperation or partnership to build biogas facility or biogas PPs
		No value or reward on effort to reduce GHG emissions and support the utilisation from renewable energy		Ministry of Finance, Ministry of Industry and Ministry of Energy and Mineral Resources to communicate and attract investors to be familiarized with the type of incentives
		Electricity selling price is no longer economically feasible in the current economic conditions	incentives to electricity producers to get higher electricity selling price that use most of the local content in their products	
			review the mechanism of FIT, or, if it is necessary to give the subsidy for renewable energy fuels price that is higher than non-subsidized fossil fuels price	Ministry of Energy and Mineral Resources, Ministry of Finance and Ministry of State-Owned Enterprise (c.q. PT PLN (Persero)) to review the regulations
		Buying mechanism of direct and the cooperative	To develop the ease of business	

Governance levels	Actors and their networks	Problem definitions and objectives	Strategies and instruments	Responsibilities and resources
		model of BOOT are not flexible	the scheme of BOOT is changed into Build Own Operate (BOO), and the buying mechanism of direct selection is changed into a direct assignment for local partnership cooperation.	
		The ease of selling electricity business by PT PLN (Persero)	PT PLN (Persero) to implement their plans on the Reformation of Electricity (simplifying the procedure, the change of business perspective from downstream to upstream, more efficient in process to add electricity connection, tariff and reliability, and more transparent in B2B agreements with POCs (the installed capacity and the amount that can be sold).	Ministry of Energy and Mineral Resources and Ministry of State-Owned Enterprise (c.q. PT PLN (Persero))
		Fiscal or non-fiscal incentives	to continue the existing incentives and add new incentives	Ministry of Finance, Ministry of Energy and Mineral Resources, Ministry of Industry, Ministry of Trade
			clear and transparent procedure in the	

Governance levels	Actors and their networks	Problem definitions and objectives	Strategies and instruments	Responsibilities and resources
			cooperation between government and business entities scheme (KPBU) related to infrastructure projects	
			develop and monitor the implementation of Renewable Energy Fund	Ministry of Finance and Ministry of State-Owned Enterprise to assign a state-owned company or develop a new financial institution to manage the renewable energy fund or to deal with the financial matter in renewable energy power plants development
			To accelerate energy policy targets	Coordination from all key stakeholders

VI. Conclusion and Recommendations

The findings and analysis are summarized in the Conclusion (section 6.1), and the recommendations for future research (section 6.2) are presented in this chapter.

6.1 Conclusion

In a conclusion, in a production process of CPO, POME has the potential to be used either as organic fertilizers or converted into biogas to generate electricity in biogas PPs. As one of the largest producers of palm oil, Indonesia has a high resource potential (60% of POME is being produced in CPO Production). The utilization of POME as organic fertilizers could develop new business opportunity, but it needs a better method in the pre-treatment process and a clear business scheme from upstream to downstream. While the conversion of POME into biogas is possible because the technology is already available and not too difficult to be learned and implemented. Moreover, the utilization of POME as feedstock in biogas PPs has been well demonstrated by several POCs and shows the reductions of GHG emissions. By using the concept of sustainable energy management which applies the sustainability criteria in the framework of thinking of MCA, researcher found that the option to convert POME into biogas and use it to generate electricity is considered as the most promising option. Because it is not only can support to achieve the national targets in renewable energy but also to show the country's real commitment in combatting global climate change.

The challenge or barriers that needs to overcome in the implementation of biogas PP-POME based, such as the lack of awareness of sustainable palm oil and the familiarization of the type of incentives, business schemes and financial solutions, the gap in the market of products equipment which has to have local contents and the ambition to achieve renewable energy target as stated in the NEP. The stakeholders, any individuals, groups or community that can affect or is affected by the policy implementation, are not only the government as policy maker or the POCs and electricity companies that make the agreements, but also the local community, financial institutions and associations of palm oil producers, biogas developer or bioenergy power producers. These complex processes require strong commitment and cooperation from multi-actors (all key stakeholders) which involve coordination in multi-policy-sectors.

The recommended actions to overcome the barriers are as follow: to improve awareness creation and the information on fiscal and non-fiscal incentives, including the plan to apply emission reduction incentive and Renewable Energy Fund; to evaluate the ease of business, including the option to review the policies and regulatory instruments, such as the regulations in buying mechanism of electricity, change the BOOT scheme into BOO, adjustment in electricity tariffs from renewable energy resources and the risks allocation between government and business players; and to develop human resources capacity with high standard of skills and knowledge. Nevertheless, all these actions need significant changes in good governance, better coordination among Ministries and with main players in the oil palm industry in achieving the target to accelerate renewable energy development in Indonesia.

6.2 Recommendations

In answering the main research question, this thesis manages to analyse the options or the advantages in utilising POME either to be used in electricity generation or as other by-products. This thesis also manages to identify the barriers in cross-sectoral alignment and suggest several actions that can be implemented by policy makers in solving current problems. In order to optimise the contribution of POME to achieve the Indonesian national target of bioenergy PPs in 2025, researcher found that it needs strong commitment from key stakeholders in removing the barriers/bottlenecks. Particularly, to motivate all palm oil producers of their waste treatment, to use cleaner technology and to support the development of sustainable palm oil in Indonesia. Researcher also learns that the implementation of policy in multi sectors requires cross-sectoral coordination and it needs to monitor the policy implementation continuously. So that the objectives and the targets of the policy implementation can be achieved.

Due to limited access and data confidentiality, particularly in quantitative data, researcher found a quite big challenge in this thesis. Thus, researcher cannot calculate the estimation of contribution percentage of POME to achieve the national target. This study also limited in sample size, particularly to analyse the barriers from the perspective of smaller companies that have not built biogas facility. This research only use framework of thinking in the MCA and the chosen criteria based on sustainability principles are also not involving the stakeholders.

For future research, the study could add the sample size of the palm oil mills that have not yet develop biogas PPs and add more parameters or indicators in the criteria. It can also involve the stakeholders at the beginning of the research, for example by conducting meetings or focus group discussions to have more in-depth information. Further research also needed to analyse the impacts to the local community, in terms of economic, social and environmental impacts thoroughly.

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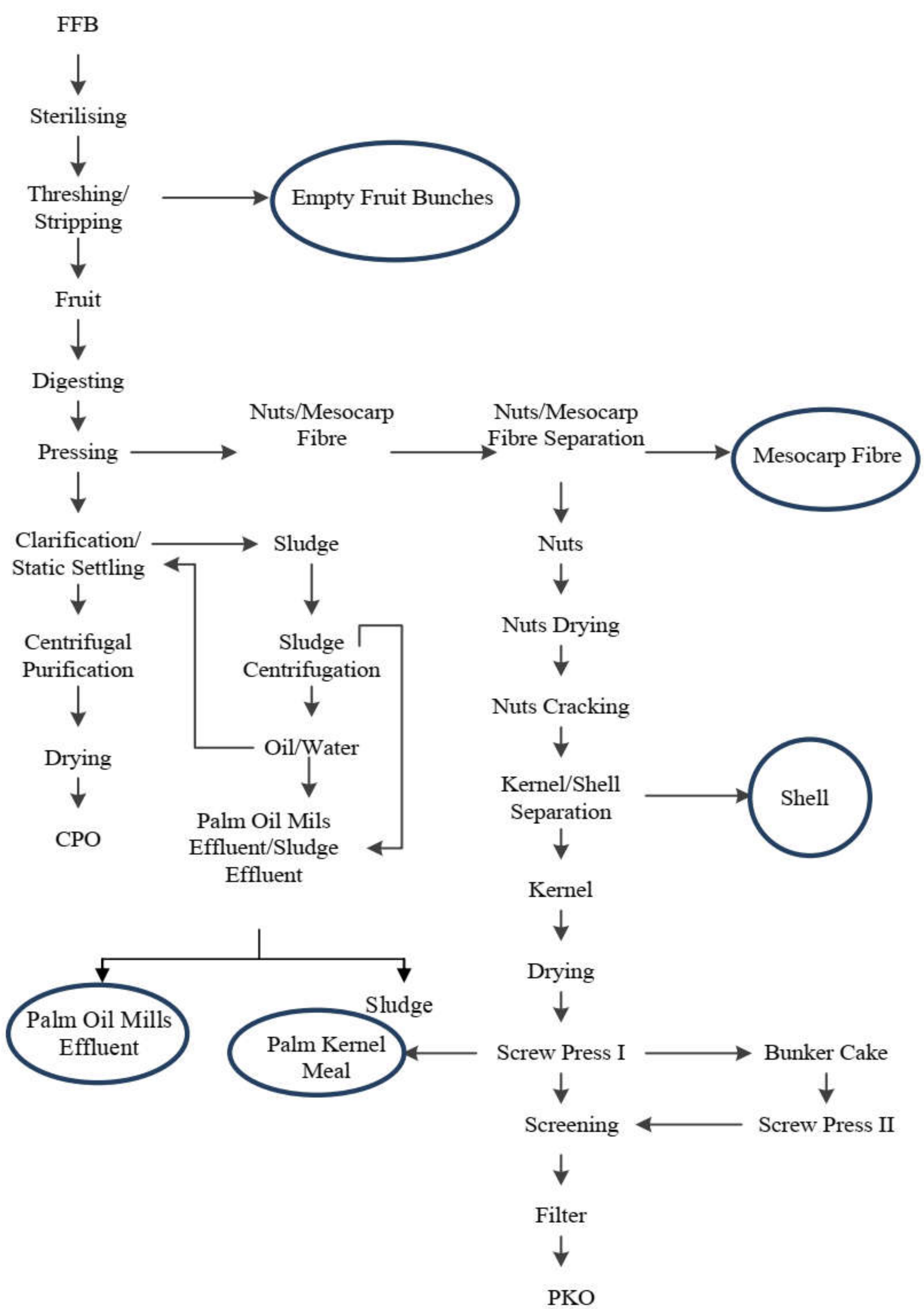
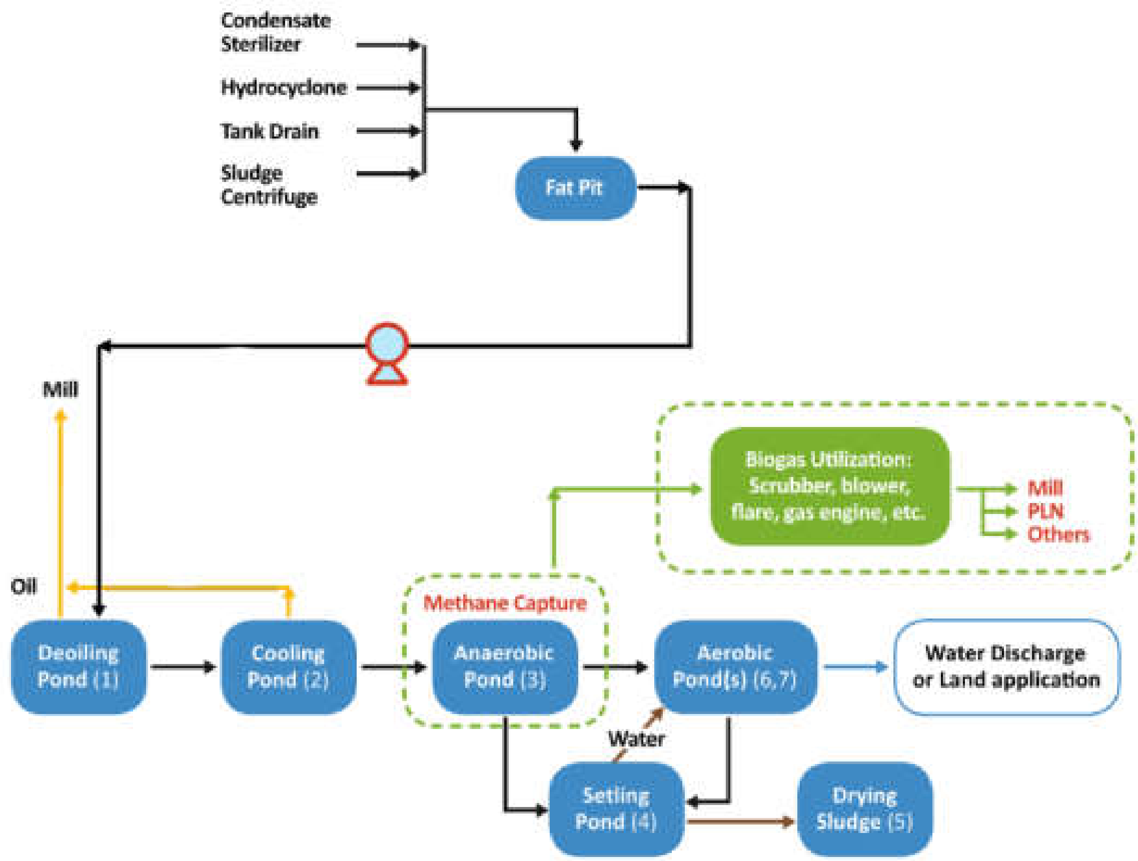
APPENDICES

Appendix 1 Flow Diagram of POME Waste in CPO Production Process



Source: Hambali and Rivai, 2017

Appendix 2 Flow Diagram Process in Typical Palm Oil Mills in Indonesia



Source: Winrock International, 2015

Appendix 3 Formulas to Calculate the Mill's Potential Power from POME

Basic Assumptions:

Volume per methane produced per kg of COD removed from the wastewater:

$CH_4/COD = 0.35\ Nm^3\ CH_4/kg\ COD\ removed$

The percentage of COD that will be converted to methane:

$COD_{eff} = 80 – 95\%$

The energy content of methane:

$CH_{4,ev} = 35.7\ MJ/m^3$

Efficiency of gas engine in converting energy value of methane to electrical energy:

$Gen_{eff} = 38\text{-}42\%$

Formulation:

$$(1)\ \text{Daily throughput (tons FFB/day)} = \frac{\text{Annual FFB}}{\text{Operating days}}$$

$$(2)\ \text{Daily wastewater flow } (m^3/day) = \text{Daily throughput} \times \text{Ratio POME to FFB}$$

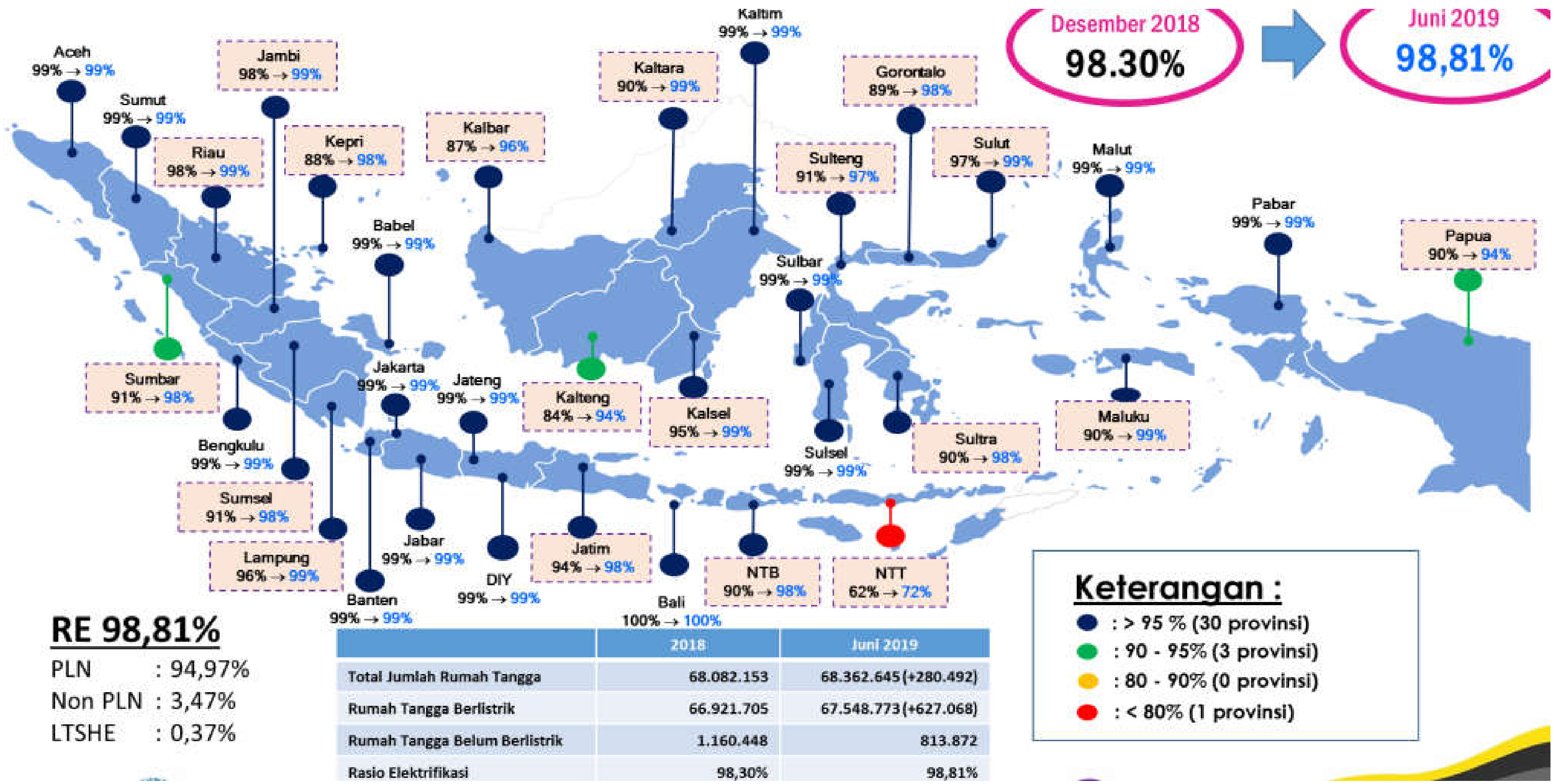
$$(3)\ \text{COD loading (kg COD/day)} = \text{Typical COD} \times \text{Daily wastewater flow} \times \frac{kg}{1{,}000{,}000\ mg} \times \frac{1000\ L}{m^3}$$

$$(4)\ CH_4 \text{ production } (Nm^3\ CH_4/day) = \text{COD loading} \times COD_{eff} \times CH_4/COD$$

$$(5)\ \text{Generated power capacity (MWe)} = \frac{CH_4 \text{ production} \times CH_{4,ev} \times Gen_{eff}}{24 \times 60 \times 60}$$

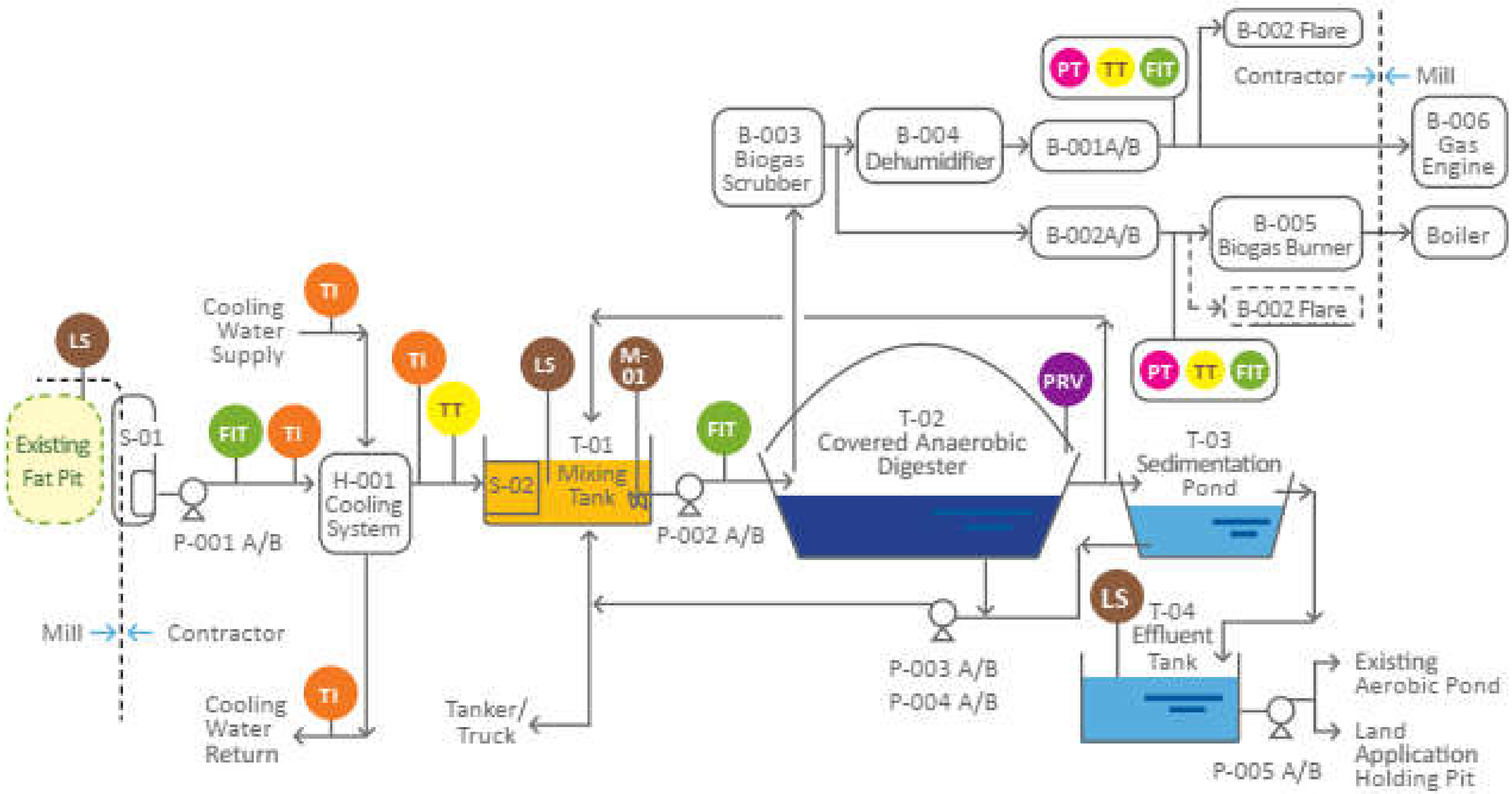
Source: Winrock International, 2015

Appendix 4 Indonesian Electrification Ratio 2019 (status of June 2019)



Source: PLN, 2019

Appendix 5 Flow Diagram Process of POME to Energy



Source: Winrock International, 2015

Notes:

T-01 : Mixing tank

T-02 : Anaerobic digester

T-03 : Sedimentation pond

T-04 : Effluent tank

B-001A/B : Biogas blowers to gas engine or flare

B-002A/B : Biogas blowers to burner or flare

B-002 : Biogas flare

B-003 : Scrubber

B-004 : Biogas dehumidifier

B-006 : Biogas engine

S-01 and S-02 : Coarse screen

H-001 : Cooling system

P-001A/B : Raw POME pumps

P-002A/B : Digester feed pumps

P-003A/B : Recirculation pumps

P-004A/B : Sludge pump

P-005A/B : Anaerobic effluent pumps

LS : level switch

FIT : flow indicating totalizer

TI : temperature indicator

TT : temperature transmitter

PT : pressure transmitter

PRV : pressure relief valve

- - - - - : battery limit of scope of the work typically managed by the contracted developer