ERIA Research Project Report 2022 No. 01

Forecast of Biomass Demand Potential in Indonesia: Seeking a Business Model for Wood Pellets

By

Economic Research Institute for ASEAN and East Asia

Economic Research Institute for ASEAN and East Asia (ERIA)

Sentral Senayan II 6th Floor

Jalan Asia Afrika No. 8, Gelora Bung Karno

Senayan, Jakarta Pusat 10270

Indonesia

ERIA Research Project FY2022 No. 01

Published in May 2022

Preface

By 2025, Indonesia aims to increase its renewable energy share to 23% in line with its commitment made during the COP 21 conference on climate change in Paris in 2015 to reduce its greenhouse gas emissions. Using bioenergy is one of the strategies to meet that target.

To do so, Indonesia needs to develop its industry of biofuels, biomass, and their related feedstock, such as palm oil and wood pellets. President Joko Widodo, for instance, has reiterated recently that Indonesia would like to focus more on processing palm oil into higher-value derivatives and products, such as biodiesel and green diesel for both domestic use and export. Wood pellets and wood chips for power generation have also been seriously considered as amongst the most important bioenergy resources and have entered into the long-term development plan of the forestry industry.

In the transport sector, the 2014 biodiesel blend mandate following the Ministry of Energy and Mineral Resources' regulation has been implemented with an increasing blending rate of 10% in 2014, known as 'B10', to 20% (B20) in 2016 and 30% (B30) in December 2019; this has made Indonesia the world frontrunner in the usage of biodiesel in transportation. Indonesia also has a lot of potential to produce bioethanol as transport fuel. The inability to implement the planned 5% blending mandate for bioethanol in gasoline shows some difficulties and challenges in creating a financing mechanism that stimulates the market.

The use of bioenergy in transportation is only the initial step. In power generation, the Ministry of Energy and Mineral Resources has identified that bioenergy's potential might reach as high as 32.6 GW, though only around 1.95 GW of biomass-fired plants' capacity has been installed. Co-firing, by converting a certain amount of the country's existing 18 GW coal-fired power plants to accommodate 5%–10% biomass, i.e. wood pellets and wood chips, is certainly one feasible solution to increase the use of bioenergy.

This report is based first on the solid analysis of biomass's supply and demand potential for the energy sector in Indonesia to 2040. Second, biomass-based power generation in Japan is analysed in relation to biomass development in Indonesia. Following this, a wood pellet business model in Indonesia is elaborated. Finally, an analysis of opportunities and challenges of biomass development for the energy sector in Indonesia and a set of recommended strategies to increase biomass use for energy sector in Indonesia are given.

ERIA will continue to support bioenergy industry policies and planning in Indonesia.

H. Nishimura

Prof. Hidetoshi Nishimura
President
Economic Research Institute for ASEAN and East Asia

Acknowledgements

This report was developed by a working group consisting of an ERIA team and an IEEJ team. The IEEJ team, led by Mr. Yoshiaki Shibata, oversaw analysing biomass power generation and wood pellets in Japan (chapter 4).

On behalf of the working group, I would like to acknowledge the excellent contribution of several experts who have dedicated their time to give lectures in a series of workshops:

- Mr Ir Djoko Winarno, Head of the Indonesian Biomass Energy Society (MEBI)
- Mr Dr Untung Murdyatmo, Chairman of the Association of Denatured Alcohol and Ethanol (ASENDO)
- Mr Indra Chandra Setiawan, S.T., M.T, Project Deputy General Manager, Toyota Daihatsu Engineering & Manufacturing – Thailand
- Mr Yoshinobu Kusano, Executive Advisor, RENOVA
- Dr Kazuyuki Murakami, Team Leader, JCOAL
- Ms Cecilya Laksmiwati Malik, Independent Energy Consultant for ERIA

Special thanks are delivered to ERIA team, which consists of Mr Shigeru Kimura (Special Advisor on Energy Affairs), Dr Han Phoumin (Senior Energy Economist), Dr Alloysius Joko Purwanto (Energy Economist), and Ms Dian Lutfiana (Research Associate).

Saleh Abdurrahman

Member of Committee for Downstream Oil and Gas Regulatory Body

Ministry of Energy and Mineral Resources, Indonesia

September 2021

Contents

List of Project Members	vi
List of Figures	vi
List of Tables	ix
List of Abbreviations	xi
Executive Summary	xiii
Chapter 1. Introduction	1
Chapter 2. Biomass Demand Potential up to 2040	5
Chapter 3. Biomass Supply Potential up to 2040	19
Chapter 4 Biomass Power Generation and Wood Pellets in Japan	29
Chapter 5. Wood Pellets Business Model in Indonesia	46
Chapter 6. Conclusion and Recommendations	57
References	59
Appendices	64

List of Project Members

Economic Research Institute for ASEAN and East Asia (ERIA)

Mr Shigeru Kimura, Special Adviser to the President on Energy Affairs

Dr Han Phoumin, Senior Energy Economist, Energy Unit

Dr Joko Purwanto, Energy Economist, Energy Unit

Ms Cecilya Laksmiwati Malik, independent consultant for ERIA

Ms Dian Lutfiana, Research Associate, Energy Unit, ERIA

Ms Citra Endah Nur Setyawati, Research Associate, Energy Unit, ERIA

Ministry of Energy and Mineral Resources (MEMR), Indonesia

Dr Saleh Abdurrahman, Member of Committee for Downstream Oil and Gas Regulatory Body - former Senior Advisor for Environment and Spatial Planning

The Institute of Energy Economics, Japan (IEEJ)

Mr Yoshiaki Shibata, Senior Economist, Manager, New and Renewable Energy Group, Electric Power Industry & New and Renewable Energy Unit

Ms Tomoko Matsumoto, Senior Researcher, New and Renewable Energy Group, Electric Power Industry & New and Renewable Energy Unit

List of Figures

Figure 3.1 Map of Potential Industrial/Energy Plantation Forest 21

Figure 3.2 MEMR Feedstock and Offtake Plans 23

Figure 3.3 Biomass Use in Oil Palm Industry 24

Figure 4.1 Approved Capacity under the FIT Scheme 30

Figure 4.2 Operating Capacity under the FIT Scheme 31

Figure 4.3 Major Power Utilities' Coal-fired Power Plants Co-firing with Biomass (FY2019) 32

Figure 4.4 Biomass Capacity under the FIT Scheme and the 2030 Target 32

Figure 4.5 Breakdown of Biomass Power Generation Fuel in Japan 38

Figure 4.6 Input Biomass Fuel for Each Type of Biomass Power Generation 39

Figure 4.7 Wood Pellets Import 39

Figure 4.8 Domestic Wood Pellets Production 40

Figure 4.9 Average Cost, Insurance and Freight (CIF) Prices of Wood Pellets and Wood Chips 40

Figure 4.10 Installed Capacity of Biomass Power Generation at Present (September 2020) and in 2030 41

Figure 4.11 Needed Wood Pellets Import in the Future 41

Figure 4.12 Cost Breakdown of Woody Biomass Power Plant in Japan 42

Figure 5.1 Operating Cost Structure by the three Department of A company 50

Figure 5.2 Operating Cost Structure by the cost items of A company 50

Figure 5.3 Overall Cost Structure of A company 51

Figure 5.4 Capital Cost Structure of the Three Departments 52

Figure 5.5 Accumulated Cash Flows for ROI and ROE 53

Figure 5.6 Cash Flow of IRROI and IRROE of the Case Study 56

Figure 3.1 Map of Potential Industrial/Energy Plantation Forest 21

Figure 3.2 MEMR Feedstock and Offtake Plans 23

Figure 3.3 Biomass Use in Oil Palm Industry 24

Figure 4.1 Approved Capacity under the FIT Scheme 30

Figure 4.2 Operating Capacity under the FIT Scheme 31

Figure 4.3 Major Power Utilities' Coal-fired Power Plants Co-firing with Biomass (FY2019) 32

Figure 4.4 Biomass Capacity under the FIT Scheme and the 2030 Target 32

Figure 4.5 Breakdown of Biomass Power Generation Fuel in Japan 38

Figure 4.6 Input Biomass Fuel for Each Type of Biomass Power Generation 39

Figure 4.7 Wood Pellets Import 39

Figure 4.8 Domestic Wood Pellets Production 40

Figure 4.9 Average Cost, Insurance and Freight (CIF) Prices of Wood Pellets and Wood Chips 40

Figure 4.10 Installed Capacity of Biomass Power Generation at Present (September 2020) and in 2030 41

Figure 4.11 Needed Wood Pellets Import in the Future 41

Figure 4.12 Cost Breakdown of Woody Biomass Power Plant in Japan 42

Figure 5.1 Operating Cost Structure by the three Department of A company 50

Figure 5.2 Operating Cost Structure by the cost items of A company 50

Figure 5.3 Overall Cost Structure of A company 51

Figure 5.4 Capital Cost Structure of the Three Departments 52

Figure 5.5 Accumulated Cash Flows for ROI and ROE 53

Figure 5.6 Cash Flow of IRROI and IRROE of the Case Study 56

List of Tables

Table 2.1 Demand of Power Generation by Type of Fuel (Kton) 5

Table 2.2 Biomass Energy Potential for Electricity (Unit: MW) 6

Table 2.3 Biomass Co-firing Tests on Existing CFPPs by the PLN 7

Table 2.4 Fossil Fuel Demand of Power Generation by Type of Fuel (Mtoe) 8

Table 2.5 Forecasted Demand for woodchip to meet biomass and coal combustion (Kton) in 2025 8

Table 2.6 Forecasted Demand for woodchip to meet biomass and coal combustion (Kton) in 2040. 9

Table 2.7 Potential of 2nd generation bioethanol production from the different feedstock in Indonesia 10

Table 2.8 Pure Diesel Supply and Demand Balance (million kilolitres) 12

Table 2.9 Total diesel fuel needed for road transport sector use in Indonesia in term of energy and volume unit 13

Table 2.10 FAME (pure biodiesel) needed for road transport sector use in Indonesia in B30 and B40 mandates in term of energy and volume unit 13

Table 2.11 CPO needed in road transport sector B30 and B40 mandates (million tonnes) 14

Table 2.12 Gasoline Supply and Demand Balance (million kilolitres) 15

Table 2.13 Total diesel fuel needed for road transport sector use in Indonesia in term of energy and volume unit 16

Table 2.14 Gasoline consumption in East Java and Java Island and bioethanol needed in scenarios (million kilolitres) 17

Table 2.15 Needed molasses in scenarios (million tonnes) 17

Table 3.1 Biomass Energy Annual Potential (million tonnes) 21

Table 3.2 Estimation of Estates Crops Waste Potency 22

Table 3.3 Harvesting Areas, Productions and Waste Potency of Some Food Crop Products 22

Table 3.4 Area and Production of Crude Palm Oil (CPO): 2015 - 2021 25

Table 3.5 Area and Production of Crude Palm Oil (CPO): 2040 25

Table 3.6 Sugarcane production, and potential production of molasses and bioethanol in Indonesia, 2040 27

Table 3.7 Development of sugarcane harvested area, production and productivity in 2040 27

Table 3.8 Potential Ethanol Production (2nd G) from Different Feedstock 28

Table 4.1 The Biomass Power Target of the Long-term Energy Demand and Supply Outlook 2015 29

Table 4.2 The Biomass Outlook 33

Table 4.3. The FIT Tariff Rates 34

Table 4-4 Auction Result 36

Table 4.5 Examples of Subsidy for Biomass Energy 37

Table 4.6 Forest and Forestry Basic Plan (draft) 43

Table 5.1 Forecasted Income Statement of A company ($1,000) 49

Table 5.2 Forecasted Cash Balance Tables of A Company ($1,000) 52

Table 5.3 Income Statement of the Case Study 54

Table 5.4 Cash Balance Statement of the Case Study 55

List of Abbreviations

CO_2	Carbon dioxide
ASENDO	Indonesian Spirits and Ethanol Association
BAU	Business-as-Usual
BEV	Battery Electric Vehicle
boepd	barrel of oil equivalent per day
CFB	circulating fluidised bed
CFPP	coal fired power plants
CPO	Crude Palm Oil
EAS	East Asia Summit
FAME	fatty acid methyl esters
FIP	Feed-in Premium
FIT	Feed-in-Tariff
GAPKI	Indonesia Palm Oil Association
GDP	Growth Domestic Product
GHG	greenhouse gas
GSEN	Grand Strategy of National Energy
GW	Giga Watt
GWh	Gigawatt hour
HIP	Market Price Index
IPP	Independent Power Producers
IRROE	Internal Rate of Return on Equity
IRROI	Internal Rate of Return on Investment
JPA	Japan Wood Pellet Association
KEN	National Energy Policy
Kl	Kilolitres
MEMR	Ministry of Energy and Mineral Resources
MSW	Municipal Solid Waste
mtoe	million tonnes of oil equivalent

MW	Megawatt
MWe	Megawatt electrical
MWp	Megawatt peak
NZE	Net Zero Emission
PC	Pulverised Coal
PKS	Palm Kernel Shell
PLN	State-owned Electricity Company
POME	Palm Oil Mill Effluent
ROE	Return on Equity
RPS	Renewable Portfolio Standard
Solar PV	Solar Photovoltaics
TWh	Terawatt hour

Executive Summary

A low-carbon energy transition is crucial for Indonesia. The major CO_2 emission sectors in Indonesia are power generation and transport, especially road transport. In addition, most power generation is from coal power plants and gasoline, with diesel oil mainly used as transport fuel. Thus, reduction of coal consumption for power generation and gasoline and diesel consumption for vehicles is indispensable. Rapid increase of solar energy is one of the options for Indonesia; however, due to its negative characteristics, which are intermittent power supply, small capacity factor, and seasonality, its baseload is insufficient. A combination of solar energy and batteries seems to be appropriate; however, batteries are still expensive and have limited electricity storage time. In road transport, battery electric vehicles (BEVs) are an option for Indonesia, but due to their higher price and the need for investment to equip the charging stations, their penetration will still take time. Despite these conditions, Indonesia has significant potential to contribute to reduce coal consumption and gasoline and diesel oil consumption through biomass.

Biomass co-firing in coal power plants is an available technology in Japan and other East Asia Summit countries. Currently, the mixing rate of biomass co-firing in Japan is 20%–25%, which would help Indonesia reduce CO_2 emissions from coal power plants. In addition, biomass power generation systems in Japan are also using wood pellets as a fuel. This technology also can be applied in Indonesia using wood chips in lieu of pellets since they are cheaper. In the Indonesian road transport sector, B30 and B50 biofuels, i.e. bioethanol and biodiesel, can substitute for gasoline and diesel oil. Thus, biofuels have substantial potential to reduce CO_2 emissions in the Indonesian road sector.

Biomass supply in Indonesia can cover demand up to 2040; nonetheless, reforestation should be implemented continually. In addition, the wood chips/pellets supply chain should also be established. However, the higher biomass supply price of woodchips/pellets and biofuels is still an issue. One way to decrease the price is expansion of biomass demand; in other words, seeking scale merit. Initially, however, government support is needed in the form of co-firing and biofuels mixing ratios, enforced biomass use by government sector, and supplemental conditions on licenses to independent power producers and motor companies. Another way to decrease the price is technology development; second- and third-generation bioethanol is expected to realise an affordable price under open biomass markets to foreign companies in Indonesia.

While the Association of Southeast Asian Nations (ASEAN) region including Indonesia does not have abundant wind and solar resources, in contrast with, respectively, Europe and the Middle East, it is a so-called rich green area, making utilization of biomass an important energy policy. Thus, this report recommends Indonesia to use biomass for co-firing coal power generation and bio-gasoline and biodiesel oil.

Chapter 1

Introduction

1. Background

Indonesia is endowed with various types of renewable energy that are found across the archipelago. Solar energy has the largest potential with 207.8 GW, followed by hydro (94.6 GW), wind (60.6 GW), bioenergy (32.6 GW), geothermal (23.9 GW), and wave energy (17.9 GW). In 2020, the largest installed capacity was hydro at around 6.1 GW, followed by geothermal (2.1 GW), bioenergy (1.9 GW), wind (154.3 MW), and solar (153.8 MW).

Indonesia is a tropical country with huge forests and plentiful agricultural land, and biomass sources varying from wood residues/scraps, rice husks, corn residues, or from dedicated wood plantations. Of a total of around 74.4 million hectares of production forest, around 1.3 million hectares are allocated for energy-related plantations, with 32 companies already committed to development (MEBI, 2021). In terms of biomass supply for electricity, Sumatra has the biggest potential of 15,588 MWe, followed by Java and Bali (9,215 MWe), Kalimantan (5,062 MWe), Sulawesi (1,937 MWe), Nusa Tenggara (636 MWe), and Maluku and Papua (218 MWe). When classified into types of biomass, the largest potential is palm oil at around 12,654 MWe, rice husks (9,808 MWe), municipal waste (2,066 MWe), rubber (2,781 MWe), corn (1,733 MWe), wood (1,335 MWe), sugar cane (1,295 MWe), others (983 MWe) (DJ EBTKE, 2020).

Indonesia has set its long-term energy mix policy, with renewables targeted to reach 23% of the total in 2025 and 31% in 2050. Indonesia has also set its Nationally Determined Contribution (NDC) to reduce greenhouse gas (GHG) emissions in 2030 by 29% from the business-as-usual (BAU) scenario by its own effort and 41% with international support. To reach this target, the energy sector must reduce its emissions by around 314 million tonnes by 2030.

Based on Government Regulation Number 79 of 2014 on the National Energy Policy (NEP), the targeted primary energy supply of 2025 is around 400 million tonnes of oil equivalent (mtoe), of which around 92 mtoe is from renewables, or 23% of the total. By 2025, around 69 mtoe of the renewables total is projected to be used for electricity sector, with bioenergy's share of the total renewables supply projected to reach 5,532 MW, or 12.2%; in 2050, it will reach 26,123 MW or 15.6% of total. For the non-electricity sector, the projected supply of biofuel in 2025 is 13.9 million kL (not including biodiesel for electricity use at around 0.7 million kL), biomass for other use 8.4 million tonnes, and biogas at around 489 million cubic metres. In 2050, the biofuel supply is projected to reach 52.3 million kL (not including biodiesel for electricity use at 1.2 million kL), biomass for other use (22.7 million tonnes), and biogas (1.958 billion cubic metres).

Given biomass's enormous potential, the related policy is getting more progressive, with the government increasing its mix in diesel fuel to 30% (B-30) since January 2020. The supply of biodiesel also increased from 0.9 million kL in 2015 to 8.46 million kL in 2020. In contrast to the success of biodiesel, the implementation of bioethanol in the transportation sector has not been as expected. According to Ministry of Energy and Mineral Resources Decree Number 12 of 2015, the gradual mix of bioethanol has been determined at 1% (E1) in 2015 to 5% (E5) in 2020 and E20 in 2025 for public transport and other uses, while, for non-public transport, and the industrial and commercial sectors, the mix shall be 2% in 2015, 10% in 2020 and 20% in 2025. The use of bioethanol E5 in the transport sector started in 2006–10 in West Java and Bali, but was then not continued due to several factors, especially those related to the price of bioethanol and issues of storage and blending.

Recently, Indonesia has updated its plan under the Grand Strategy of National Energy (GSEN) to increase the use of biofuel from 159,000 barrels of oil equivalent per day (boepd) in 2020 to 238,000 boepd in 2030 and 257,000 boepd in an effort to reduce import dependency and to help reduce GHG emissions from fossil fuel use. Under the GSEN, the use of dimethyl ether and bioethanol are projected to reach 3.5 million tonnes liquefied propane gas equivalent in 2025 and 2.7 million tonnes liquefied propane gas equivalent in 2040. In line with the increasing share of renewables in the transport sector, the state-owned oil and gas company PT Pertamina is currently conducting studies to develop green diesel, green gasoline, and green aviation fuel utilising crude palm oil (CPO). The company is expected to produce this green energy in 2022. The impact of GHG reduction from the use of bioethanol and green fuel is huge as the consumption of gasoline and diesel fuel is projected to increase in the future.

Another initiative to increase the use of biomass is a co-firing programme with coal conducted by the state electricity company, PT PLN. Under the co-firing programme, 3% to 5% biomass in the form of wood pellets or woodchips will be injected in 114 units of coal-fired power plants (CFPPs) in 52 locations across the country. The co-firing program will be conducted in Java with the capacity of 14,330 MW, Sumatra (2,315 MW), Kalimantan (824 MW), Sulawesi (473 MW), Bali and Nusa Tenggara (142 MW), and Maluku and Papua (70 MW). With 3% to 5% mix, annual demand for biomass is projected to be around 4.2 million tonnes. Electricity production from biomass is projected to reach 8,783 GWh/year from 2021 to 2024 and 10,601 GWh/year from 2025 to 2035. The demand for biomass is projected to reach 7.54 million tonnes/year in 2021–24 and will reach around 9.02 million tonnes/year in 2025–35 (DJ EBTKE, 2021).

The benefit of a co-firing program is not only reducing GHG and sulphur emissions from the power sector, but also creating a local economic value chain. The study made by PT Pembangkitan Jawa Bali, a subsidiary of PT PLN, shows that co-firing of 5% biomass on the Java Bali system created 160 biomass industries employing around 1,600 people (PJB, 2020). The co-firing program can also reduce the electricity production cost (BPP) as indicated from one CFPP in West Java that reduced it to Rp. 21.26/kWh (around

$0.0015/kWh) and one in West Kalimantan to Rp. 5.09/kWh (around $0.0004/kWh) (DG Electricity, 2020).

Despite enormous opportunities, some challenges hinder biomass for energy use. The most important is the security of biomass supply for electricity. There are no mature biomass industries currently with the capacity to meet the prospective demand. This makes the price of wood pellets and wood chips uneconomical when compared to coal, especially when they are imported. Another challenge is that only PT PLN has indicated its commitment by starting to implement co-firing. As a result, the biomass market has yet to attract large-scale wood pellet or wood chip industries. As the main off-taker, PT PLN determines the price of biomass with a certain formula that is less attractive to biomass producers. A further challenge is that most biomass feedstock is coming from the sawdust, palm oil, rice husk, rubber and corn residues that are suitable for co-firing, but not sufficient for large-scale biomass power plants, which need sustainable dedicated biomass sources.

The challenge facing the use of biomass for transportation, especially bioethanol, is that it still costs more than gasoline. The challenge on the price can be traced back to the price of molasses, the main feedstock of bioethanol production. With less certainty on the security of domestic demand for bioethanol, most producers prefer to sell molasses to other industries or export it. This causes some of bioethanol factories to stop production. Another challenge is the lack of government incentives. This is important since developing second-generation bioethanol will secure Indonesia's supply for a long time. However, the cost to produce this type of bioethanol currently is even more expensive than the price of the first-generation bioethanol unless collaboration is made with global second-generation producers.

2. Objectives

The objectives of this study are as follows:

- To analyse biomass demand potential for energy sector to 2040;
- To analyse biomass supply potential for energy sector to 2040;
- To analyse biomass power generation business in Japan related to technical and environmental requirement as a reference for biomass development in Indonesia;
- To analyse wood pellet business model in Indonesia;
- To analyse opportunities and challenges of biomass development for energy sector in Indonesia; and
- To recommend strategies to increase biomass use for energy sector in Indonesia

3. Methodology

This study was conducted first with data collection on the potential of biomass resources in Indonesia. To understand the supply and demand outlook for energy sector biomass, this study refers to the outlook made and published by the Economic Research Institute for ASEAN and East Asia (ERIA). A series of discussions were conducted with relevant stakeholders including government representatives, biomass producers/associations, bioethanol producers/experts, wood pellet consumers from Japan, and the Japanese coal association to gain direct and in-depth understanding of the biomass potential. A webinar was also conducted with biomass consumers and the coal association to understand its demand for wood pellets, including technical and environmental requirements.

Chapter 2

Biomass Demand Potential up to 2040

1. Biomass Demand Potential in Power Generation

ERIA's energy outlook (Kimura and Han, eds., 2021) estimated that Indonesia's power generation is projected to reach 941 TWh by 2050, increasing at an average rate of 4% per year (Table 2.1). By type of fuel, generation from 'Other' will have the fastest growth at an average rate of 10.6% per year. The main reason for this very rapid growth is the Government's policy to increase the use of new and renewable energy sources including solar, wind, biomass, etc., which are classified as 'Other'. Generation from geothermal and hydro are also growing, but much slower than 'Other', 4.5% and 4.2%, respectively.

Power generation from natural gas will continue to increase but at a much slower rate of 5.3% per year, while coal-based power generation will be growing at an average annual rate of 3.6%. No nuclear plant is considered under the BAU scenario. The share of coal will remain dominant in the total power generation of the country, and it is expected that this share will continue to increase in the future but will eventually even out at 50.8% of share in 2050.

Natural gas share will increase to 32.7% by 2050, while oil share will continue to decline and reach 0.1% by 2050. The assumption was that oil-based plants (diesel plants) will be replaced with other fossil fuel or renewable sources, except in areas where substitution is not feasible.

The total share of renewable energy in the generation mix will reach 17% by 2050, with hydropower's share at 7.7%, geothermal at 5.7%, and other renewables at 3%.

Table 2.1. Demand of Power Generation by Type of Fuel
(in kilotonnes)

	1990	2000	2017	2020	2030	2040	2050
Coal	10	34	148	166	232	348	478
Oil	12	12	19	11	12	2	1
Natural gas	3	32	56	69	97	170	308
Hydro	6	10	19	20	38	54	72
Geothermal	1	3	13	13	28	41	54
Others	-	-	1	1	12	21	28
Total	**32**	**91**	**255**	**279**	**420**	**636**	**941**

Source: ERIA's Energy Outlook and Saving Potential (Kimura and Han, eds. 2021).

1.1. Biomass potential for power generation in Indonesia

Agriculture and forestry, both major industries in Indonesia, generate a significant amount of waste and sub-products that can be used as raw materials to generate power.

The total biomass potential for electricity is 32,655 MWe (Table 2.2). Palm oil waste has the largest potential because it is cultivated in large plantations in Sumatra and Kalimantan. Palm kernel shell (PKS), empty fruit bunch (EFB), and palm oil mill effluent, which are wastes from the production of palm oil, can be used for power generation. Jamali and Sulawesi, which have few palm plantations, have substantial rice husks. Jamali, which has many urban areas, has a high possibility of using municipal solid waste (MSW) to generate power. Even though every area has potential waste, few of them use it.

Table 2.2. Biomass Energy Potential for Electricity

(in megawatts)

	Sumatra	Kalimantan	Jamali	Sulawesi	Other	Total
Palm oil	8,812	3,384	60	323	75	12,654
Sugar cane	399	-	854	42	0	1,295
Rubber	1,918	862	-	-	1	2,781
Coconut	53	10	37	38	39	177
Rice husk	2,255	642	5,353	1,111	447	9,808
Corn	408	30	954	251	90	1,733
Casava	110	7	120	12	22	271
Wood	1,212	44	14	21	44	1,335
Cow dung	96	16	296	65	62	535
MSW	326	66	1,527	74	73	2,066
Total	**15,589**	**5,061**	**9,215**	**1,937**	**853**	**32,655**

Jamali = Jawa, Madura, Bali. MSW = municipal solid waste.

Source: Country presentation by Indonesia’s representative at the First WG Meeting for the Phase I Study, 6 February 2019.

1.2. Trials testing mixing rate of biomass co-firing

To fulfil its commitment to increase new and renewable energy (NRE) shares in electricity generation, PT PLN initiated a green booster programme, under which it is integrating biomass co-firing into its existing Co-firing Power Plants (CFPPs). PT PLN has conducted several tests on biomass co-firing trials on existing CFPPs, as shown in Table 2.3. The boiler types tested were Pulverised Coal and circulating fluidised bed (CFB), and the biomass used was wood pellets, PKS, and MSW, which are suitable for Pulverised Coal boilers due to good ‘grindability’.

Table 2.3. Biomass Co-firing Tests on Existing CFPPs by the PLN

CFPP	MW	Boiler	Location	Mixed biomass	Mixed rate	Biomass feedstock rate (tonne/day)	Test result
Jeranjang	3 x 25	CFB	Lombok	MSW	1, 3, 5%	15	Good
Paiton	2 x 400	PC	East Java	Wood pellet	1, 3, 5%	432	Good
Indramayu	3 x 300	PC	West Java	Wood pellet	1, 3, 5%	684	Good
Tenayan	2 x 110	CFB	Riau	PKS	5%	192	Good
Ketapang	2 x 10	CFB	West Kalimantan	PKS	1, 3, 5%	22	Good

CFPP = Co-firing Power Plants, CFB = circulating fluidised bed, MSW = municipal solid waste, PC = pulverised coal, PLN = Perusahaan Listrik Negara.
Source: Country presentation by Indonesia's representative at the First WG Meeting for the Phase II Study, 16 June 2020.

1.3. Estimates of potential demand for biomass co-firing with coal

There is potential for biomass and coal co-combustion in Indonesia. In this study, we estimate the demand for woodchip biomass as a potential growth in the power generation mix in the following scenarios:

- Scenario1 is the mixing rate of biomass with coal combustion of 5%
- Scenario2 is the mixing rate of biomass with coal combustion of 10%
- Scenario3 is the mixing rate of biomass with coal combustion of 20%

To simply the calculation, the mixing rate is the replacement of coal demand in power generation by woodchip biomass at 5%, 10%, and 20% respectively. However, the moisture content of woodchips affects the power output. In this regard, the study uses the conversion factor based on the moisture content assumptions in Kofman (2017). It is important to note that the biomass woodchips in Indonesia used for power generation are mentioned by experts as having a moisture content around 10%. However, this is not the case internationally, where experience that have found the moisture content in the woodchip. Thus, this study calculates woodchip demand using a moisture context of 20% and above.

It is important to note that not every boiler can handle every moisture content. Therefore, values are shown for a dry fuel boiler (25% or 30% moisture content), a medium moisture content boiler (45%) and a wet fuel boiler (55%).

For the basic woodchip demand in 2025, 2040 and 2050, we need to know the coal demand in those years (Table 2.4). Thus, the mixing rate of woodchips with coal operations is simply a replacing of coal demand in 2025, 2040, and 2050, with the woodchip demand for mixing rates of 5%, 10%, and 20%, respectively.

Table 2.4. Fossil Fuel Demand of Power Generation by Type of Fuel

(mtoe)

	2017	2020	2025	2030	2040	2050
Total	**63.61**	**68.77**	**79.53**	**86.32**	**123.02**	**169.12**
Coal	48.80	53.88	62.12	66.40	93.65	117.41
Oil	5.10	2.97	3.16	3.31	0.62	0.20
Natural gas	9.70	11.91	14.25	16.60	28.75	51.51

Source: ERIA's Energy Outlook and Saving Potential (Kimura and Han, eds., 2021).

Table 2.5 and Table 2.6 are the main results of the woodchip demand in 2025 and 2040, respectively. It is noted that the woodchips with moisture content from 10%–15% are suitable for wood pellet biomass, as they are not too wet or too dry. However, all moisture contexts can be used in power generation, which requires different design of boilers.

Table 2.5. Forecasted Demand for Woodchips to Meet Biomass and Coal Combustion in 2025

(in kilotonnes)

			Woodchip demand in 2025 (Ktonne)			
	(Moisture 10%)	**(Moisture 15%)**	**(Moisture 25%)**	**(Moisture 30%)**	**(Moisture 45%)**	**(Moisture 55%)**
Scenario1 (mixing rate 5%)	2,751	2,886	3,048	3,310	4,461	5,776
Scenario2 (mixing rate 10%)	5,502	5,778	6,097	6,621	8,922	11,554
Scenario3 (mixing rate 20%)	11,003	11,554	12,194	1,342	17,843	23,107

Note: 1 Mtoe= 3.720930667 TWh= 981.776 kt (Moisture content 10%) = 885.936 kt (Moisture content 15%) = 930.233 kt (Moisture content 25%) = 1,066.17 kton (Moisture content 30%) = 1,436.65 (Moisture content 45%) = 1,860.47 (Moisture content 55%). This is based on the Long-range Energy Alternatives Planning System conversion factor. For the woodchip moisture context, refer to Kofman (2017).
Source: Author's calculation.

Table 2.6. Forecasted Demand for Woodchips to Meet Biomass and Coal Combustion in 2040

(in kilotonnes)

			Woodchip demand in 2040 (Kton)			
	(Moisture 10%)	**(Moisture 15%)**	**(Moisture 25%)**	**(Moisture 30%)**	**(Moisture 45%)**	**(Moisture 55%)**
Scenario1 (mixing rate 5%)	4,148	4,356	4,596	4,992	6,727	8,711
Scenario2 (mixing rate 10%)	8,296	8,711	9,193	9,984	13,454	17,422
Scenario3 (mixing rate 20%)	16,593	17,423	18,387	19,968	26,907	34,844

Note: 1 Mtoe= 3.720930667 TWh= 981.776 kt (Moisture content 10%) = 885.936 kt (Moisture content 15%) = 930.233 kt (Moisture content 25%) = 1,066.17 kton (Moisture content 30%) = 1,436.65 (Moisture content 45%) = 1,860.47 (Moisture content 55%). This is based on the Long-range Energy Alternatives Planning System conversion factor. For the woodchip moisture context, refer to Kofman (2017).
Source: Author's calculation.

2. Biomass demand for road transport use

Indonesia aims to achieve four main objectives for biofuels in the road transport sector: contributing to meeting its 23% renewables share target of total energy mix by 2025; supporting the government's intention to reduce 29% of GHG emissions by 2030 compared to BAU; decreasing the national trade balance deficit and improving energy security and self-sufficiency by reducing fossil fuel consumption and imports; and developing the palm oil industry by stabilising CPO prices and adding value by down-streaming the palm oil industry.

Setiawan (2021) pointed out the importance of biodiesel and bioethanol policies in Indonesia, targeting all road transport vehicles and showed that an implementation of the B50 biodiesel and E10 bioethanol mandate would have the potential to reduce oil consumption by nearly 15.9% by 2030, i.e. a 10.3% and 5.4% reduction, respectively, from B50 and E10.

In 2008, Indonesia issued Ministry of Energy and Mineral Resources (MEMR) Regulation No. 32 that targeted the biofuel blending level at 10% by 2015 for industrial, transport, and power plant use. This regulation was amended twice – No. 25 in 2013 and No. 20 in 2014 – that finally set the starting date of B10 implementation in January 2014. In March 2015, the MEMR issued Regulation No. 12 Year 2015 to increase the blending percentage to 15% for industry and transport use starting on 1 April 2015, and 20% beginning on 1 January 2016. The regulation set a blend rate of 25% for power generation beginning on 1 April 2015 and 30% starting 1 January 2016. The regulation set a blend rate of 30% of biodiesel for all uses starting 1 January 2020. MEMR Minister Regulation No. 227 K/10/MEM/2019 set the blending percentage to 30%, which began on 16 December 2019.

Indonesia's current target is to switch to a B40 blending mandate, but the exact time of this implementation has so far been unknown (CNBC Indonesia, 2021). Setiawan (2021) stated that several automotive manufacturers in Indonesia including Toyota have been involved in the preparation of B40 implementation. Currently, testing on the effect of B40 on fuel filter flogging and on material compatibility was ongoing.

Blending bioethanol with gasoline is not as successful as in the case of biodiesels. MEMR Regulation No. 12 Year 2015 targeted a mandatory bioethanol blending level of 5% (E5) by 2020 and a further 20% (E20) by 2025. In practice, according to the Indonesian Spirits and Ethanol Association, between 2012 and 2017 around 500 kL of bioethanol were blended with gasoline fuels. However, since 2018 there has been practically no more bioethanol to be mixed with gasoline fuel. Concrete measures on closing the price gap with fuel-grade bioethanol, which is around twice the price of 88-octane gasoline (Murdiyatmo, 2021) are still needed. As Wiratmini (2020) reported, the mandatory blending policies of bioethanol are under revision. Sources of incentive funding were being sought so the government could start a pilot project of blending 2% bioethanol in gasoline fuel in East Java in 2020. However, until the report was issued, no fixed decision on the bioethanol mandate has been taken.

Murdiyatmo (2021) estimated that by early 2021 there were seven companies that produced conventional or first-generation bioethanol in Indonesia, all using molasses as feedstock with the total installed capacity of 230,000 kL per year. However, only three factories can currently produce fuel-grade bioethanol in Indonesia, with a total installed capacity of 45,000 kL of bioethanol per year.[1] However, according to the United States (US) Department of Agriculture (USDA) (2019), Indonesia has an installed bioethanol refinery capacity of up to 100,000 kL per year.

Murdiyatmo (2021) also pointed out the abundance of Indonesia's potential feedstocks to produce second-generation bioethanol, especially from sugarcane bagasse, rice straw, corn stover, sago hampass, and EFB (see Table 2.7), with the total potential of around 34.6 million kL per year, which is enough to replace all gasoline imports via 20% blending with conventional gasoline.

Table 2.7. Potential of Second-Generation Bioethanol Production from the Different Feedstock in Indonesia

Feedstock	kL per year
Bagasse	480,000
Rice straw	19,440,000
Corn stover	8,271,000
Sago hampass	136,000
Oil palm EFB	6,283,000
Total	34,610,000

[1] As explained by ASENDO Chairman, Dr Untung Murdiyatmo during the Workshop on 9 December 2019.

EFB = empty fruit bunch.
Source: Murdiyatmo (2021).

However, the main obstacle with producing second-generation bioethanol is the cost of enzymes. Murdiyatmo (2021) stated that, at the pilot scale, the cost of enzymes is very high, i.e. Rp18,000 per litre of ethanol produced. Some studies provided the cost of enzymes in the US. NREL (2011), for instance, estimated that the cost of enzymes to produce second-generation bioethanol in the US was equivalent to around $0.34 per gallon or Rp1,529[2] per litre of ethanol produced, i.e. less than one-tenth of the cost of enzymes in Indonesia.

In the next sub-sections, we analyse biodiesel and bioethanol introduction in Indonesia. In each sub-section, we first discuss the current supply and demand of the biofuels and the related conventional transport fuel. Second, we estimate the conventional transport fuel, i.e. gasoline and diesel fuel demand in road transportation during the period of 2020–50. Third, we estimate the volume of pure biofuel (fatty acid methyl ester [FAME]/biodiesel and bioethanol) needs in scenarios, and in the amount of feedstock, i.e. CPO in biodiesel and molasses in bioethanol needed to meet the demand required in each scenario.

2.1. Diesel and biodiesel use

The consumption of diesel fuel in Indonesia, used primarily for road freight transport, fluctuated between 2010 and 2019 as it correlated with the economic condition (Table 2.8). Diesel consumption in the industry sector decreased significantly, around 10% per year between 2010 and 2019, resulting from the shift to another energy type. During the same period, with some fluctuations, diesel production increased at 3.6% annual growth rate, while imports were cut by half from nearly 13 billion litres in 2010 to nearly 6.5 billion litres in 2018. The biodiesel blending rate increased from only 1% in 2010 to nearly 20% in 2019, representing a growing level of mandatory biodiesel programmes. Apparently, diesel imports dropped with the increase of the biodiesel (B100) blending rate.

[2] Assuming average inflation rate of 2% between 2011 and 2021 and an exchange rate of $1 = Rp14,131.

Table 2.8. Pure Diesel Supply and Demand Balance

(million kL)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019*
Transport use	26.9	25.7	29.0	27.8	25.7	24.8	22.8	25.6	25.1	23.7
Industry use	9.3	11.5	8.2	7.5	7.4	5.5	4.7	3.6	3.4	3.4
Production	17.1	18.5	19.7	19.8	20.7	20.6	19.8	21.4	22.5	n/a
Import	12.7	13.6	12.5	11.9	11.5	7.3	5.7	6.8	6.5	n/a
Export	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	n/a
B100 blending rate %	0.70 %	1.10 %	1.80 %	2.90 %	5.40 %	2.60 %	10.30 %	8.20 %	12.70 %	19.90 %

Source: MEMR (2019) and USDA (2019) for 2019 (preliminary) figures.

Current biodiesel production capacity is around 12.05 million kL, which means an average monthly capacity of 1 million kL. With the opening of three additional plants in 2020, the total national production capacity should reach 12.85 million kL (Bisnis.com, 2020).

This study assumes that the blending rate of 30% and 40% of FAME produced from CPO in transport diesel fuel, known as B30 and B40, respectively. B30 started in December 2019, while B40 was scheduled to be implemented by mid-2021 but is currently postponed to mid-2022 due to the novel coronavirus (COVID-19) pandemic.

It is possible to build scenarios of higher blending rates of FAME such as 50%. However, such scenarios are too speculative, and studies on the compatibility of diesel engines with the higher blending rates of FAME need to be conducted first. Scenarios assuming penetration of bioethanol can also be created but are also speculative, as it has been more than 13 years since the first target for bioethanol penetration has been set and yet practically there is currently no bioethanol blended with gasoline fuel.

2.1.1. Diesel fuel demand model in road transport sector

In Malik (2021), diesel fuel demand from the road transport sector in Indonesia was estimated as a function of gross domestic product (GDP) and the forecasted diesel fuel price.

$$RODS_y = -3807.1 + 0.2.10^{-5}.GDP_y - 0.0024914.RPADOIN_y + 0.0987.RODS_{y-1}$$

where:

$RODS_y$: demand of diesel fuel from road transport sector of the year *y* (thousand TOE)

GDP_y: gross domestic product of the year *y* (Rp million)

$RPADOIN_y$: diesel fuel price of the year *y* (Rp/litre)

$RODS_{y-1}$: demand of diesel fuel from road transport sector of the year *y-1* (thousand TOE)

Table 2.9 shows that the demand of diesel fuel from road transport shall increase from around 20 million tonnes of oil equivalent (mtoe) in 2020 to around 99 mtoe in 2050, which means a compound annual growth rate of 5.4%. In terms of volume, this means an increase from around 21 million kL in 2020 to around 101 million kL in 2050. This estimation is line with the BAU scenario of Indonesia Energy Outlook and Saving Potential study in Malik (2021).

Table 2.9. Total Diesel Fuel Needed for Road Transport Sector Use in Indonesia in Terms of Energy and Volume Unit

	2020	2025	2030	2035	2040	2045	2050
million-toe (Mtoe)	20.3	27.5	36.7	48.1	62.3	78.6	99
million-kL	20.7	28.1	37.4	49.1	63.6	80.2	101.0

Source: Malik, 2021, and author's calculation.

2.1.2. Volume of FAME needed in B30 and B40 programs

Using the volume of diesel fuel needed for road transport sector use in Indonesia, as shown in Table 2.10, the demand of FAME can be calculated for both B30 and B40 mandates assuming that each programme would be implemented in two separate scenarios starting from 2020.

Table 2.10. FAME (Pure Biodiesel) Needed for Road Transport Sector Use in Indonesia in B30 and B40 Mandates in Terms of Energy and Volume Unit

Scenarios (energy or volume units)	2020	2025	2030	2035	2040	2045	2050
B30 (Mtoe)	6.09	8.25	11.01	14.43	18.69	23.58	29.70
B40 (Mtoe)	8.12	11.00	14.68	19.24	24.92	31.44	39.60
B30 (Million-kL)	6.2	8.4	11.2	14.7	19.1	24.1	30.3
B40 (Million-kL)	8.3	11.2	15.0	19.6	25.4	32.1	40.4

Source: Author's calculation.

Implementation of the B30 mandate from 2020 to 2050 would need 6.2 million kL of FAME in 2020 and 40.4 kL of FAME in 2050. Looking at the current FAME production capacity at around 12.85 kL as mentioned in the introduction of this section, the demand of the B30 mandate scenario could be met until 2030. The current production capacity would not be enough to meet the B40 mandate FAME demand by 2030.

2.1.3. Volume of crude palm oil needed in B30 and B40 programmes

Assuming 0.92 kg of CPO would be needed to produce 1 litre of FAME (pure biodiesel), the needed CPO was calculated for both B30 and B40 mandates in road transport (Table 2.11). To meet B30 and B40 mandates in transport sector, 27.9 and 37.2 million tonnes, respectively, of CPO would be needed in 2050.

Table 2.11. CPO Needed in Road Transport Sector B30 and B40 Mandates

(million tonnes)

	2020	2025	2030	2035	2040	2045	2050
B30	5.7	7.7	10.3	13.5	17.5	22.1	27.9
B40	7.6	10.3	13.8	18.1	23.4	29.5	37.2

CPO = crude palm oil.
Source: author's calculation.

According to the Indonesia Palm Oil Association (GAPKI) (2020), 48 million tonnes of CPO were produced in 2019. From that amount, only 8.7 million tonnes were converted for pure biodiesel (FAME) production, while the rest was used for other industries, exports, and stocks. This signifies that pure biodiesel production currently needs no more than 20% of the total produced CPO in the country. More CPO demand for pure biodiesel (FAME) production could be met, but this would require a shift of volume used in other industries, or reduction in CPO export or stock.

2.2. Gasoline and bioethanol use

Table 2.12 shows the gasoline supply and demand balance in Indonesia between 2010 and 2019. Between 2010 and 2018, gasoline fuel demand increased at an annual growth rate of 6.2%. During the same period, production dropped by 2.4% annually, and imports increased by 5.5%. Between 2016 and 2018, the decline in gasoline production was stronger, i.e. 9.2% per year. This incited a more robust rise in imports (8.8%), while demand grew weaker at 3.6% per annum.

Table 2.12. Gasoline Supply and Demand Balance

(million kL)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Transport use	23.9	36.5	29.3	30.5	30.9	31.5	32.0	33.6	34.4	35.2
Production	11.3	10.8	11.2	11.4	11.9	11.9	11.1	8.1	8.8	n/a
Import	12.7	15.6	17.9	1.7	19.5	18.2	15.7	17.9	18.6	19.1
Export	0.004	0.014	0.020	0.015	0.003	0.002	0.001	0.006	0	n/a

Source: MEMR (2019), USDA (2019) for transport use in 2019, and Tan et al. (2020) for import in 2019.

Despite a higher consumption share than diesel, Indonesia's bioethanol programme to substitute gasoline use has never known actual implementation. Indonesia practically knows only the first-generation bioethanol production method. The process includes producing molasses from sugarcane, followed by the fermentation process.

As reported in Hidayat (2020), the Indonesia Biofuel Producer Association estimates that all-grades ethanol domestic need is around 90 million to 100 million litres per year, with the current total annual production capacity of 180 million litres. The maximum yearly installed capacity is about 245 million litres. Between 2010 and 2015 (USDA, 2019), only 29 million litres were produced, and all were exported. No bioethanol has been produced since then.

2.2.1. Gasoline demand model in road transport sector

In Malik (2021), diesel fuel demand from road transport sector in Indonesia was estimated as a function of GDP and the forecasted diesel fuel price.

$$RDGSLCAR_y = \frac{NDDCAR_y}{MGSLFE_y} . MGSCAR_y . 0.8$$

where:

$RDGSLCAR_y$: demand of gasoline from road transport sector of the year *y* (thousand TOE).

$NDDCAR_y$: average gasoline fueled road vehicle mileage of the year *y* (km). This is assumed to remain constant at 10,000 km per year.

$MGSLFE_y$: average gasoline-fuelled road vehicle economy of the year *y* (km/litre) which is assumed to remain constant at 13.4 km/litre.

$MGSCAR_y$: number of gasoline-fuelled road vehicles of the year *y* (thousands of vehicle units) which is assumed to grow at the same rate as the GDP.

Table 2.13 shows that the demand of diesel fuel from road transport demand shall increase from around 28.1 mtoe in 2020 to around 117.4 mtoe in 2050 that means a compound annual growth rate of 4.9%. In terms of volume, this means an increase from around 32.7 million kL in 2020 to around 136 million kL in 2050. As in the case of diesel fuel, this estimation of gasoline consumption is line with the BAU scenario of Indonesia Energy Outlook and Saving Potential study in Malik (2021).

Table 2.13. Total Diesel Fuel Needed for Road Transport Sector Use in Indonesia in Terms of Energy and Volume Unit

	2020	2025	2030	2035	2040	2045	2050
million-toe (mtoe)	28.1	36.2	46.7	59.6	75.6	94.2	117.4
million-kL	32.7	42.1	54.3	69.3	87.9	109.5	136.5

Source: Malik, 2021, and author's calculation.

2.2.2. Volume of bioethanol needed in scenarios

As mentioned previously, Wiratmini (2020) reported Indonesia would have started with a bioethanol blending mandate at 2% in East Java province.

In this report, we assume two scenarios of bioethanol blending mandate as follows:

- KEN scenario: bioethanol blending mandate is set at 2% for East Java starting in 2023 and then in Java starting in 2025. This scenario reflects the National Energy Policy (KEN or *Kebijakan Energi Nasional*) as decreed in the government regulation PP no 79/2014.
- NZE scenario: bioethanol blending mandate is set at 5% level for East Java starting in 2023 and then in Java starting in 2025. This more higher blending mandate of bioethanol reflects the Net Zero Emission (NZE) scenario of Indonesia.

To calculate the need of bioethanol, we need to estimate first the total consumption of gasoline in East Java province and in the whole Java Island. For this purpose, we calculated the percentage of East Java province and the whole Java Island, covering six provinces, in the allocation of 'Premium' gasoline product in all provinces in Indonesia in 2019, as given in Pertamina (2020): East Java province's percentage was around 13%, while the whole Java Island was around 38%. Assuming these percentages remain the same from 2020 to 2050, we obtained the following results in Table 2.14, showing gasoline fuel consumption in East Java province and in Java Island and the needed bioethanol in both scenarios.

Implementation of the bioethanol blending mandate starting at 2% (KEN scenario) and 5% (NZE scenario) in 2023 in East Java Province would need respectively around 0.1 and 0.2 million kL of bioethanol. The needed bioethanol would increase by more than threefold in 2025 as the mandate covering the area would be extended to the whole Java Island. The needed bioethanol would reach 0.4 and 1 million kL by 2030, 0.7 and 1.7 million kL in 2040 and 1 and 2.6 million kL in 2050, respectively, in the KEN and NZE scenarios.

Table 2.14. Gasoline Consumption in East Java and Java Island and Bioethanol Needed in Scenarios

(million kL)

	2020	2023	2025	2030	2035	2040	2045	2050
Gasoline consumption (million kL)								
East Java	4.3	5.0	5.5	7.1	9.1	11.5	14.4	17.9
Java Island	12.3	14.3	15.9	20.5	26.1	33.2	41.3	51.5
Total bioethanol needed in the scenarios (million kL)								
KEN Scenario	0.0	0.1	0.3	0.4	0.5	0.7	0.8	1.0
NZE Scenario	0.0	0.2	0.8	1.0	1.3	1.7	2.1	2.6

KEN = National Energy Policy, NZE = net zero emissions.

Source: author's calculation.

With the current yearly fuel-grade bioethanol production capacity of around 45,000 kL (0.045 million kL), the amount needed in both scenarios cannot be met. In 2023, with the blending mandate implemented only in East Java, only 45% and 18% of the bioethanol demand can be met, respectively, in the KEN and NZE scenarios. In 2025, with the blending mandate implemented in the whole Java Island, only 14% and 6% of the bioethanol demand can be met, respectively, in the KEN and NZE scenarios.

2.2.3. Volume of molasses needed in scenarios

Using USDA (2019) time series 2010–15 data of bioethanol for fuel production and the needed molasses in Indonesia allowed us to calculate that, on average, 3.75 kg of molasses are needed to produce 1 litre of bioethanol.

Assuming this conversion rate remains the same until 2050, we can calculate the needed molasses in both scenarios as given in Table 2.15 below.

Table 2.15. Needed Molasses in Scenarios

(million tonnes)

	2020	2023	2025	2030	2035	2040	2045	2050
KEN Scenario	0.000	0.374	1.191	1.536	1.961	2.487	3.099	3.862
NZE Scenario	0.000	0.936	2.977	3.841	4.901	6.217	7.747	9.655

KEN = National Energy Policy, NZE = net zero emissions.

Source: author's calculation.

According to Agustian et al. (2021), total sugarcane production in Indonesia steadily increased from around 2.3 million tonnes in 2015 to 2.6 million tonnes in 2019. The potential of molasses (24% of sugarcane production) increased from around 0.550 million tonnes in 2015 to 0.632 million tonnes in 2019. This means that the current potential of molasses would possibly be sufficient only to meet the need of the KEN scenario in 2023, but not be enough to meet feedstock demand to produce bioethanol the rest of the period and would not be enough to meet demand in the NZE scenario in 2023, even after switching all the molasses use from export and chemical industries to bioethanol production only.

Molasses alone as feedstock would not be enough to meet bioethanol production demand in both scenarios. Other types of feedstocks would be needed to produce bioethanol such as sago and cassava. Indonesia once exported cassava-based bioethanol to the Philippines. According to Murdiyatmo (2021), two cassava-based bioethanol plants in Lampung once operated with installed production capacity 110,000 kL per year between 2009 and 2013. However, this industry was closed as the bioethanol production cost and price from the US was lower.

Chapter 3
Biomass Supply Potential up to 2040

Biomass is any organic matter produced through photosynthetic processes, both in the form of products and waste of recently living plants or animal origin. It is available in many forms such as agricultural products, forestry products, municipal, and other waste.

Bioenergy is derived from biomass to generate electricity and heat, or to produce liquid fuels for transport. It can be used indirectly by converting it into fuels or directly through combustion to generate heat, or it can be converted to methane gas or transportation fuels like ethanol and biodiesel.

Pirard et al. (2017) pointed out that the potential for bioenergy development is assumed to be significant, as millions of hectares of degraded land could theoretically be used for the production of various kinds of biomass, either as residues (e.g. from agriculture, forestry or municipal waste), alternative products (e.g. biofuels vs. other palm-oil-derived products), or dedicated tree plantations (established and managed specifically to supply the mill). Indonesia also plans to stimulate the restoration of degraded lands and to support access to electricity in remote rural areas, in a context of declining production of fossil fuels and increased reliance on imports that are expected to play in favour of bioenergy.

According to Mahidin et al. (2020), the total biomass energy potential in Indonesia is about 38 mtoe. The quantity of biomass that can be used is roughly 32 mtoe. This section covers only the biomass potential for power generation and transport fuels.

1. Biomass supply potential for power generation

As shown in the previous Table 2-2, the type of biomass feedstocks for power generation are palm oil, sugar cane, rubber, coconut, rice husk, corn, cassava, wood, cow dung, and MSW. The estimated total potential of biomass energy-based power plants is around 33 GW.

Regarding the wood-based electricity production, Indonesia is promoting a scheme whereby the biomass power plants will be supplied by woody biomass from dedicated tree plantations. Although the scheme is still at its infancy stage, a number of investors have shown interest in on-grid wood-based electricity projects, including power plants and associated tree plantations to supply fuel, either large-scale plantations (Hutan Tanaman Industri – HT/HTI) or out-grower schemes. Alternative options of interest to investors include using woody biomass for co-firing with other energy sources (e.g. coal or PKS) or making economic use of residues from wood processing such as sawn wood or plywood (Pirard et al., 2017).

According to Winarno (2021), approximately 70% of Indonesia's total land is designated as the State Forest Area (Kawasan Hutan) within the mandate of the Ministry of Environment and Forestry. An area of 36.99 million hectares has not been issued a license, 10.06 million of which is reserved for HT/HTI (industrial plantation forest).

The area based on forest functions is divided into Conservation Forest (Hutan Konservasi – HK), Protection Forest (Hutan Lindung – HL), and Production Forest (Hutan Produksi Tetap – HP). Of these three, the Production Forests covered a total area of 74.44 million hectares (62.57%) at the end of 2020.

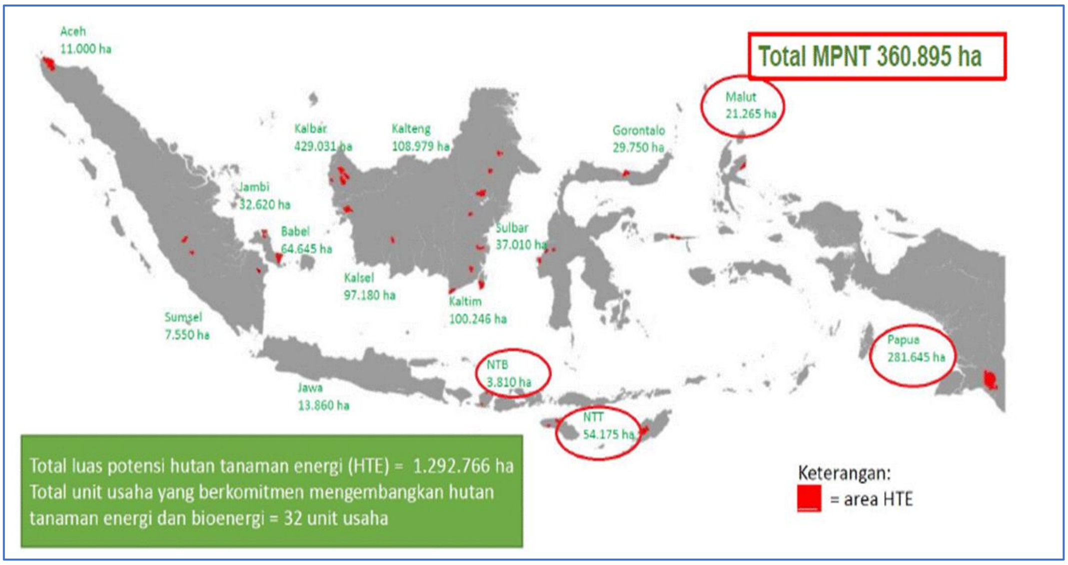
Production forest area consists of Permanent Production Forest (HP), Limited Production Forest (Hutan Produksi Terbatas, HPT), and Convertible Production Forest (Hutan Produksi yang Dapat Dikonversi, HPK). The area of HP is 28.99 million hectares, HPT is 28.41 million hectares, and HPK is 18.04 million hectares.

The HT/HTI forest is 5 million hectares. HT/HTI is a man-made forest cover class, and includes all types of planted forests, both Industrial Plantation Forest/IUPHHK-HT and planted forest from reforestation/regreening within or outside the forest area. It is determined based on image interpretation, and appears as a neat pattern on flat areas, in contrast to surrounding areas with different colours on non-flat/wavy topographies. The production of wood is around 21 million m^3/year.

The government scheme to promote wood-based electricity generation is being popularised as Tree Plantations for Energy (Hutan Tanaman Energi – HTE). HTE does not refer to specific rules applied to plantations, as they still operate within the usual HT/HTI framework. However, it provides room for bioenergy-oriented investments to unfold and, hopefully, thrive as the scope is expanded and other species are permitted. This HTE concept is currently included under MoEF Regulation P.12/Menlhk-II/2015 on Industrial Tree Plantations. This Ministry regulation embraces three main groups of species: woody forest trees, woody estate crops, and other crops that are allowed as part of HT (Pirard et al., 2017).

Winarno (2021) showed that the area under HT/HTI is 1.325 million Ha. Of this, the total area of potential energy plantation forest (HTE) is 1.293 Ha. Figure 3.1 shows the distribution of the HTI/HTE plantation forest throughout Indonesia (Figure 3-1).

Figure 3-1. Map of Potential Industrial/Energy Plantation Forest



Note: MPNT = HTE area of Maluku, Papua, and Nusa Tenggara Provinces; HTE = potential energy plantation forest; ha = hectare; NTB = Nusa Tenggara Barat Province; NTT = Nusa Tenggara Timur Province
Source: Winarno (2021).

Mahidin et al. (2020) showed that the biomass energy potential of Indonesia is 130 million tonnes. In energy value, this is around 39 mtoe (Table 3.1). Most of the biomass potential comes from crop and forest residues (73%).

Table 3.1. Biomass Energy Annual Potential
(million tonnes)

Biomass Type	Annual Potential (million tonnes)	Energy Value (mtoe)
Crops	75	25
Forest Residues	25	5.7
Residues from agro-industry	12	3.5
Residues from wood-industry	7	1.8
Animal Waste	8	1.6
Others	10	1.8
TOTAL	137	39.4

Source: Mahidin et al. (2020).

Widodo et al. (2021) showed the biomass total potential from different estate crop wastes (Table 3.2) by taking into account the area of plantation and its specific potential (tonne/Ha).

Table 3.2. Estimation of Estates Crops Waste Potency

No	Kind of waste	Area (ha)	Conversion factor (%)	Potency (m^3/ha)	Total Potency (ton/yr)
1	Rubber trunk	3,279,391	3.33*	35	3,279,391
2	Oil palm	6,370,217			11,861,615
	Trunk		5.46*	78	16,277,688
	Shell		5**		593,080
	EFB		20**		2,372,323
	Ditch CPO		15**		1,779,242
3	Coconut	3,803,614			3,096,845
	Trunk		2.0*	80	3,651,469
	Shell		12****		371,621
4	Sugarcane	381,786			2,241,806
	Bagasse		4****		76,357.2
	Molasses		3****		57,267.9
Total					45,658,705

CPO = crude palm oil, EFB = empty fruit bunch.
Remarks: * Rate of tree replantation per year, ** Percentage from Fresh Fruit Brunch,
**** Percentage from the whole fruit.
Source: Widodo et al. (2021).

Widodo et al. (2021) also provided the data on the plantation area, production, and wastes of some food crop products (Table 3.3).

Table 3.3. Harvesting Areas, Productions and Waste Potency of Some Food Crop Products

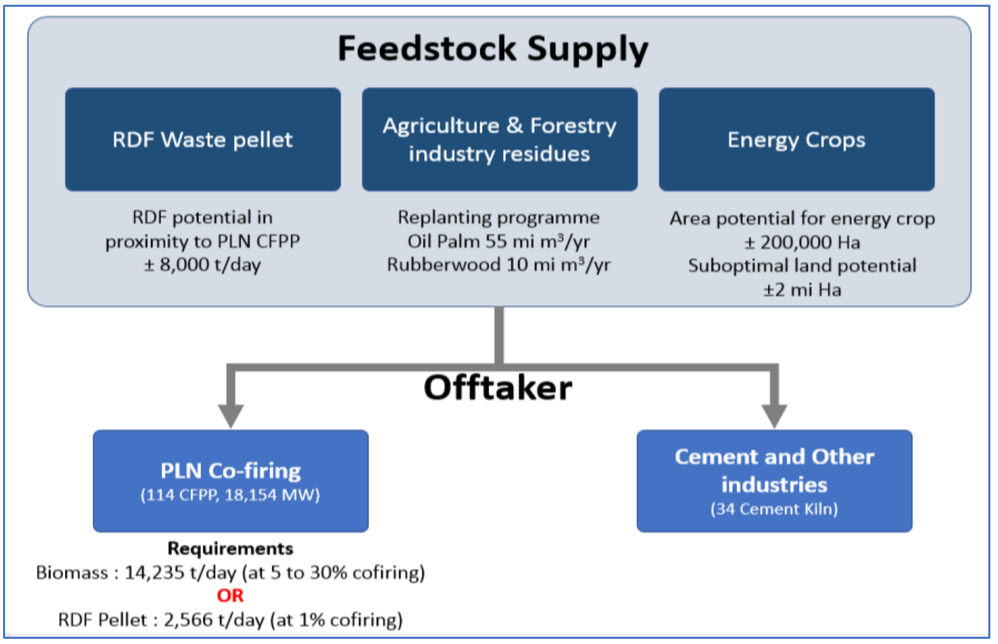
No	Kind of Agricultural Products	Harvesting area (10^3 ha)	Production (10^3 ton)	Yield Rate (quintal/ha)	Conversion Factor (ton/ha)	Potency (10^6 ton)
1	Paddy**	11,786.430	54,454.937	46.20	5.1	60.110
2	Maize	3,345.805	11,609.463	34.70	5.2	17.398
3	Cassava	1,227.459	19,986.640	163.00	6.1	7.487
4	Peanuts	706.753	838.096	11.86	2.0	1.413
5	Soybeans	580.534	747.611	12.88	1.8	1.045
	Total					87.453

Source: Widodo et al. (2021).

In the case of biomass for co-firing in coal power plants, Table 2-6 above provides the biomass demand in 2040 for different mixing share options (5%, 10%, 20%). The demand was calculated at different moisture content levels (10%, 15%, 25%, 30%, 40%, and 50%). The demand is between 4 million tonnes for under 5% mixing rate at 10% moisture to almost 35 million tonnes under the 20% mixing rate and 50% moisture content.

According to Adhiguna (2021), large biomass potential does not necessarily translate into the economical use of biomass in power generation. Attracting industrial biomass investments at the low selling price PLN is likely to require would certainly cast doubts, which need to be clearly addressed upfront. Securing stable and economic feedstock will be necessary to successfully implement the biomass co-firing program. In this regard, Adhiguna (2021) provided the MEMR as shown in Figure 3.2.

Figure 3.2. MEMR Feedstock and Offtake Plans



MEMR = Ministry of Energy and Mineral Resources; RDF = refuse-derived fuel; PLN = perusahaan listrik negara.
Source: Adhiguna (2021).

Three main biomass sources endorsed by MEMR are municipal waste, forestry/agriculture industry residue, and energy crops. These sources will supply PLN and other industries, such as cement. Large MSW sources are usually available in heavily populated Java Island, while other wood-based biomass supplies are concentrated primarily in Sumatra. Potential use of rice husks for co-firing has not been considered due to the technical complexity of straw-based biomass and market impacts due to competing uses. Within the forestry/agriculture sector, palm and rubber plantation replanting has been suggested as a potential biomass source to provide 65 million m^3 of biomass annually. Replanting activities are performed in existing plantations with low-productivity mature crops.

2. Biomass Supply Potential for Biofuel

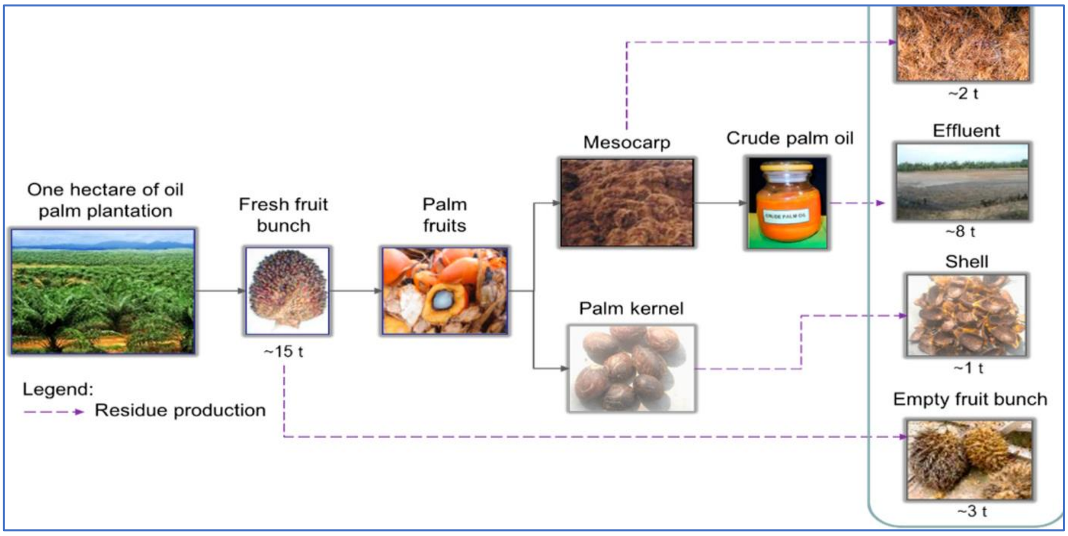
2.1. Biodiesel

Indonesia is the largest palm oil producer in the world, producing more oil palm fruit than the other countries, including Malaysia. Palm oil is used in several commercial products including cooking oil, soap, cosmetics, and margarine. Palm oil is also used as a lubricant in industrial processes and to produce plastics, textiles, emulsifiers, esters, explosives, and pharmaceutical products (Casson, Muliastra, and Obidzinski, 2014). The development of biofuels from biomass has raised interest in expanding the palm oil plantation area. This is because palm oil is the main raw material for biodiesel in Indonesia.

CPO is the primary product derived from the red fruit of the oil palm, while palm kernel oil, derived from the fruit's nut, is considered a secondary product. Oil palm biomass includes EFBs, palm mesocarps fibres (PMFs), PKS, oil palm fronds, oil palm trunks, as well as palm oil mill effluent (POME). Oil palm fronds account for 70% of the total oil palm biomass produced, while EFB accounts for 10% and oil palm trunks account for only about 5% of the total biomass produced.

According to Harahap et al. (2019), Indonesia housed 11 million hectares (Mha) of oil palm plantations and produced 31 million tonnes (Mt) of CPO in 2015. Oil extraction from palm fruits occurs in palm oil mills. One tonne (t) of CPO production results in nearly 5 t of solid biomass waste, including EFBs, PKSs, PMFs, and POME; see Figure 3.3. This implies that, in 2015, Indonesia produced around 155 Mt of palm biomass residue.

Figure 3.3. Biomass Use in Oil Palm Industry



Source: Harahap et al. (2019).

Regarding the potential for biodiesel, the previous Table 2.10 projected the demand of FAME for both B30 and B40 mandates using the volume of diesel fuel needed for the road transport sector. As shown, the FAME demand will reach 19.1 million kL in 2040 for the B30 mandate and 25.4 million kL for the B40 mandate. The current FAME production capacity is 12.85 million kL, indicating a shortage of supply to meet the 2040 demand for both the B30 and B40 mandates.

Increasing the capacity for FAME production implies that the demand for domestic CPO will continue to increase. The estimated CPO required to produce FAME in 2040 is also calculated above (Table 2.11). The estimated CPO consumption for B30 and B40 mandate in 2040 will be 17.5 and 23.4 million tonnes, respectively. This was calculated based on the assumption that 0.92 kg of CPO would be needed to produce 1 litre of FAME (pure biodiesel).

The increase in CPO will also be directly proportional to land requirements, especially because the average productivity per hectare is still low. Table 3.4 shows the palm oil average productivity from 2015 to 2021.

Table 3.4. Area and Production of Crude Palm Oil, 2015–21

YEAR	Area (ha)	CPO (tonnes)	Productivity (tonnes/ha)
2015	11,260,277	31,070,015	2.76
2016	11,201,465	31,730,961	2.83
2017	14,048,722	37,965,224	2.70
2018	14,326,350	42,883,631	2.99
2019	14,456,611	47,120,247	3.26
2020*)	14,858,300	48,297,070	3.25
2021**)	15,081,021	49,710,345	3.30

CPO = crude palm oil.
Source: DG Estate Statistik (2020).

The total area used for palm oil has grown from 11 million ha in 2015 to 15 million ha in 2021. According to da Conceição et al. (2021), the country's palm oil is mostly produced on private lands. Estates owned by large producers account for 53% of the country's palm oil, while smallholder palm oil production accounts for 40%. Government estates account for only a small part of the production.

Assuming that the productivity increased to 5 tonne/Ha, the land requirement to ramp up biofuel production will be 5 million Ha under the B30 mandate and almost 10 million Ha under the B40 mandate.

Table 3.5. Area and Production of CPO, 2040

Mandate	Plantation Area (million ha)	CPO Production (million tonnes)	Productivity (tonne/ha)
B30	3.50	17.51	5.00
B40	4.67	23.37	5.00

CPO = Crude Palm Oil.
Source: DG Estate Crop Statistik (2020).

Da Conceição et al. (2021) informed that the Indonesian government has prioritised the development of biodiesel and set a production target of 15 mkL by 2030 and 54.2 mkL by 2050. To support the achievement of that target, the government will allocate 4 million ha of area to support biodiesel production by 2025.

2.2. Bioethanol

Sugarcane is one of the major crops in Indonesia and is conventionally used for sugar production. The sugarcane plantations were established on existing smallholder agricultural lands, mostly in Central and Eastern Java. Prior to 1985, the sugar sector of Indonesia was self-sufficient. Since then, cane yields have stagnated due to political, economic, and market disfunctions. Indonesia is now one of the largest sugar importers (around 57% of total sugar consumption). Total Indonesian sugarcane area, especially on Java, is declining. Currently, 70% of sugarcane is cultivated on Java with smallholder sugarcane farming predominating the sector.

With the policy to reduce petroleum consumption with biofuel, the government has been promoting the use of sugarcane drop (molasses) as a raw material for bioethanol. Molasses is a by-product of the sugarcane industry, which still contains enough sugar. This national energy policy mandated the ethanol-blending of E5 and E10 by 2020 and E20 by 2025.

The production of bioethanol from molasses started with a demo plant in 2005 with a capacity of 8 kL/day (2,880 kL/year). The government planned to increase the number of bioethanol plants from 17 plants in 2006 with a capacity of 60 kL per day to a target of 25 plants in the year 2016. This plan has not been fully implemented. Based on Indahsari et al., (2011) study, the bioethanol industry in Indonesia has become stagnant. Potential problems include the availability of raw materials, competition with other plants, marketing, and consumption.

The previous Table 2.14 projected the bioethanol demand in 2040 to be 0.7 million kL under KEN scenario and 1.7 million kL under the NZE scenario. As mentioned above, the current annual fuel-grade bioethanol production capacity of around 45,000 kL (0.045 million kL), will not be enough to fully meet the bioethanol demand of both scenarios even in 2023.

The amount of molasses needed to produce the projected bioethanol as calculated in Table 2.15 will be 2.5 million tonnes for the KEN scenario and 6.2 million tonnes for the NZE scenario. The assumption was that the ratio, on average, is that 3.75 kg of molasses is needed to produce 1 litre of bioethanol. Based on Agustian et al.’s 2021 analysis, the potential molasses was predicted to be 24% of sugarcane production (Table 3.2). Thus, the sugarcane production to supply the 2.5 million tonnes of molasses required under the KEN scenario will be around 10 million tonnes.

Table 3.6. Sugarcane Production, and Potential Production of Molasses and Bioethanol in Indonesia, 2040

Scenarios	Sugarcane Production (Tonnes)	Potential Molasses (Million Tonnes)	Bioethanol Potential (Million Kilolitres)
KEN	10.4	2.5	0.7
NZE	25.9	6.2	1.7

Source: author's calculation.

Agustian et al. (2021) showed the development of the sugarcane harvested area, production, and productivity from 2015–19. Based on this, the productivity of the sugarcane increased from 4.96 tonnes/ha in 2015 to 6.43 tonnes/ha in 2019. Assuming that productivity will reach 10 tonnes/ha by 2040, the harvested sugarcane area will reach 1.04 million Ha for the KEN scenario and 2.6 million Ha for the NZE scenario (Table 3.3).

Table 3.7. Development of Sugarcane Harvested Area, Production and Productivity in 2040

Scenarios	Harvested Area (Ha)	Production (Million Tonnes)	Productivity (Tonnes/Ha)
KEN	1,036,250	2.5	10
NZE	2,590,417	6.2	10

Source: author's calculation.

Compared to the current area of around 450,000 Ha, an expansion of more than 600,000 by 2040 will be required for both scenarios. The government has programmes to expand the sugarcane plantation to reduce dependence on sugar imports. In this regard, Sulaiman et al. (2019) informed that the government has encouraged investment in integrated sugar mills. This includes sugar plantations. Land acquisition, however, is one of the largest obstacles in Indonesia. To obtain new land for sugar plantations, many aspects have to be considered, including: (1) the status of the area, i.e. the development of a new area being limited to only certain land use classes (discussed in a later section); (2) land suitability for sugarcane needs; and (3) land ownership.

Expansion of sugarcane plantations is still an issue, as well as that molasses, the raw material for bioethanol production, is competing for other usage and exports. In addition, the cost of molasses is increasing every year as a raw material, which makes the production cost for 1 litre of bioethanol high since it is four times the molasses cost/kg. Since the bioethanol price was determined from the market price index, the bioethanol price per litre is higher than gasoline. The price factor and land acquisition and competitiveness with other usage makes fuel-grade bioethanol from molasses (G1) still not available commercially as targeted.

More important attention is now being placed on the option of cellulosic ethanol (G2). Bagasse as sugar factory waste is one of the potential lignocellulosic materials to be developed into energy sources such as bioethanol. The conversion of lignocellulosic materials into bioethanol can secure its supply as substitute for gasoline (biogasoline), and, at the same time, reduce dependence on fossil fuel import.

Lignocellulosic materials in bagasse consist of 38.6% cellulose, 27.9% hemicellulose, and 17.8% lignin. The conversion process of lignocellulosic material into ethanol basically consists of pre-treatment, hydrolysis of cellulose to sugar, fermentation of sugar to ethanol, and purification of ethanol through distillation and dehydration processes. As mentioned in the previous section on demand potential, cellulosic ethanol technology is still developing, especially to reduce the cost of production. The cost of production of bioethanol G2 can be reduced by implementing effective pre-treatment and by using local enzymes for the saccharification process.

Winarno (2021) and Murdiyatmo (2021) presented that potential for obtaining ethanol from bagasse produced by sugar factories in Indonesia can reach 480,000 kilolitres/year. This was calculated based on the data that sugarcane production is approximately 38 million tonnes and the resulting total dry bagasse will be 4.75 million tonnes (12.5% of sugarcane production). Only 33% of the dry bagasse be used to produce ethanol (1.6 million dry tonnes) and that ethanol yield will be 300 litres/dry tonne.

Other Agricultural Products

Bioethanol from bagasse is still not sufficient to supply the demand in 2040 under both the KEN and NZE scenarios. As shown in Table 2-7 above, the other potential feedstocks for second-generation bioethanol production are rice straw, corn stover, sago hampas, and oil palm EFB. In total, the potential second-generation bioethanol production will reach 34.61 million kL (Table 3.8). This amount will be enough to meet not only the 2040 demand for both the KEN and NZE scenarios but also the 2050 demand (1.0 and 2.6 million kL for KEN and NZE, respectively).

Table 3.8. Potential Ethanol Production (Second-Generation) from Different Feedstock

Feedstock Type	Harvested Area (million ha)	Production (million tonnes)	Dry Yield (million tonnes)	Ethanol Yield (litres/tonne)	Potential Ethanol (million litres)
Sugarcane Bagasse*)		38	1.6	300	480
Rice Straw**)	8.1	81	48.6	400	19,440
Corn Stover***)		21	19.4	427	8,271
Sago Hampass****)	0.1	5	0.3	400	136
Oil Palm EFB*****)	9.3	204	15.7	400	6,283
TOTAL					34,610

Note: *) Bagasse production is 12.5% sugarcane production (4.75 million dry tonnes). Dry yield is the 33% bagasse for feedstock to produce ethanol.

**) Harvest time is times per year with straw production at 5 tonne/ha/harvest. Feedstock is 60% of Dry Straw (DS).

***) Dry yield is the corn stover amount (grain:stover = 1.067:1).

****) Production of Sago is the Trunk production. Dry Yield is the dry bagasse feedstock.

*****) Production of Fresh Fruit Bunch (FFB/TBS) is based on the productivity assumption of 22 ton/ha/year. Empty Fruit Bunch (EFB/TTKS) amount is 22% of FFB and dry FFB is 35% of the FFB.

Source: Winarno (2021).

Chapter 4

Biomass Power Generation and Wood Pellets in Japan

1. Current situation of the biomass power business in Japan

Renewable energy has increasingly received attention along with the accelerated transition to clean energy. Japan is committed to fighting climate change, having announced in October 2020 carbon neutrality by 2050, and, in April 2021, a 46% reduction in GHG emissions from the 2013 level. Renewable energy is considered indispensable to Japan's pledged decarbonisation.

Japan's energy policy was significantly changed by the 2011 Great East Japan Earthquake and the Fukushima Nuclear Accident. The 5th Strategic Energy Plan adopted in July 2018 describes renewable energy as a major power source for the first time and plans to expand the share of renewables to 22%–24% of the power generation mix in fiscal year (FY) 2030, of which biomass makes up 3.7%–4.6%.[3] This target is aligned with the Long-term Energy Demand and Supply Outlook 2015, in which the biomass energy is estimated by type as shown in Table 4.1 and general wood is likely to be the major source, accounting for around a half of the total biomass power.

Table 4.1. The Biomass Power Target of the Long-term Energy Demand and Supply Outlook 2015

Category	2030 Target
Unutilised wood	240MW
Construction wood waste	370MW
General wood	2,740–4,000MW
Biogas	160MW
Waste materials and other biomass	1,240MW
Renewable Portfolio Standard*	1,270MW
Total	**6,020–7,280MW**

* Some biomass facilities introduced under the Renewable Portfolio Standard of 2003 did not get transferred to the feed-in-tariff scheme.

Source: Ministry of Economy, Trade and Industry (METI) (2015).

To increase the renewable energy use including biomass energy, the Renewable Portfolio Standard (RPS) scheme started in 2003, followed by the feed-in-tariff (FIT) in 2012. Although the RPS was not as effective as expected, the generous tariff rates of the FIT

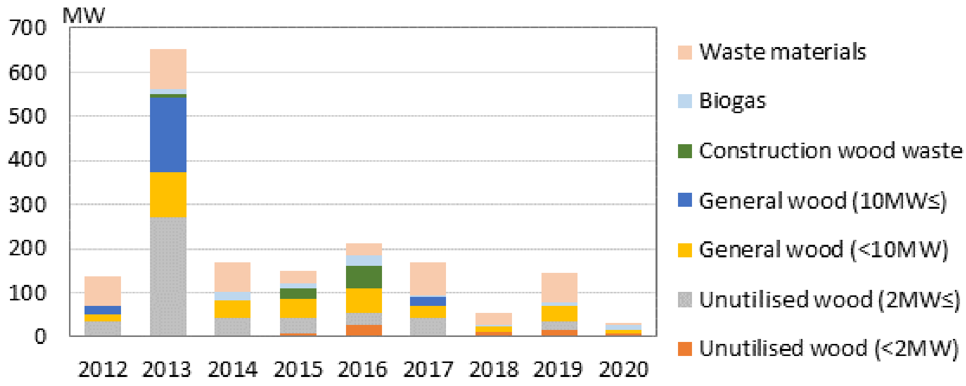
[3] This ratio was decided at the previous 4th Strategic Energy Plan of 2014 and maintained in the 5th Strategic Energy Plan. The Strategic Energy Plan outlines Japan's basic energy policy and is revised every few years.

scheme helped the biomass power capacity to increase by more than double in 7 years. Under the FIT scheme, biomass fuels for power generation are grouped into six categories.

- General wood: sawmill residues, import wood such as pellets and chips, palm kernel shell (PKS) and palm trunk
- Liquid biomass: palm oil
- Unutilised wood: domestic thinned wood
- Construction wood waste: wood waste salvaged from construction and other wood materials
- Waste materials and other biomass: pruned branched, paper, food waste, waste cooking oil, and black liquor
- Biogas: methane derived from sewage sludge, manure, and food waste.

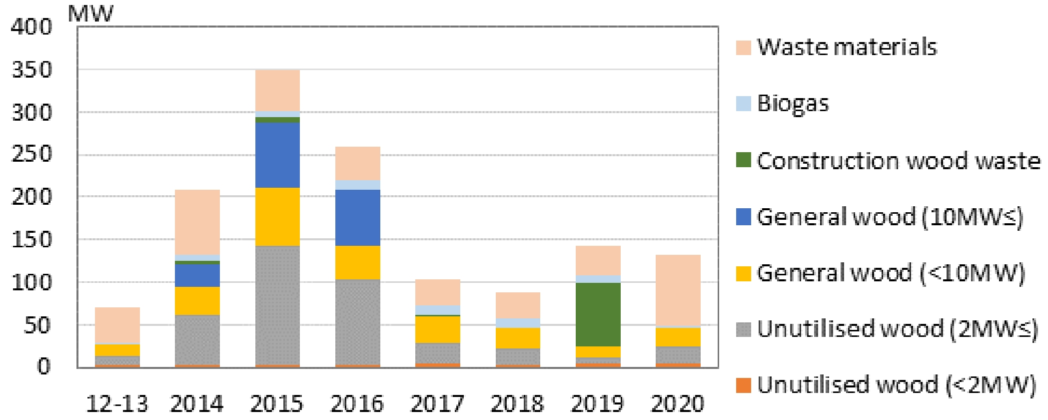
While inexpensive biomass sources such as wood waste from construction and waste materials, were the main fuels under the RPS, the domestic unutilised wood and the general wood whose tariff rates are set higher increased specifically (Figure 4.1, 4.2).

Figure 4.1. Approved Capacity under the FIT Scheme



FIT = feed-in-tariff.
Note: Liquid biomass approved under the FIT scheme between FY2012 and FY2017 is included in general wood and no liquid biomass has been approved since FY2018.
Source: METI (2021a).

Figure 4.2. Operating Capacity under the FIT Scheme



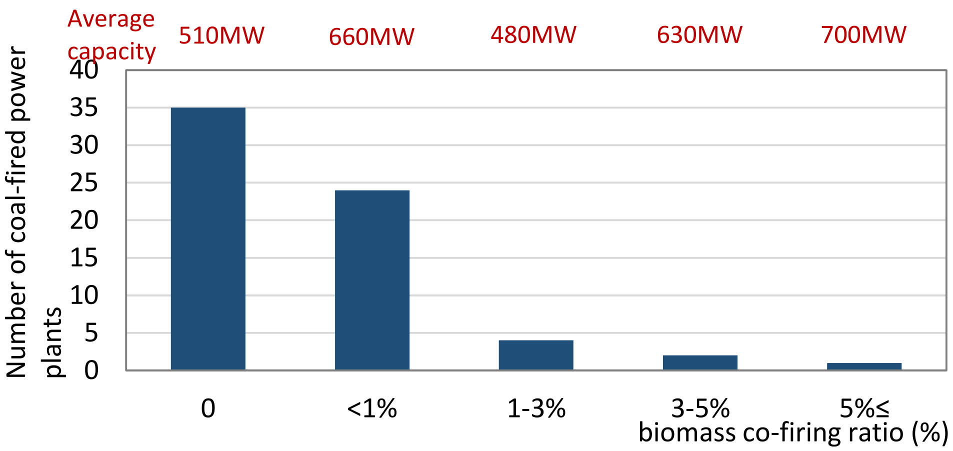
FIT = feed-in-tariff.
Source: METI (2021a).

The newly approved capacity has stagnated lately because some strict measures reduced the accumulated idle capacity in the revised FIT Act of 2017. For instance, developers are required to have entered into the grid connection agreement with a utility company for an FIT approval and to submit a business plan for assessment of feasibility and sustainability. As a result, the approved biomass power capacity is about 160MW on average in FY2018 and FY2019.

A recent change in the FIT scheme is that new projects of biomass co-firing with coal in the category of unutilised wood, general wood, and construction wood waste are no longer eligible for the FIT scheme from FY2019.[4] The data collected after implementation of the FIT scheme revealed that the generation costs of these biomass co-firing with coal are lower than the estimated costs of conventional biomass power plants in terms of capital expenditures, operation and maintenance, and fuels. Hence, biomass co-firing with coal does not have a rationale to receive support through the FIT scheme since it could make profits without it. For reference, Figure 4.3 illustrates a biomass co-firing ratio of the major power utilities' coal-fired power plants. Nearly half of the coal-fired power plants co-combusted biomass in FY2019 and most of them are less than 1% ratio of biomass.

[4] Biomass of waste materials co-firing with coal is not eligible for the FIT scheme from FY2021.

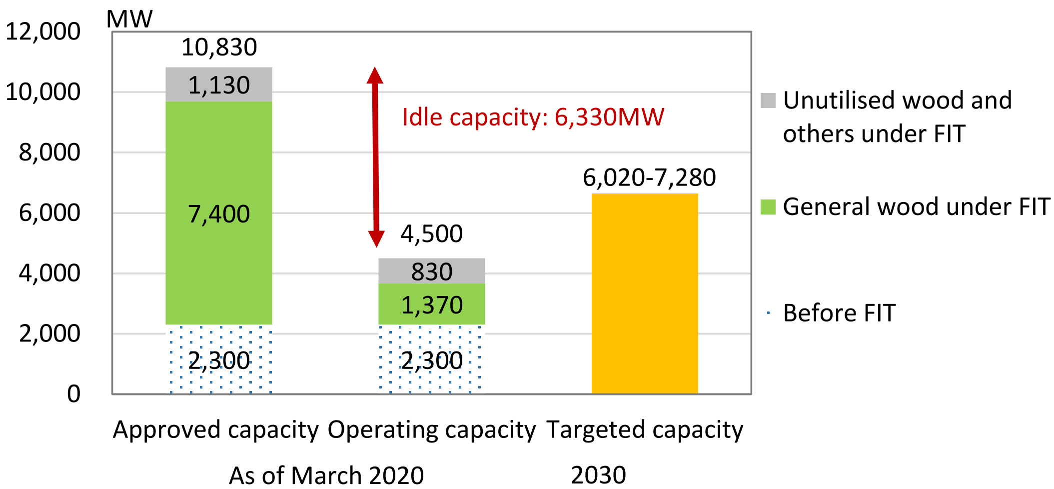
Figure 4.3. Major Power Utilities' Coal-fired Power Plants Co-firing with Biomass (FY2019)



Source: METI (2021c).

As of March 2020, the approved biomass power capacity under the FIT scheme has reached 10,830 MW, which already surpasses the 2030 targeted capacity of 6,020–7,280 MW, whereas the actual operating capacity is merely 4,500 MW (Figure 4.4). In other words, the capacity that was approved but has not started operation stands at 6,330 MW. Most of the idle capacity is explained by the general wood.

Figure 4.4. Biomass Capacity under the FIT Scheme and the 2030 Target



FIT = feed-in-tariff.
Source: METI (2021b).

Given the current situations, the government estimated how much biomass power capacity would increase toward 2030 (Table 4.2). Commencing operation of the idle capacity will be expedited first. Suppose that 40% of the woody biomass which encompasses unutilised wood, general wood, and construction wood waste and all of the remaining idle projects starts operation; the biomass power of 2,267 MW is expected to start operation by 2030. There is also the scenario analysis to estimate the newly approved capacity: the business as usual (BAU) scenario assumes continuous efforts based on the current policies and the new measure scenario (NMS) seeks to strengthen measures to secure more domestic supply. A difference between the two scenarios is found only in the woody biomass, that is, 310 MW for the BAU and 390 MW for the NMS.

Table 4.2. The Biomass Outlook
(in MW)

	Operating Capacity	Expected Operation of Idle Capacity	Newly approved		Total		2030 Target
			BAU*	NMS*	BAU	NMS	
Woody biomass*	1,836	2,108	310	390	4,254	4,340	3,350–4,610
Biogas	64	22	90		176		160
Waste materials	298	137	57		492		1,240
Before FIT**	2,300				2,300		1,270
Total	**4,506**	**2,267**	**457**	**540**	**7,230**	**7,310**	**6,020–7,280**

BAU = business as usual scenario, FIT = feed-in-tariff, NMS = new measure scenario.
Note: *Woody biomass includes unutilised wood, general wood, and construction wood waste.
** The figure before the FIT scheme includes the facility which did not switch from the Renewable Portfolio Standard.
Source: METI (2021b).

2. Supporting mechanism for biomass power in Japan

The FIT scheme is the main support measure to increase biomass, as well as other renewable energy in power generation. Biomass power approved under the FIT scheme is purchased at a fixed rate for 20 years. Japan's FIT tariff rates for biomass power are different by category (Table 4.3): for FY2021, ¥40 ($0.38)/kWh for unutilised wood with less than 2MW capacity, ¥32 ($0.30)/kWh for unutilised wood with more than or equal to 2MW capacity, ¥24 ($0.22)/kWh for general wood with less than 10 MW capacity, ¥13 ($0.12)/kWh for wood waste from construction, ¥17 ($0.16)/kWh for waste materials, and ¥39 ($0.37)/kWh for biogas. These tariff rates have remained the same since the onset of the scheme, and the domestic unutilised wood with less than 2MW capacity even went up from ¥32/kWh to ¥40/kWh in FY2015 to encourage small-scale biomass power plants. The domestic unutilised wood and the general wood would be treated as the construction wood waste without necessary documents to prove that these feedstocks are sustainably and legally sourced and are handled properly.[5] The long-term target set for biomass power is to be economically viable without financial support. However, this target seems too hard to achieve since the generation cost remains high.

Table 4.3. The FIT Tariff Rates

(in ¥/kWh)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Unutilised wood	32			40 (<2MW)							
				32 (2MW ≤)							
General wood	24					24 / 21 (20MW ≤)	Auction (10MW ≤)				
						24 (<20MW)	24 (< 10MW)				
Liquid biomass (palm oil)	24					24 / 21 (20MW ≤)	Auction				
						24 (<20MW)					
Construction wood waste	13										
Waste materials	17										
Biogas	39										

FIT = feed-in-tariff.
Source: METI.

Currently, the FIT scheme is under review to make renewable energy the major power source under the Act for Establishing Energy Supply Resilience, which passed the Diet in June 2020 and will take effect in April 2022. This Act covers partial revisions of the Act on Renewable Energy Special Measures (the FIT Act), the Electricity Business Act, and the Act on the Japan Oil, Gas and Metals National Corporation. Japan aims to develop a new scheme that provides investment incentives and reasonable foreseeability, while facilitating the market integration of renewable energies, since the new measure, Feed-in Premium (FIP) is planned to be applied from FY2022. Under the FIP scheme, renewable power generators are encouraged to sell electricity directly at the wholesale market or

[5] Woody biomass needs to follow 'Guidelines for Verification of Woody Biomass for Use in Power Generation' stipulated by Forestry Agency to be eligible for the FIT scheme.

over-the-counter transactions. They are eligible to receive a premium price, a difference between a previously defined guaranteed price (the FIT price) and the average wholesale price over a certain period on top of the wholesale market price.

Scope of the FIP scheme will be large-scale solar, geothermal, and hydro projects with more than or equal to 1MW capacity, biomass (general wood and the others) projects with more than or equal to 10MW capacity, and liquid biomass projects with more than or equal to 50kW capacity. Previously, biomass was not considered as a renewable energy to be covered by the FIP scheme due to the high costs. However, advantage, i.e. the stability and flexibility it provides to the grid, indicates that biomass energy power plants, especially large-scale ones, would be suitable for the FIP scheme. Therefore, biomass (general wood and the others) projects with more than or equal to 10MW capacity will comply with the FIP scheme from April 2022 and then those with more than or equal to 1MW capacity may also follow FY2023. New projects with more than or equal to 50kW capacity will be allowed to apply for the FIP scheme if it is preferred over the FIT scheme.

On the other hand, the FIT scheme will remain for the locally utilised power source. Biomass (general wood and the others) projects with less than 10 MW capacity, and hydro and geothermal projects with less than 1MW capacity will be required to meet certain conditions to be eligible for the FIT scheme from FY2022. The FIT scheme is grouped into either self-consumption or community-based types. The self-consumption type is required that the generated power is consumed at least 30% for their own use or a retailer of the generated power provides at least 50% of its power supply to a local government where a facility is located. For combined heat and power (CHP), in addition to utilisation of the generated heat, self-consumption of power at least 10% is necessary. The community-based type needs to meet one of three conditions: i) utilisation of the generated power or heat is agreed with a local government; ii) the project is either managed or financed by the local government; and iii) the generated power is supplied to a retailer managed or financed by the local government.

The auction system was introduced under the revised FIT Act in 2017. Biomass power plants using general wood with more than or equal to 10MW capacity and liquid biomass are subject to auction, with a pay-as-bid pricing scheme. Japan has conducted three biomass auctions so far (Table 4.4). The first auction of 2018 attracted interest in that the registered capacity exceeded the auctioned capacity for both categories. However, qualification requirements narrowed down the number of bids and only one bid in each category actually participated in the auction. As a result, there was one successful bid in general wood, but the bidder did not reach a contract since the commitment bond was not paid. For liquid biomass, the bidding price surpassed the ceiling price, which resulted in no award.

After unsuccessful two auctions, the third auction was held in 2020 and there was one award. The bidding price of ¥18.50/kWh is lower compared to the FIT tariff rate for general wood of ¥24/kWh. Still, the awarded capacity of 1.92MW is merely 1.6% of the auctioned capacity of 120MW.

Table 4.4. Auction Result

	First auction in 2018		Second auction in 2019	Third auction in 2020
	General wood	Liquid biomass		
Auctioned capacity	180MW	20MW	120MW	120MW
Ceiling price	¥20.60/kWh	¥20.60/kWh	¥19.60/kWh	¥19.60/kWh
Registered capacity	264MW (7)	169MW (26)	101MW (20)	319MW (7)
Qualified capacity	95MW (4)	11MW (5)	6MW (4)	164MW (3)
Participating capacity	35MW (1)	2MW (1)	4MW (3)	1.92MW (1)
Awarded capacity	35MW (1)	0MW (0)	0MW (0)	1.92MW (1)
Average bidding price	¥19.60/kWh	¥23.90/kWh	¥20.55/kWh	¥18.50/kWh

Note: ( ) is the number of bids.
Source: Green Investment Promotion Organization.

Furthermore, ministries across the government have encouraged biomass use for various benefits. For instance, biomass use is expected to revitalise the agriculture, forestry, and fishery sectors, reduce GHG emissions, and cultivate a recycling-based society. Hence, the 2009 Basic Act for the Promotion of Biomass Utilization stipulated developing the Basic Plan for Biomass Usage for comprehensive and strategic support, to establish the Biomass Utilization Promotion Council which coordinates measures amongst seven relevant ministries, and to implement financial or regulatory measures to encourage biomass use.[6]

The Basic Plan for Biomass Usage, which was initially laid out in 2010 and revised in 2016, clarifies the policy direction on measures to create community-led business to help the agriculture, forestry, and fishery sectors, and to bring in profitable opportunities to the community. The Basic Plan also sets the national target and addresses research and development of technology regarding biomass use. Woody biomass was identified as one of the priority strategic areas in the Biomass Commercialization Strategy adopted by the Biomass Utilization Promotion Council in 2012, which led to an aim for an integrated system to collect and transport the unutilised wood and utilisation of woody biomass at the power plants in a systematic way.

[6] The Biomass Utilization Promotion Council is consisted of Ministry of Internal Affairs and Communications, Ministry of Education, Culture, Sports, Science, and Technology, Ministry of Agriculture, Forestry and Fisheries, Ministry of Economy, Trade and Industry, Ministry of Land, Infrastructure, Transport and Tourism, Ministry of the Environment, and Cabinet Office.

The cross-government support has been provided to increase biomass utilisation, that is, subsidy, preferential tax treatment, and finance schemes. The biomass use facilitated by the government includes not only woody biomass but also other different types of biomass such as sewage sludge and food waste. This report focuses on measures on woody biomass, which are presented below.

Subsidy: Biomass utilisation is subsidised in various phases including planning, research, development, and demonstration of technology, and facility development. Table 4.5 presents some examples of subsidy to promote biomass related to energy use along with the ministry in charge and the budget allocated in FY2021.

Table 4.5. Examples of Subsidy for Biomass Energy

Ministry	Objective	Phase	FY2021 Budget
MAFF	Facility development for utilisation of woody biomass	Facility development	¥8,185 million*
MAFF	Facility development for quality improvement of woody biomass fuels	Facility development	¥14,701 million*
METI & MAFF	Stable and efficient supply system development of woody biomass fuels	Research, design, and development	¥1,250 million
METI	Promotion of regional renewable energy utilisation	Planning and facility development	¥3,470 million
MOE, METI, & MIC	Promotion of enhancing regional renewable energy and resilience through cost reductions of renewables	Planning, research, and facility development	¥5,000 million

MAFF = Ministry of Agriculture, Forestry and Fisheries, METI = Ministry of Economy, Trade and Industry, MOE = Ministry of the Environment, MIE = Ministry of Internal Affairs and Communication.
Note: * These budget amounts cover other items.
Source: Relevant Ministries Liaison Committee for Biomass Industrial Area (2021).

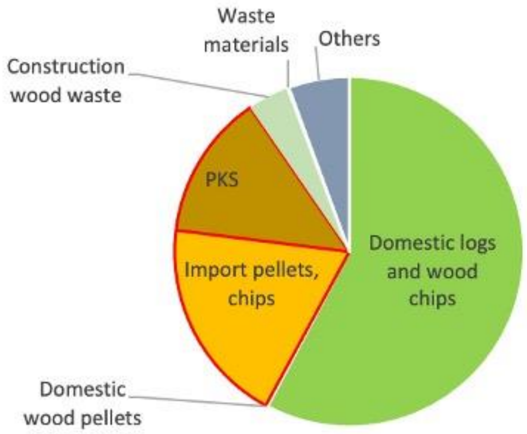
Preferential tax treatment: Property taxes on renewable power plants are reduced for 3 years by one-half for biomass power plants with capacity of less than 10MW and two-thirds for ones with capacity of more than or equal to 10MW and less than 20MW.

Finance scheme: Japan Finance Corporation, a public corporation wholly owned by the Japanese government, provides a program mainly for the cooperatives of agriculture, forestry, or fishery which plan to upgrade, refurbish, or acquire a joint facility to utilise biomass. The conditionality is an interest rate of 0.20% (as of January 2021), a loan limit of 80% of the required amount, and repayment term of 20 years (MAFF, 2021a).

3. Perspective of supply and demand balance of wood pellets and cost structure in Japan

According to a survey taken by the Japan Woody Bioenergy Association in FY2018 (from April 2018 to March 2019) with 55 biomass power generators, more than half of fuel for biomass power generation is domestically produced wood biomass at present in Japan in terms of weight (Figure 4.5).

Figure 4.5. Breakdown of Biomass Power Generation Fuel in Japan



PKS = palm kernel shell.

Note: The share of fuel calculated in terms of biomass fuel weight (‘Wood pellets’, ‘Construction wood waste’, ‘Waste materials’, ‘Others’: tonne; others: dry tonne).

Source: Depicted by IEEJ based on Japan Woody Bioenergy Association (JWBA), 2020.

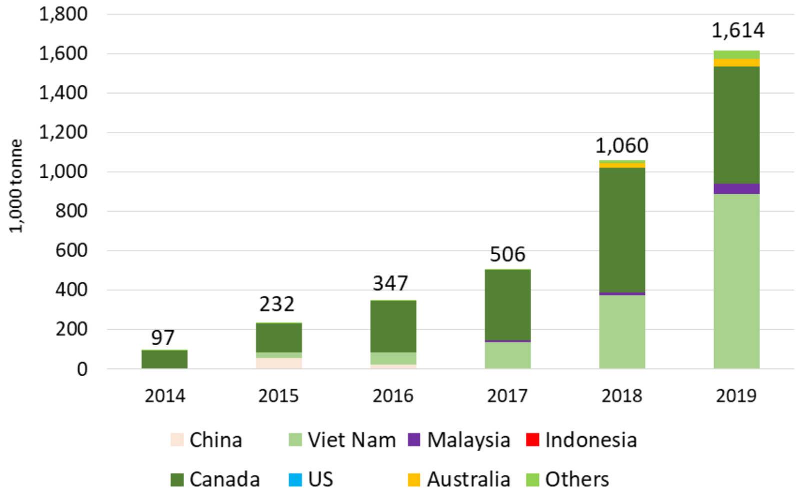
When translating the survey result into energy form, it is estimated that, within biomass power generation using wood biomass (‘Unutilised wood’, ‘General wood’, and ‘Construction wood waste’), around 30% of input fuel is met by import biomass fuel (Figure 4.6).

Figure 4.6. Input Biomass Fuel for Each Type of Biomass Power Generation

PKS = palm kernel shell.
Heat value used: Domestic logs and wood chips: 19.4 MJ/kg; Domestic wood pellets, Import pellets, chips: 15.5 MJ/kg; PKS: 18 MJ/kg; Construction wood waste, Other waste, and Others: assuming the same with wood pellets.
Source: Depicted by IEEJ based on Japan Woody Bioenergy Association, 2020.

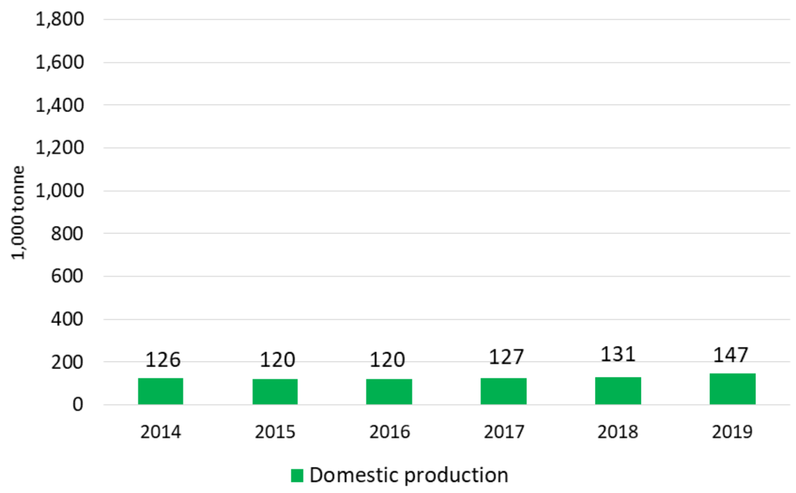
According to Japan's trade statistics, its import of wood pellets has increased around 16 times from 2014 to 2019. Viet Nam and Canada are the largest suppliers of Japan's wood pellet imports (Figure 4.7). On the other hand, domestic wood pellet production stayed almost the same over the same period (Figure 4.8).

Figure 4.7. Wood Pellets Import



Source: Trade Statistics of Japan.

Figure 4.8. Domestic Wood Pellets Production

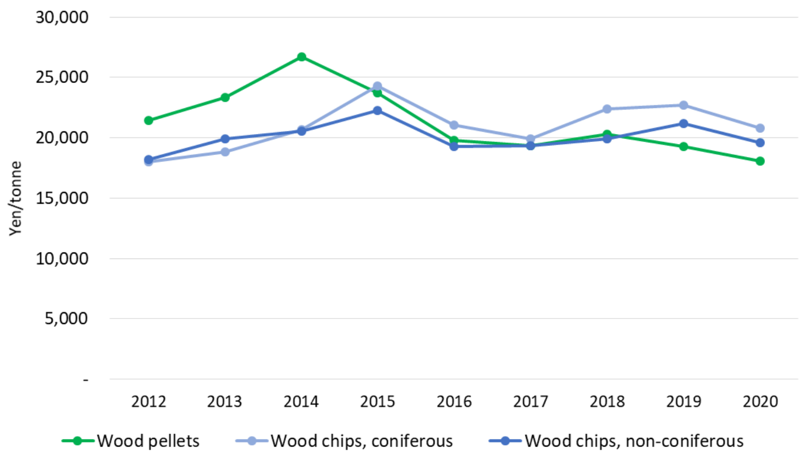


Source: Forestry Agency, Ministry of Agriculture, Forestry and Fishery (MAFF), 2020.

Applications of wood pellets in Japan include power generation, boilers, stoves, agriculture use, and others. Although the trade statistics do not specify the usage of the imported wood pellets, according to the Japan Wood Pellet Association (JPA), most are used for power generation.

The price of domestic wood pellets for power generation has a wide range. According to a survey of domestic wood pellet manufacturers undertaken by JPA in 2020, the average price of domestic wood pellets for power generation is around 14,000~29,000 ¥/tonne, while according to the Trade Statistics of Japan, the average cost, insurance, and freight (CIF) price of imported wood pellets is around 18,000 ¥/tonne in 2020 (Figure 4.9).

Figure 4-9. Average Cost, Insurance, and Freight Prices of Wood Pellets and Wood Chips

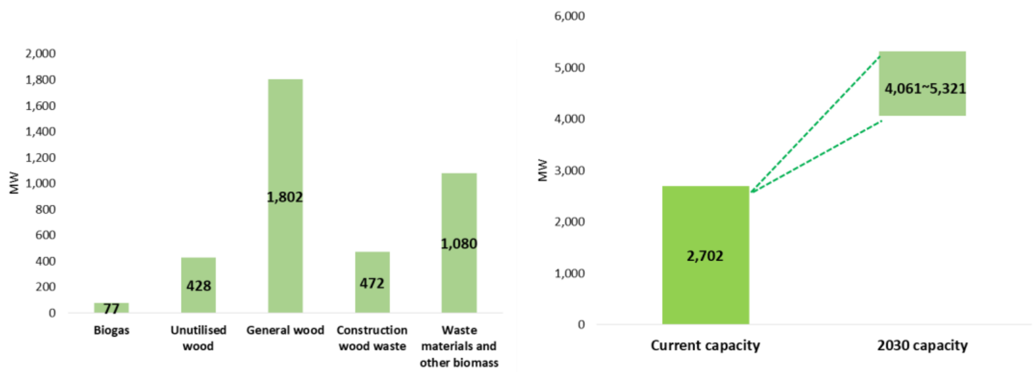


Average price = import value/import tonne.
Source: Estimated by IEEJ based on Trade Statistics of Japan.

According to JPA, most domestic wood pellet manufacturers are small scale, which contributes to their higher price. Besides, even with the increasing demand of wood pellets for power generation, domestic production has seen little scaling up. Imported wood pellets will continue to play an important role in future biomass power generation.

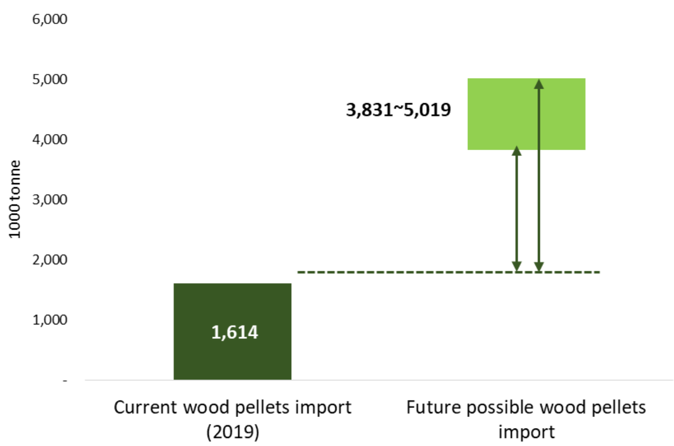
As of September 2020, total installed capacity of biomass power generation is around 3,859 MW (Figure 4.10), of which woody biomass power generation's capacity is 2,702 MW. It is estimated that to achieve the 2030 power generation mix, woody biomass power generation needs to be increased to around 4,061~5,321 MW. Assuming biomass power generation's capacity factor is 50%, thermal efficiency is 32%, and 30% of the biomass fuel input comes from imported wood pellets, by 2030 wood pellets imports are expected to be 3.831~5.019 million tonnes to meet the fuel demand for biomass power generation, which is around 2.4~3.1 times of imported wood pellets in 2019 (Figure 4.11).

Figure 4.10. Installed Capacity of Biomass Power Generation at Present (September 2020) and in 2030



Average price = import value/import tonne.
Source: METI compiled by IEEJ.

Figure 4-11. Needed Wood Pellets Import in the Future



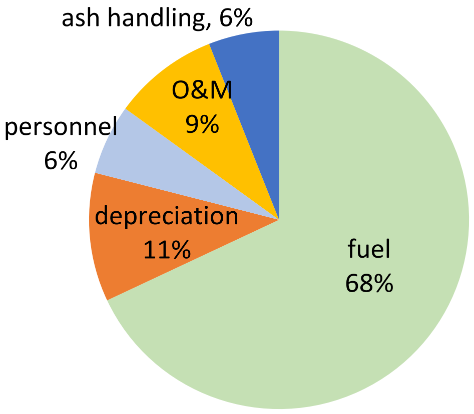
Average price = import value/import tonne.
Source: IEEJ estimation.

4. Issues and challenges

The first challenging issue is that generation cost remains high. In general, the tariff rates under the FIT scheme in Japan are higher compared with those in the European countries. The tariff rate for a biomass power plant with 5 MW capacity and the use of wood pellets is ¥24/kWh in Japan, whereas the equivalent case in Germany was ¥12.7/kWh in 2016 (METI, 2020a).

Unlike the other renewable technologies such as solar and wind power, the biomass power plants need fuels for operation. In Japan, the fuel cost makes up 68% of the generation cost of the biomass power (Figure 4.12) (METI, 2020b). Hence, it is necessary to reduce fuels costs, which will ultimately contribute to reductions of the biomass power generation cost. In particular, the cost reduction is critical for the biomass power plant stakeholders to stay in business after financial assistance under the FIT scheme ends in 20 years.

Figure 4.12. Cost Breakdown of Woody Biomass Power Plant in Japan



O&M = operations and management.
Source: METI (2020b).

To cope with this concern, it is important to create an environment that facilitates cost reductions of woody biomass harvested domestically. It would be effective if the processing and transporting system were adjusted or designed so that thinned wood and forest residues would be efficiently utilised as fuel resources (METI, 2020b). The current forestry is centred on planting and management of conifers, mainly for construction materials. This indicates that woody biomass for energy use comes second after production of construction materials as the main purpose of forestry. Inevitably, the supply of woody biomass for energy use is affected by demand for construction materials. Therefore, a well-organised system is required for collection and delivery of woody biomass for energy.

Another feasible approach is to plant and grow broadleaf trees and fast-growing trees in a coordinated way. Although broadleaf trees are not suitable for the construction materials as they tend to bend in a growing process, they are abundant in Japan. Advantages of fast-growing trees should also be highlighted in that they could save time and costs due to a shortened period of growth. If they are planted collectively in a certain place to be used specifically for energy, efficiency would be enhanced in collecting and transporting them. Moreover, productivity would improve because a thinning process will not be necessary.

The second issue is to secure a stable supply source. Based on the Forest and Forestry Basic Plan, availability of domestic woody biomass is determined (Forestry Agency, 2021). The drafted Basic Plan for revision in FY2021 estimates that demand for fuelwood, i.e. wood pellets, wood chips, firewood, and charcoal, will be 15 million m^3 log equivalent in FY2025 and 16 million m^3 log equivalent in FY2030, whereas domestic availability of fuelwood will be 8 million m^3 log equivalent and 9 million m^3 log equivalent in the respective years (Table 4.6). Imported wood products are expected to fill the gap between them. Therefore, it is essential to secure both domestic and imported biomass resources to meet operation of biomass power plants and to increase the biomass energy as planned.

Table 4.6. Forest and Forestry Basic Plan (draft)

	Demand for fuelwood*	Domestic availability for fuels	Equivalent capacity**
2019	10 million m^3	7 million m^3	280MW
2025	15 million m^3	8 million m^3	320MW
2030	16 million m^3	9 million m^3	360MW

Note: * Fuelwood includes wood pellets, wood chips, firewood, and charcoal.
**Equivalent capacity is estimated by METI.
Source: MAFF (2021b).

The third challenging issue is sustainability. The FIT scheme approves woody biomass on the condition that it is sustainably and legally harvested. Sustainability of fuels is ensured based on the Forest Act for domestic fuels and the third-party sustainability scheme for the imported ones. General wood needs to comply with the Guidelines for Verification of Compliance and Sustainability of Wood and Wood Products issued by the Forestry Agency in 2006. In addition, for sustainability to be qualified, the Guidelines require that woody biomass is harvested from forests which are confirmed by forest certification schemes such as the Forest Stewardship Council, the Programme for the Endorsement of the Forest Certification Scheme, and the Sustainable Green Ecosystem Council. Further, the woody biomass needs to be properly handled and not to be mixed with other uncertified products through the entire supply chain, which is verified by the chain-of-custody system.

In April 2019, the Biomass Sustainability Working Group under the umbrella of the New and Renewable Energy Subcommittee was established to examine the technical standards and aspects of sustainability. Currently, general wood encompasses sawmill residues, wood pellets and chips, PKS, and palm trunk under the FIT scheme. Yet, it is likely that different biomass fuels will be needed to meet demand, which will necessitate examining whether they are valid for the FIT scheme. Along with robust increases of imported woody biomass and agricultural residues like PKS, there is also a growing concern about their sustainability. In response, the Working Group has initiated a review of the current sustainability assessment criteria under the FIT scheme from 2020.

Table 4.7 lists the criteria how sustainability of biomass feedstock is assessed to be eligible for the FIT scheme. The Biomass Sustainability Working Group has investigated new subjects which are the food-versus-fuel dilemma, lifecycle assessment of GHGs, and the new third-party sustainability scheme as new assessment criteria to be added. While they are still under review, the Green Gold Label for PKS and palm trunk was added to the certified sustainability scheme in addition to Renewable on Sustainable Palm Oil for palm oil and Roundtable on Sustainable Biomaterials for PKS and palm trunk.

Table 4.7. Sustainable Assessment Criteria

Subjects	
Environment	Greenhouse gas emission reductions
	Consideration of land use changes
	Biodiversity protection
Society and labour	Impacts on society and labour assessment
Governance	Legal compliance
	Information disclosure
	Renewal/cancellation of certification
Appropriate management throughout the supply chain	
Securing independence of certification	

Source: METI (2021a).

The imported woody biomass and agricultural residues may be affected by the GHG lifecycle assessment standards, depending on policy direction on biomass energy. The certification systems do not include assessment of GHG. If GHG lifecycle assessment standards are required, business opportunities in Japan may change for biomass feedstock suppliers from abroad.

5. Conclusion

Biomass power generation has increased in Japan, mainly supported by the FIT scheme. Since the approved capacity of biomass power under the FIT scheme has already surpassed the 2030 target, it is a matter of time when pre-operational facilities commence operation to achieve the target.

If more biomass power plants start operation toward 2030, fuel demand for operation will inevitably rise. Currently, more than half of fuels for biomass power generation are woody biomass produced domestically but domestic woody biomass production has been limited, which has boosted imports of wood pellets in recent years. Hence, it is likely that imported wood pellets will play an important role to meet the fuel demand for future biomass power generation.

However, the imported fuels for biomass power generation are associated with the issues Japan needs to deal with. The price of the imported fuels needs to be competitive since the fuel cost for biomass power generation is key to reduce the generation cost which remains high in Japan. In addition, sustainability and lifecycle assessment of GHG on the imported fuels will be scrutinised, given the growing momentum for the 2030 Agenda for Sustainable Development worldwide. Japan will certainly pursue pathways to secure affordable and sustainable fuels to fulfil commitments.

Chapter 5

Wood Pellets Business Model in Indonesia

Referring to session 2.1, the amount of biomass especially wood chips or pellets will be estimated as 4.6 million tonnes to 34.8 million tonnes in 2040, for biomass co-firing coal power generation due to biomass mixing rate. In order to secure this remarkable volume of biomass, the supply chain must be maintained through applying some business model. Thus, in this chapter, appropriate business models are examined.

1. Types of biomass supply chain business model

The biomass supply chain consists of following segments:

- Cutting raw woods at a forest site and transporting to a fabrication factory
- Fabricating wood chips and pellets
- Transporting wood chips/pellets to coal plant sites

The biomass business model has the following three types of organization:

- Pure private company (pure business basis)
- Private company with government support such as subsidies and feed-in tariff (FIT)
- Public company such as a national company

The best way for Indonesia is the pure private company because it can produce wood chips/pellets affordably, allowing it to compete with coal. However, if private companies cannot produce the chips/pellets at affordable prices, second- and third-generation options are considered. But the third option will fully depend on national budget, so that it is almost impossible. As a result, the second option is suggested in this report. The biomass supply chain will be implemented on business basis; however, in order to secure this business, Indonesia may provide financial incentives or formulate appropriate FIT system. In addition, Indonesia regulates lower biomass mixing ratio such as 5%–10%, so that the power generation cost could not increase highly.

Another point on the business model of biomass supply chain is the function of the private company, i.e.:

- One company covers all the segments
- One company covers each segment

The first option can minimise the total cost of the biomass supply chain, and the enterprise should be large. On the other hand, the second option can expect an economic rationale in each segment, but it should be a group of small enterprises. Therefore, the business configuration is vulnerable. Thus, the report recommends the first option.

2. Economic study of the wood pellets business model

This section assesses the economics of the wood pellet supply chain business model based on several assumptions:

(1) Business configuration

A company engages the whole wood pellets supply chain, which comprises cutting raw woods, fabrication from raw woods to wood pellets and transportation of woods pellets from the fabrication site to coal power plants. In other words, this company consists of following departments:

a. Maintain woods including reforestation and cutting raw woods
b. Fabricate wood pellets based on the raw woods cut
c. Transportation of the wood pellets

(2) Basic assumption of the business model

a. Coal Power Plant
   - Capacity: 500 MW
   - Capacity factor: 80%
     = Generation amount: 3,504 GWh (500,000 kW x 24 x 365 x 80%) / year
   - 40% for thermal efficiency and 10% for biomass mixing ratio
     = Coal consumption: 3,504 GWh * 0.086 /40% = 753.36 ktoe (1toe = 10^7kcal) / year
     = Wood pellets consumption: 753.36 * 10% = 75 ktoe /year
     = Wood pellets consumption: 148.809 (75 / 5040 (kcal/kg)*10,000) ktoe /year = 150 ktoe /year and 407.696 = 408 tonne /day

b. Definition of biomass supply chain business model
   - Cutting raw woods by chainsaws
   - Fabrication from raw woods to pellets under assumed yield at 90%
   - Transportation: 100 km of distance between the fabrication site to a coal power plant

c. Others
   - Shared capital ratio: 30%
   - Interest rate of long-term borrowed money: 5%
   - Repayment years: 10 years after 3 years taxi holiday
   - Interest rate of short-term borrowed money: 7%
   - Interest rate of earning: 3%
   - Depreciation period: 10 years for all the equipment

(3) Cost assumptions

a. Cutting raw woods
   - Yield of fabrication factory: 90%
     = Cutting woods amount: 408 / 0.9 = 453 tonnes /day
   - Raw woods price: $35 / ton
   - Cutting equipment (chainsaw): $3,000 / unit
     = $3,000 x 70 units =$210,000
   - Number of labourers: 140 persons

b. Fabrication from raw woods to chips

- Fabricate 408 tonnes of pellets per day from 453 tonnes of raw woods
- Equipment: $1 million (21 tonnes of pellets production per day) and 20 units
- Number of labourers: 100 persons
- Electricity consumption per wood pellet: 0.1375 kWh / kg
- Electricity price: $0.07 /kWh

c. Transportation
   - Number of trucks: $70,000 per truck (10-tonne capacity) and 15 trucks
   - Number of drivers: 15 trucks x 2 = 20 persons
   - Fuel economy of 10-tonne truck: 5 km/litre
     = Diesel consumption: 100km /5 km/litre x 2 (return) x 15 trucks =600 litre /day
   - Diesel oil price: $0.050 /litre

(4) Forecasted income statement of A company

a. Annual revenue
   - Price of wood pellets: $100 / tonne
     * Annual revenue: 150 (148.809) ktoe / year x $100/tonne = $ 15,000/ year
b. Operation cost
   - Cutting raw woods
     * Raw wood cost: 165 ktoe x $35 /tonne = $5,775 /year
     * Labour cost: 70 team x 2 persons / team x $1,500 /person month x 12months = $2,520,000 /year
     *Total operation cost: $5,775 + $2,520 = $8,295,000 / year
   - Fabrication
     * Electricity cost: 150 ktoe x 0.1375 kWh/kg x 0.07 $/kWh x 1000 = $1,443.75 / year
     * Labour cost: 20 machines x 5 persons /machine x $1,500 /person month x 12 months / 1,000 = $1,800,000 /year
     * Total operation cost: $324,375,000/ year
   - Transportation
     * Diesel oil cost: 600 litre/day x $0.5 / litre x 365 = $ 10,950,000 /year
     * Labour cost: 15 trucks x 2 persons /truck x $1,500 /person month x 12 = $ 540,000 / year
     * Total operation cost: $649,000 /year

c. Depreciation

- Cutting raw woods
  * Chainsaw: $3,000 /unit x 70 units / 1,000 / 10 years = $21,000 / year
- Fabrication
  * Wood pellets producer: $1 million /unit x 20 units x 1,000 / 10 years = $2,000,000 /year
- Transportation
  = 10-tonne truck: $70,000 / unit x 15 units / 1,000 / 10 years = $105,000 /year

d. Income statement

This business will start in 2024 and the forecasted income statement of A company is show below from 2024 to 2040 (refer to Table 5.1).

Table 5.1. Forecasted Income Statement of A company ($1,000)

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Revenue of wood pellets		15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Operation costs		12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188
Cutting raw woods		8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295
Fabrication		3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244
Transportation		650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650
Depreciation		2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	0	0	0	0	0	0
Cutting raw woods		21	21	21	21	21	21	21	21	21	21						
Fabrication		2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000						
Transportation		105	105	105	105	105	105	105	105	105	105						
Profit after Ope. & Dep.		686	686	686	686	686	686	686	686	686	686	2,812	2,812	2,812	2,812	2,812	2,812
Interrest payment		744	744	744	744	670	595	521	446	372	298	223	149	74	0	0	0
Long-term		744	744	744	744	670	595	521	446	372	298	223	149	74	0	0	0
Short-term																	
Interest received		0	62	126	191	213	236	262	289	319	350	384	397	412	429	492	556
Profit before tax		-58	4	68	133	229	327	427	529	632	738	2,972	3,060	3,149	3,241	3,304	3,368
Income tax			1	24	46	80	114	149	185	221	258	1,040	1,071	1,102	1,134	1,156	1,179
Profit after tax		-58	2	44	86	149	212	277	344	411	480	1,932	1,989	2,047	2,106	2,147	2,189

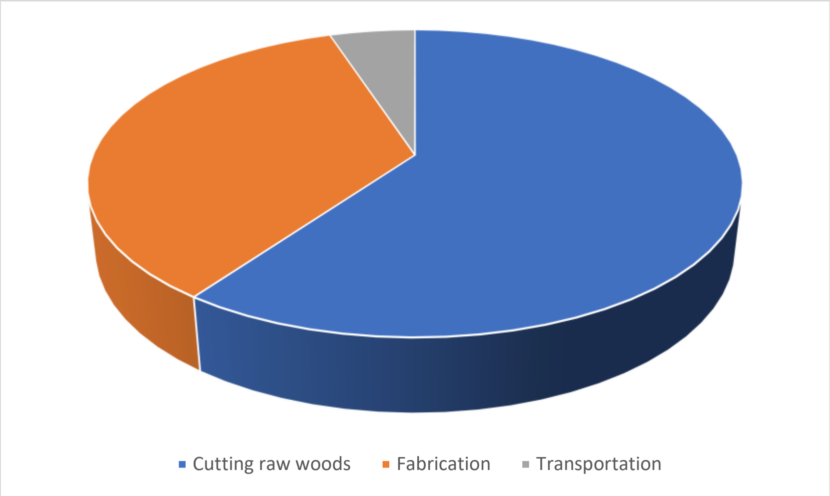
Source: Author.

Based on the income statement shown above, the following key findings are extracted:

i. A company will show a negative profit at the first year (2025) but after that will show a positive profit continuously until 2040.
ii. The department of cutting raw woods will mark highest cost share of a company at 60%, followed by the fabrication department at 35%, and the transportation department at 5% (refer to Figure 5.1).

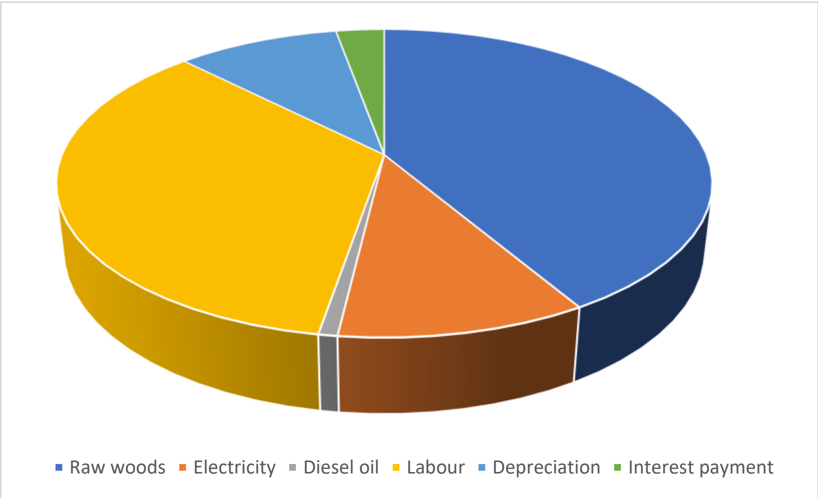
iii. Looking at cost items, the cost of raw woods procurement will be highest share at 42%, followed by labour cost at 35%, electricity cost of the fabrication department at 10% (refer to figure 5-2). For this analysis, $35 per tonne is assumed for raw wood costs and this assumption will be crucial to maintain the economics of this business model.
iv. This business model will be operating cost-oriented not capital cost-oriented (refer to figure 5.1); thus, management of raw wood cost, labour cost, and electricity cost is essential. Few variations of capital cost will not affect this business seriously.
v. Assumed selling price of wood pellet is $100 per tonne and appropriate.

Figure 5.1. Operating Cost Structure by the Three Departments of A Company



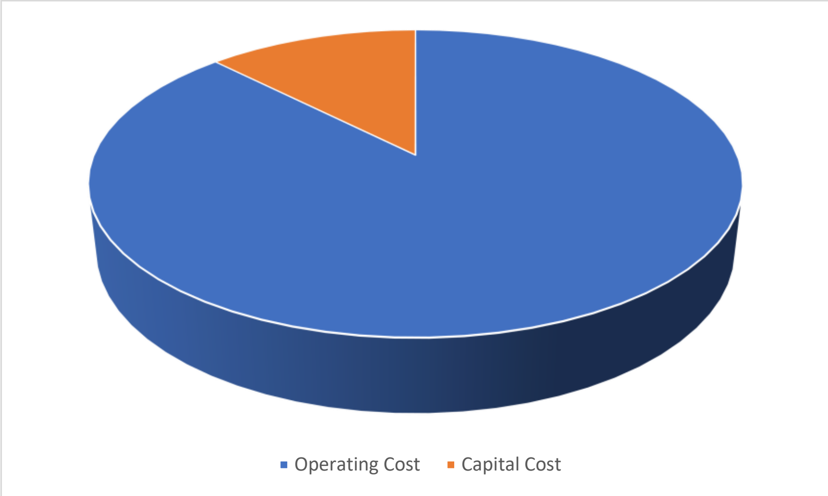
Source: Author.

Figure 5.2. Operating Cost Structure by the Cost Items of a Company



Source: Author.

Figure 5.3. Overall Cost Structure of a Company



Source: Author.

(5) Forecasted cash balance statement of a company

a. Capital cost

- Cutting raw woods: price of chainsaw $3,000 /unit and 70 units
  * $3,000 x 70 units = $210,000
- Fabrication: price of fabrication facility $1 million /unit and 20 units
  * $1 million x 20 = $20,000,000
- Transportation: price of truck $70,000 /unit and 15 units
  = $70,000 x 15 = $1,050,000
- Total capital cost
  =$210 + $20,000 + $1,050 = $21,260,000

b. Finance of capital cost

- Share of shared capital: 30%
  = $21,260 x 30% = $6,378,000
- Share of borrowed money (long-term): 70%
  = $21,260 x 70% = $14,882,000

c. Condition of borrowed money (long-term)

- Repayment period: 10 years with straight line method and 5% interest rate
- Repayment holiday; first 3 years

d. Cash balance statement

This business will start in 2024 and the forecasted cash balance statement of A company is shown below from 2024 to 2040 (refer to Table 5.2).

Table 5.2. Forecasted Cash Balance Tables of a Company
($1,000)

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Cash in Total	21,260	2,068	2,128	2,170	2,212	2,275	2,338	2,403	2,470	2,537	2,606	1,932	1,989	2,047	2,106	2,147	2,189
Profit after tax		-58	2	44	86	149	212	277	344	411	480	1,932	1,989	2,047	2,106	2,147	2,189
Depreciation		2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	0	0	0	0	0	0
Equity	6,378																
Long-term borrowed money	14,882																
Short-term borrowed money																	
Cash out Total	21,260	0	0	0	1,488	1,488	1,488	1,488	1,488	1,488	1,488	1,488	1,488	1,488	0	0	0
Repayment (long-term)					1,488	1,488	1,488	1,488	1,488	1,488	1,488	1,488	1,488	1,488			
Repayment (short-term)																	
Capital costs	21,260																
Cutting raw woods	210																
Fabrication	20,000																
Transportation	1,050																
Cash Balance	0	2,068	2,128	2,170	724	786	850	915	981	1,049	1,118	444	501	559	2,106	2,147	2,189
Accimulated cash balance	0	2,068	4,196	6,366	7,090	7,876	8,727	9,642	10,623	11,672	12,790	13,233	13,734	14,293	16,399	18,547	20,736

Source: Author.

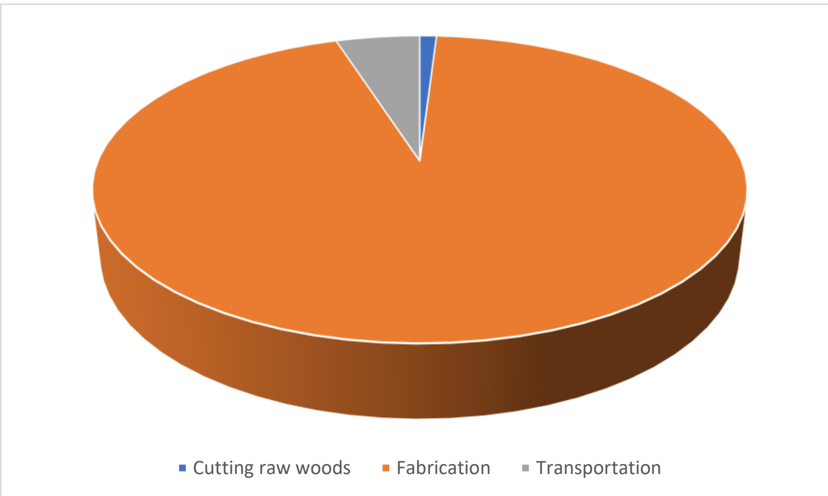
Based on the cash balance statement mentioned above, the following key findings are extracted:

i. A company will never face a money shortage until 2040.

ii. In terms of share of capital cost, the fabrication department shows its largest at 94%, followed by transportation department at 5%. Thus, a wood pellets production facility becomes key regarding capital cost (refer to Figure 5.3).

iii. Total cash gain in 2025–40 will be $21,194,000 and it is almost same amount of total capital cost, $21,260,000.

Figure 5.3. Capital Cost Structure of the Three Departments



Source: Author.

(6) Internal rate of return of A company

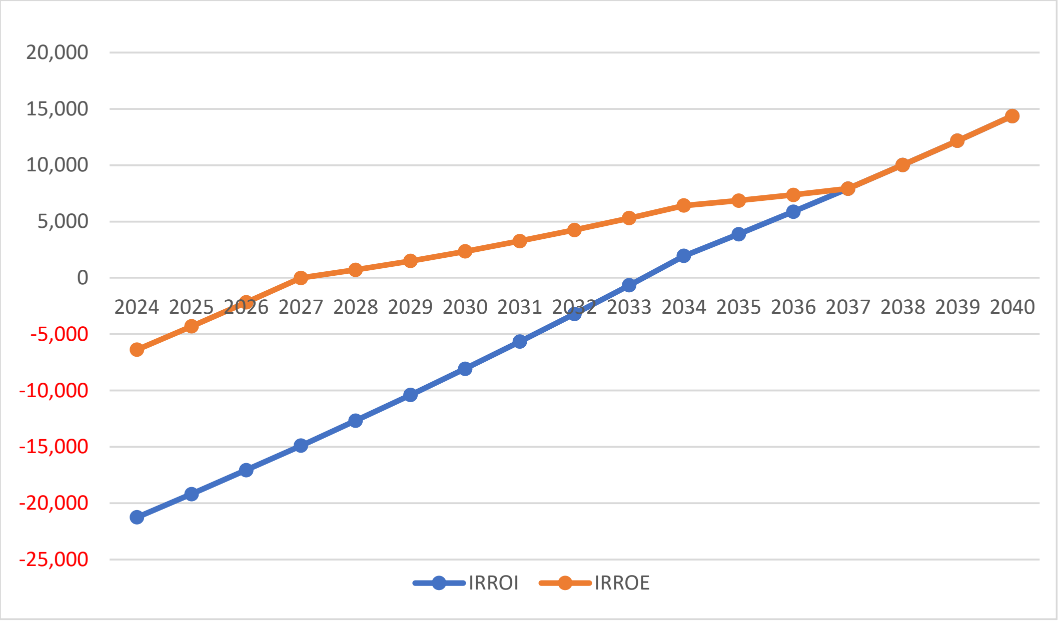
Next, the Internal Rate of Return (IRR) of A company is analysed. There are two types of IRR; one is Return on Investment, which is called Internal Rate of Return on Investment (IRROI) and other is Return on Equity, which is called Internal Rate of Return on Equity (IRROE). Definitions of both cash flows are:

- IRROI: cash flow = - total capital cost + profit after tax + depreciation
- IRROE: cash flow = - equity + profit after tax + depreciation – repayment (long term)

IRROI is meant to calculate rate of return on total investment. In other words, it shows real project economics. On the other hand, IRROE is meant to calculate just the economics of equity; in other words, shared capital or economics of shareholder.

Accumulated cash flows for Return on Investment and Return on Equity are shown in Figure 5.5.

Figure 5.5. Accumulated Cash Flows for Return on Investment and Return on Equity



IRROI = Internal Rate of Return on Investment; IRROE = Internal Rate of Return on Equity.
Source: Author.

Based on these cash flows, IRROI and IRROE are calculated using IRR function equipped in MS-Excel. The results are:

- IRROI: 7%
- IRROE: 22%

The economics of this wood pellets business model looks good and the return to shareholders also seems to be much better because the dividend ratio will be higher than 10%. If following important parameters could be secured, the following business model could be approved:

- Price of wood pellets: $100 per tonne
- Cost of raw woods: $35 per tonne
- Cost of electricity: $0.07 per kWh
- Capital costs of fabrication: $1 million per unit

(7) Case study

We assume the first 3 years for a repayment grace period, but we analyse the economics if we cannot apply this grace period. This is a basic concept of the case study.

The income statement of the case study is shown at Table 5.3. One of important implications extracted from the income statement is a decrease of total interest payment compared to Table 5.1. Because repayment of the borrowed money (long term) will start from the first year, the outstanding borrowed money in 2025–35 is lower than Table 5.1. Thus, after-tax profit of the case study is improved.

Table 5.3. Income Statement of the Case Study

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Revenue of wood pellets		15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Operation costs		12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188	12,188
Cutting raw woods		8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295	8,295
Fabrication		3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244	3,244
Transportation		650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650
Depreciation		2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	0	0	0	0	0	0
Cutting raw woods		21	21	21	21	21	21	21	21	21	21						
Fabrication		2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000						
Transportation		105	105	105	105	105	105	105	105	105	105						
Profit after Ope. & Dep.		686	686	686	686	686	686	686	686	686	686	2,812	2,812	2,812	2,812	2,812	2,812
Interrest payment		744	670	595	521	446	372	298	223	149	74	-0	0	0	0	0	0
Long-term		744	670	595	521	446	372	298	223	149	74	-0	0	0	0	0	0
Short-term																	
Interest received		0	17	37	59	82	108	135	164	196	229	265	325	386	448	512	577
Profit before tax		-58	33	128	224	322	421	523	627	733	840	3,076	3,136	3,198	3,260	3,324	3,388
Income tax			12	45	78	113	147	183	219	256	294	1,077	1,098	1,119	1,141	1,163	1,186
Profit after tax		-58	22	83	145	209	274	340	407	476	546	2,000	2,039	2,078	2,119	2,160	2,202

Source: Author.

Next, we check the cash balance statement of the case study. Table 5.4 indicates that the cash balance in the first 3 years becomes worse; in other words, lower than Table 5.2 due to the starting repayment from the first year (2025). Fortunately, money shortage does not occur until 2040.

Table 5.4. Cash Balance Statement of the Case Study

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Cash in Total	21,260	2,068	2,148	2,209	2,271	2,335	2,400	2,466	2,533	2,602	2,672	2,000	2,039	2,078	2,119	2,160	2,202
Profit after tax		-58	22	83	145	209	274	340	407	476	546	2,000	2,039	2,078	2,119	2,160	2,202
Depreciation		2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	2,126	0	0	0	0	0	0
Equity	6,378																
Long-term borrowed money	14,882																
Short-term borrowed money																	
Cash out Total	21,260	1,488	1,488	1,488	1,488	1,488	1,488	1,488	1,488	1,488	1,488	0	0	0	0	0	0
Repayment (long-term)		1,488	1,488	1,488	1,488	1,488	1,488	1,488	1,488	1,488	1,488						
Repayment (short-term)																	
Capital costs	21,260																
Cutting raw woods	210																
Fabrication	20,000																
Transportation	1,050																
Cash Balance	0	579	660	721	783	847	912	978	1,045	1,114	1,184	2,000	2,039	2,078	2,119	2,160	2,202
Accimulated cash balance	0	579	1,239	1,960	2,743	3,590	4,501	5,479	6,525	7,639	8,823	10,822	12,861	14,940	17,059	19,219	21,421

Source: Author.

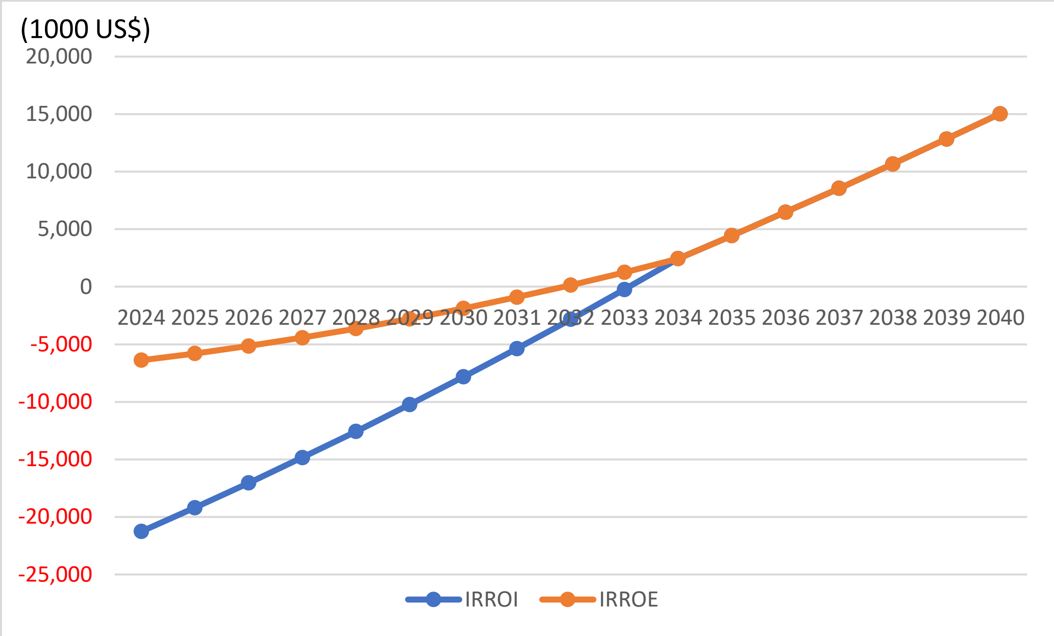
Next, we analyse IRROI and IRROE based on both cash flows shown at Figure 5-6. The calculated results are:

- IRROI: 7%
- IRROE: 14%

Repayment of the borrowed money never affects the cash flow of IRROI, so that IRROI is the same as the base case. But the repayment does affect the cash flow of IRROE (refer to the formula mentioned before); as a result, IRROE becomes worse from 23% to 15%. However, 15% is still higher than 10% of a normal dividend ratio. As a conclusion, the grace period does not impact this wood pellets business model seriously. Again, the following parameters are key:

- Price of wood pellets: $100 per tonne
- Cost of raw woods: $35 per tonne
- Cost of electricity: $0.07 per kWh
- Capital costs of fabrication: $1 million per unit

Figure 5.5. Cash Flow of IRROI and IRROE of the Case Study



IRROI = Internal Rate of Return on Investment; IRROE = Internal Rate of Return on Equity. Source: Author.

Chapter 6

Conclusion and recommendations

1. Conclusions

A low-carbon energy transition is a very important policy of Indonesia's Ministry of Energy and Mineral Resources. Indonesia must shift from fossil fuels to low-carbon energy such as hydropower, geothermal power/heat, and solar photovoltaic systems. But the low-carbon fuel should have a stable output, high capacity factor, and no seasonality. Solar is unstable due to sunshine variability, low capacity factor (only 12%–15%), and seasonality (dry and wet season). Hydropower has the drawback of seasonality, and geothermal has a short lifetime (around 10 years due to the decrease of hot water reserve). By contrast, biomass has a stable output, high capacity factor because of burning, and no seasonality. Thus, biomass is an option for low-carbon energy in Indonesia.

The study forecasts biomass demand up to 2040 based on the East Asia Summit Energy Outlook, updated by ERIA every 2 years. We forecast demand for both ethanol and diesel oil assuming a blending ratio to replace gasoline and diesel oil demand in 2040. In addition, we forecast wood pellets or chips demand for co-firing at coal power plants assuming a mixing ratio of biomass to replace coal. The demand for biomass for co-firing at coal power plants is forecasted as 4,596–34,844 kt in 2040 and biodiesel demand is forecasted to be 63.6 million kL.

Secondly, we forecast biomass supply up to 2040. Plentiful biomass supply is forecasted that will cover biomass demand mentioned above. Paying attention to sustainability, Indonesia has to engage in reforestation in order to maintain a carbon sink.

Thirdly, we review biomass power generation in Japan, which has aggressively increased it with support of FITs, as well as biomass co-firing at coal power plants for mitigating CO_2 emissions. It is clear that Japan will increase imports of wood pellets, meaning Indonesia may have an opportunity to become exporters to Japan. In addition, Japan expects that imported wood pellets may contribute to decreased procurement costs for biomass power generation companies.

Fourthly, we analyse the economics of the wood pellet supply business model. Due to the initially high cost of wood pellets, Indonesia should provide incentives to the private sector. In addition, the selling price of wood pellets and the cost of raw woods are key parameters to maintain the wood pellet business model.

2. Recommendations

Though biomass is very important for Indonesia to achieve a low-carbon energy transition, bioethanol and biodiesel and wood pellet prices are still high compared to gasoline and diesel oil and coal. Thus, some incentives from the government are essential.

One way is applying FITs for wood pellets. If PLN adds FITs on the original selling price of electricity, this system surely works; if not, PLN profit will go down. Another way is to change wood pellets to wood chips because they are much cheaper.

Indonesia currently imports gasoline and diesel oil from neighbouring countries but if it increases mixing rate of biofuels to be produced domestically, Pertamina can save costs to import gasoline and diesel oil out of Indonesia. In this way, Pertamina can allocate the cost of the imports to purchase biofuels from biofuel produces in Indonesia.

Carbon pricing is also an option for Indonesia. Once the Ministry of Environment formulates a carbon tax, coal power generation costs will increase, so that biomass power generation and biomass co-firing coal power generation will be competitive. Further, biofuel is also competitive to original gasoline and diesel oil.

International cooperation of wood pellets and biofuel production is crucial because innovative technologies are owned by developed countries; transfer of these technologies from developed countries to Indonesia inevitably drives down the cost of biomass utilisation.

References

Adhiguna, P. (2021), 'Indonesia's Biomass Cofiring Bet. Beware of the Implementation Risks', Institute for Energy Economics and Financial Analysis. http://ieefa.org/wp-content/uploads/2021/02/Indonesias-Biomass-Cofiring-Bet_February-2021.pdf (accessed 4 January 2022).

Agustian, A., E. Ariningsih, E. Gunawan, and K.S. Indraningsih (2020), 'The Study of Bioenergy with Molasses Raw Materials: Analysis of Potential and Problems in its Development in East Java, Indonesia', *E3S Web of Conferences* 232, 04005 (2021) https://doi.org/10.1051/e3sconf/202123204005 (accessed 27 October 2021).

Bisnis.com (2020), 'Hingga 2021, Kapasitas Produksi Biodiesel Bertambah 3,9 Juta Kl', 17 November. https://ekonomi.bisnis.com/read/20201117/44/1318616/hingga-2021-kapasitas-produksi-biodiesel-bertambah-39-juta-kl#:~:text=Saat%20ini%2C%20total%20kapasitas%20terpasang,mencapai%2015%2D16%20juta%20kl (accessed 22 July 2021).

Casson, A., Y.I.K.D. Muliastra, and K. Obidzinski (2014), 'Large-Scale Plantations, Bioenergy Developments and Land Use Change in Indonesia', *Center for International Forestry Research Working Paper* 170. Bogor, Indonesia: CIFOR. https://www.cifor.org/publications/pdf_files/WPapers/WP170Casson.pdf (accessed 22 July 2021).

CNBC Indonesia (2021), 'Biodiesel B40 Segera Disosialisasikan, Jadi Tahun Depan?' https://www.cnbcindonesia.com/news/20211022194733-4-285957/biodiesel-b40-segera-disosialisasikan-jadi-tahun-depan (accessed 27 October 2021).

da Conceição, H.R., N. Arifiandi, H. Finlay, J. Hartill (2021), 'How Green Are Biofuels? Understanding the Risks and Policy Landscape in Indonesia', CDP (formerly Carbon Disclosure Project). https://cdn.cdp.net/cdp-production/cms/policy_briefings/documents/000/005/722/original/Biofuel_Policy_Brief_EN.pdf?1628248407 (accessed 4 January 2022)

GAPKI (2020), 'Kinerja Industri Sawit Indonesia 2019', Gabungan Pengusaha Kelapa Sawit Indonesia (Indonesia Palm Oil Association). https://gapki.id/kinerja-industri-sawit-indonesia (accessed 10 April 2021).

Green Investment Promotion Organization (n.d.), 'The Auction System under the FIT Act', https://nyusatsu.teitanso.or.jp/ (in Japanese) (accessed 4 January 2022).

Harahap, F., S. Leduc, S. Mesfun, D. Khatiwada, F. Kraxner, S. Silveira (2019), 'Opportunities to Optimize the Palm Oil Supply Chain in Sumatra, Indonesia', MDPI. https://www.mdpi.com/1996-1073/12/3/420 (accessed 10 July 2021).

Hidayat, A. (2020), 'Permintaan Naik Dobel Digit, Produsen Etanol Molindo Belum Menambah Kapasitas', Kontan.co.id., 22 March. https://industri.kontan.co.id/news/permintaan-naik-dobel-digit-produsen-etanol-molindo-belum-menambah-kapasitas (accessed 31 March 2020).

Indahsari, G.K., A. Daryanto, E.G. Said, R. Wibowo (2011), 'The Analytic Network Process of Indonesia's Bioethanol: Future Direction of Competitive Strategy and Policy', *Analisis Kebijakan Pertanian*, 9(3). http://ejurnal.litbang.pertanian.go.id/index.php/akp/rt/printerFriendly/4194/0 (accessed 4 January 2022).

Japan Wood Pellet Association (JPA) (2020), 'Current Situation of Domestic Fuel Wood Pellet Manufacturer' (in Japanese). https://w-pellet.org/ (accessed 4 January 2022).

Japan Woody Bioenergy Association (2020), 'Trend of Domestic Biomass Fuel', Presentation material at a report meeting to Forestry Agency, Ministry of Agriculture, Forestry and Fisheries, held 28 February 2020 in Tokyo (in Japanese). https://jwba.or.jp/wp/wp-content/uploads/2022/01/66049c9ae268d14b9196dba3ccf804d1.pdf (accessed 4 April 2022)

Kimura, S., P. Han (eds.) (2021), *Energy Outlook and Energy Saving Potential in East Asia 2020*, Jakarta: ERIA, pp.102–21. https://www.eria.org/uploads/media/Books/2021-Energy-Outlook-and-Saving-Potential-East-Asia-2020/14_Ch.7-Indonesia.pdf (accessed 22 July 2021).

Kofman, P.D. (2017), 'Unit, Conversion Factors and Formulae for Wood for Energy', *Harvesting/Transportation* No. 21, Coford Connects, http://woodenergy.ie/media/coford/content/publications/projectreports/cofordconnects/ht21.pdf)(accessed on 18 October 2021).

Malik, C.L. (2021), 'Indonesia Country Report', in S. Kimura and P. Han (eds.), *Energy Outlook and Energy Saving Potential in East Asia 2020*. Jakarta: ERIA, pp.102–21. https://www.eria.org/uploads/media/Books/2021-Energy-Outlook-and-Saving-Potential-East-Asia-2020/14_Ch.7-Indonesia.pdf (accessed 22 July 2021).

Mahidin, E., M. Zaki, H.H. Muhibbuddin, R. Mamat, H. Susanto (2020), 'Potential And Utilization Of Biomass For Heat Energy In Indonesia: A Review', *International Journal of Scientific & Technology Research*, 9(10) https://www.researchgate.net/publication/346262259_Potential_And_Utilization_Of_Biomass_For_Heat_Energy_In_Indonesia_A_Review (accessed 4 January 2022).

Ministry of Agriculture, Forestry and Fishery (MAFF) (2020), 'Statistics of Wood Biomass' (in Japanese), Forestry Agency. https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&toukei=00501008&tstat=000001095155&cycle=7&year=20190&month=0&tclass1=000001095156&tclass2=000001148366 (accessed 22 July 2021).

Ministry of Agriculture, Forestry and Fishery (MAFF) (2021b), 'Targeted Amount Specified in Forest and Forestry Basic Plan (draft)' Forestry Agency, https://www.rinya.maff.go.jp/j/rinsei/singikai/attach/pdf/210329si-10.pdf (in Japanese) accessed 4 October 2021.

Ministry of Agriculture, Forestry and Fishery (MAFF) (2021a), 'Current Situations on Biomass Utilization' https://www.maff.go.jp/j/shokusan/biomass/attach/pdf/index-110.pdf (in Japanese) accessed 4 October 2021.

Ministry of Energy and Mineral Resources (MEMR) (2019), 'Pahami Istilah B20, B30, B100, BBN dalam Bioenergy (Understanding the terms of B20, B30, B100, BBN in Bioenergy)', Public Relation of the Directorate General of New and Renewable Energy and Energy Conservation (EBTKE) of the Ministry of Energy and Mineral Resources, 18 December. http://ebtke.esdm.go.id/post/2019/12/18/2433/pahami.istilah.b20.b30.b100.bbn.dalam.bioenergi?lang=en (accessed 2 March 2020).

Ministry of Economy, Trade and Industry (METI) (2015), *Long-term Energy Supply and Demand Outlook (related materials*) (in Japanese). https://www.meti.go.jp/english/press/2015/pdf/0716_01a.pdf. (accessed 6 January 2022).

Ministry of Economy, Trade and Industry (METI) (2020a), *Biomass Power Generation* (in Japanese), The 65th Procurement Price Calculation Committee. https://www.meti.go.jp/shingikai/santeii/pdf/065_04_00.pdf (accessed 6 January 2022).

Ministry of Economy, Trade and Industry (METI) (2020b), *Sustainable Woody Biomass Power Generation* (in Japanese), The 1st Working Group on Forestry and Woody Biomass Power Industry Development. https://www.meti.go.jp/shingikai/energy_environment/biomass_hatsuden/pdf/001_02_00.pdf (accessed 6 January 2022).

Ministry of Economy, Trade and Industry (METI) (2021a), *Prospective Renewable Energy Policy* (in Japanese), The 25th Subcommittee on Mass Introduction of Renewable Energy and Next-Generation Electricity Networks. https://www.meti.go.jp/shingikai/enecho/denryoku_gas/saisei_kano/pdf/025_01_00.pdf. (accessed 6 January 2022).

Ministry of Economy, Trade and Industry (METI) (2021b), *Perspectives on Renewable Energy in 2030* (in Japanese), The 31st Subcommittee on Mass Introduction of Renewable Energy and Next-Generation Electricity Networks. https://www.meti.go.jp/shingikai/enecho/denryoku_gas/saisei_kano/pdf/031_02_00.pdf (accessed 6 January 2022).

Ministry of Economy, Trade and Industry (METI) (2021c), *Summary of Interim Report* (in Japanese), The 8th Working Group on Coal-fired Power Plants. https://www.meti.go.jp/shingikai/enecho/denryoku_gas/denryoku_gas/sekitan_karyoku_wg/pdf/008_03_00.pdf (accessed 6 January 2022).

Ministry of Economy, Trade and Industry (METI) (n.d.), *FIT Tariff Rates for FY 2021 Onwards* (in Japanese), https://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/fit_kakaku.html (accessed 22 December 2021).

Ministry of Economy, Trade and Industry (METI) (n.d.), *Statistics of Renewable Power Generation* (in Japanese), https://www.fit-portal.go.jp/PublicInfoSummary (accessed 2 December 2021).

Murdiyatmo, U. (2021), *2nd Generation BioEthanol in Indonesia: Prospect & Challenges*, Presentation of Indonesian Ethanol Association (ASENDO) for the ERIA team, 29 January. (accessed 8 January 2022).

NREL (2011), 'Process Design and Economics for Biochemical Conversion of Lignocellulosic Biomass to Ethanol', Technical Report, NREL/TP-5100-47764, May. https://www.nrel.gov/docs/fy11osti/47764.pdf (accessed 27 October 2021).

Pertamina (2020), '*Kuota B30 dan Premium per Provinsi: Penyaluran BBM Bersubsidi Pertamina*'. https://pertamina.com/id/kuota-b30--premium-per-provinsi (accessed 27 October 2021).

Pirard et al. (2017), 'Prospects for Wood-based Electricity for the Indonesian National Energy Policy'. https://www.cifor.org/publications/pdf_files/WPapers/WP231Pirard.pdf (accessed 19 October 2021).

Relevant Ministries Liaison Committee for Biomass Industrial Area (2021), *Support Measures to Encourage Biomass Use* (in Japanese), https://www.maff.go.jp/j/shokusan/biomass/attach/pdf/index-105.pdf (accessed 4 November 2021).

Reuter.com (2021), *Japan boosts renewable energy target for 2030 energy mix*, 21 July, https://www.reuters.com/business/energy/japan-boosts-renewable-energy-target-2030-energy-mix-2021-07-21/ (accessed 1 April 2022)

Setiawan, I.C. (2021), 'Automotive Contribution to Support Oil Reduction through Biofuel Utilization', Presentation by Mr Indra Chandra Setiawan from Toyota for the ERIA study team, March 2021. (accessed 4 January 2022).

Sulaiman, A.M., Y. Sulaeman, N. Mustikasari, A.M. Syakir (2019), 'Increasing Sugar Production in Indonesia through Land Suitability Analysis and Sugar Mill Restructuring', Land, 8(4), p.61. https://doi.org/10.3390/land8040061 (accessed 27 October 2021).

Tan, M., C. Chiam, N.J. Zhi, and S.Y. Cheong (2020), 'Indonesia Maintains Sights on Fuel Self-sufficiency in Light of New Challenges', *S&P Global Platts*, 17 June. https://www.spglobal.com/platts/en/market-insights/latest-news/oil/061720-indonesia-maintains-sights-on-fuel-self-sufficiency-in-light-of-new-challenges (accessed 22 June 2020).

Trade Statistics of Japan (n.d.), *National statistical item information*. https://www.customs.go.jp/toukei/search/futsu1.htm (accessed 18 October 2021).

USDA (2019), 'Biofuel Annual: Indonesia Biofuel Annual Report 2019', *Global Agricultural Information Network (GAIN) Report* Number: ID1915, 15 July. https://www.fas.usda.gov/data/indonesia-biofuels-annual-4 (accessed on 2 December 2021).

Widodo, T. et al. (2021), 'Current Status of Bioenergy Development in Indonesia', Paper presented at the Regional Forum on Bioenergy Sector Development: Challenges, Opportunities, and Way Forward. https://un-csam.org/sites/default/files/2021-01/0203.pdf. (accessed on 3 November 2021).

Winarno, D. (2021), 'Biomass Production and Supply Chain in Indonesia', Presentation of the Indonesian Biomass Energy Society (IBES) for the ERIA team, 14 January 2021.

Wiratmini, N.P.E. (2020), 'Pemerintah Cari Sumber Insentif untuk Pemanfaatan Bioetanol', Bisnis.com, 27 January, https://ekonomi.bisnis.com/read/20200127/44/1194302/pemerintah-cari-sumber-insentif-untuk-pemanfaatan-bioetanol (accessed 1 April 2020).

Appendices

Appendix A

Biomass and Coal Co-Combustion in ASEAN Region (II)

ERIA-Japan Coal Energy Center (JCOAL) Working Group Meeting
22 December 2020, MS Team Platform

Phase one study findings show that Indonesia has biomass co-firing and firing potential of around 32,654 MWe and the Philippines around 4,449.54 MWe. The advantages and spillover effects of biomass co-firing include (1) CO_2 reduction using carbon-neutral biomass co-firing; (2) reduction of disposed waste by utilising domestically available agricultural waste; (3) biomass co-firing or firing can be used in a variety of boilers, including circulating fluidised bed (CFB) boilers, small pulverised boilers, and ultra-supercritical (USC); (4) biomass co-firing may help improve plant economics because the fuel is locally available, and procurement is efficient; (5) the seasonality of biomass supply would be compensated by coal, and the coal/biomass ratio would be optimised with seasonal variation; and (6) local people would be employed in the labour-intensive process of biomass co-firing, which includes collection, selection, and torrefaction or pellet manufacture as needed.

The phase one study's recommendations include (1) government authorisation to use biomass as renewable energy in each country's energy development plan; (2) tariffs and other financial incentives for biomass co-combustion; (3) development of a biomass collection scheme, regional government support for jobs related to biomass waste collection; and (4) regional and international collaboration.

For Indonesia '50MW CFB with domestic coal' was chosen as an appropriate option, whereas '50MW CFB with imported coal' was identified as an appropriate option for the Philippines. For Thailand, it was determined that co-firing in a mine-mouth subcritical/biomass gasification/small-scale gas engines, as foreseen in the government's study, would be the optimal solution. The case study using Levelized Cost of Electricity (LCOE) to determine the economic viability of biomass and coal co-firing concluded that biomass and coal co-firing are not economically viable under existing tariff conditions and in the absence of additional relevant incentives. It is advised that governments implement the appropriate incentives, such as a feed-in tariff or other forms of support, to identify necessary measures that are compatible with the Association of Southeast Asian Nation's (ASEAN) individual member states and guidelines for biomass usage with a focus on co-firing through best practices, in order to create an ideal policy framework. Additional consideration will be given to developing country-specific recommendations about optimal plant capacity, technology selection, biomass firing and/or co-firing, and appropriate incentives.

The phase two study is expected to produce guidelines for the appropriate policy framework for ASEAN to support biomass utilisation, with a particular emphasis on co-firing, and strategies for introducing, implementing, and disseminating co-firing best practices on a country-by-country basis. The applicable technology, policy approaches, and anticipated challenges to be handled will be identified, along with their associated advantages and disadvantages. Extra attention will be taken to ensure the recommended by-country strategies are clear and suitable for prompt implementation by the target member state(s). Additionally, advice regarding the role of co-firing in tackling the forthcoming issue of grid instability as a result of the widespread use of renewable energy.

For the second phase of the study, suitable biomass energy methods such as woody biomass (wood chips, torrefied fuel); agricultural waste (pellets, chips); refuse-derived fuel (RDF); waste tires; gasification (gasified biomass, methane fermentation); and liquefaction (biodiesel, bioethanol, pyrolysis oil) will be investigated. These materials would be used in biomass power applications such as co-firing with coal (on a large scale/≦1,000 MW, and the mixed rate would be no more than 20%; on a medium scale/≦200 MW, the mixed rate would be no more than 50%); co-firing in CFBs with coal or biomass alone (on a medium scale/≦200 MW); and CHP (small scale of gas engines, gas combustion, fuel cell, binary cycle). Choose the optimal plan depending on the kind and quantity of biomass, the capacity of the power generation facility, and the type and capacity of the grid.

In Cambodia, the electricity rate increased from 86% in 2017 to 92.68% in 2019. The installed capacity and demand are expected to expand from roughly 2,200 MW in 2018 to approximately 5,500 MW in 2030 as a result of planned thermal and hydro expansion. Cambodia's national commitment to climate change action in the energy sector includes the following: (1) grid-connected renewable energy generation (solar energy, hydropower, biomass, and biogas), as well as decentralised renewable energy generation connected to the grid; (2) off-grid electricity generation such as solar home systems and hydro (pico, mini, hydro); and (3) promoting energy efficiency amongst end users, which can save 1,800 Gg CO_2eq (16%) by 2030. Priority initiatives in the industrial sector include increasing the use of renewable energy and implementing energy efficiency measures in garment factories, rice mills, and brick kilns, which can result in a 727 Gg CO_2eq (7%) reduction in 2030 compared to the baseline. Priority actions in the transportation sector include promoting mass public transportation and improving vehicle operation and maintenance through motor vehicle inspection and eco-driving, as well as increased use of hybrid cars, electric vehicles, and bicycles, which can save 390 Gg CO_2eq (3%) in 2030 compared to the baseline. In the other sectors, priority actions include (1) promoting energy efficiency in buildings and more efficient cookstoves, (2) reducing waste-related emissions through the use of biodigesters and water filters, and (3) utilising renewable energy for irrigation and solar lamps, which can result in a reduction of 155 Gg CO_2eq (1%)

in 2030 compared to the baseline. All four sectors will save a total of 3,100 (2%) Gg CO_2eq in 2030 as compared to the baseline.

Cambodia is pursuing the use of wood biomass through tree planting and sustainable forest management. The following is the government's position on this: (1) With tree planting, a planned and stable supply of fuel wood is possible; (2) Even with energy tree cultivation, fuel costs are a small fraction of total electricity generation costs (11% in the case of 13 kWh monthly electricity consumption per household); (3) Using agricultural residues does not significantly reduce costs; (4) The purchasing cost of cultivated trees is low (about $20/t); (5) Using agricultural residue could be more expensive when transportation cost occurs; and (6) In general, woody biomass is the ideal fuel for gasification. Additionally, a proposed plan of action includes the following: 1) Conduct a baseline research to determine the availability of wood biomass resources in terms of quantity, area, and price. Collaboration with forestry experts is critical, as the study must consider sustainable tree planting and wood biomass utilisation; 2) Following the basic study, conduct a model study for biomass collection and procurement, keeping in mind the roles of the community and community-based organisations; 3) Biomass technologies must also be studied in close collaboration with biomass power technology specialists; 4) Literature review supplemented with interviews with biomass power technology specialists; 5) In addition to the aforementioned studies, the government is anticipated to make policy efforts toward examining and establishing incentives for biomass co-firing at existing and future coal-fired power plants; and 6) Based on the findings of the studies in 1), 2), and 3), a model project of dedicated biomass firing well-connected to the community and community-based organisations is to be planned and implemented.

In Indonesia, fossil fuels will continue to be the primary source of energy until 2050; however, reserves of fossil fuels have depleted and output of oil and natural gas has stagnated. Indonesia initiated an energy policy that advocates for increased use of new renewable energy (NRE) sources with the goal of diversifying energy sources and reducing reliance on fossil fuels in order to mitigate climate change. NRE's proportion of the economy will expand to 23% in 2025 and 31% in 2050. Finally, NRE will account for the largest share of the energy mix in 2050. In the power generation sector, coal-fired power plants will continue to dominate in the future, while the share of electricity generated by renewable energy sources will climb from 13% in 2019 to 23% in 2025.

Additionally, the country has an extensive biomass potential of approximately 32,655MWe. Palm oil, which includes palm oil mill effluent (POME), palm kernel shell (PKS), and empty fruit bunch (EFB), is Indonesia's primary source. Around 66 biomass power plants (including municipal solid waste) have been installed, totalling 1,896.5 MW in capacity. In the palm oil, sugar, pulp, and paper industries, the majority of biomass energy generation occurs off-grid.

EFB was chosen as the appropriate biomass crop for Indonesia, while rice husk was chosen for the Philippines. The international market for woody biomass has already been established, and it is quite expensive. Woody biomass is excluded from this study due to deforestation and the cost of electricity. The efficiency of the unit diminishes as the amount of biomass cofired increases. The findings for Case 1 and Case 2 indicate that their economic viability is currently unfeasible without the appropriate incentives. In comparison to ordinary coal combustion for power generation, co-firing agricultural waste and coal on CFBC boilers will significantly contribute to CO_2 mitigation.

According to PLN's Co-firing Roadmap, the company began co-firing trial tests in 2019 and will continue through 2024. PLN conducted biomass co-firing testing on six existing CFPPs with varied compositions and found excellent results. The total generation capacity of biomass co-firing on PLN's CFPP in Indonesia is 18,154 MW, with roughly 4 million tonnes of biomass consumed annually. The benefits of biomass co-firing include increased waste utilisation, increased renewable energy generation, and CO_2 emission reduction. Additionally, biomass co-firing will spur economic development and employment creation in the region. The overall capacity of the proposed coal-fired power plants (CFPP) on Jawa-Madura-Bali (JAMALI) Grid for 5% co-firing with biomass is 10,00MW, which is estimated to result in the establishment of 160 mills and 1,600 new jobs. Numerous technologies for biomass utilisation have previously been implemented in Indonesia. The technology that is relevant to biomass is scale-dependent. It is critical to understand the characteristics of biomass before using it, such as grindability, contained corrosive components, and moisture content.

Indonesia's government is increasing the share of renewable energy in the country's energy mix, including the power generation sector. The government has issued a number of directives and rules that are believed to adequately fulfil the power sector's requirements. Additionally, the government has developed a strategic plan and is advocating support for biomass expansion. As indicated previously, the Indonesian government is implementing numerous efforts to promote and disseminate utilisation of biomass, and the development of biomass-based power generation is moving apace.

Japan Coal Energy Center (JCOAL) made two recommendations: 1) Improve rural electrification and effective use of off-grid power, in which biomass power would enable village electrification via off-grid captive power sales to PLN or direct supply of such off-grid biomass power to the local area; and 2) Collecting biomass waste for power plants. Local farmers, business owners, and allied groups formed a cooperative association to manage the collecting and transportation of biomass in the region, thereby increasing the efficiency of biomass delivery.

The power generation facilities in the Philippines by the end of 2019 is 25,531 MW and it is expected increase in 2030 around 50,919 MW which is almost two times in 2040 around 90,584 MW under reference scenario. In the Philippines small to medium-sized power plants and coal-fired power plants are of the subcritical type 400 MW, and CFB 200 MW.

The Philippine Department of Energy made requests at its December 2019 meeting with JCOAL, including the installation of a bigger capacity CFB boiler and the continuation of coal-fired power generation through the use of high-efficiency, low-emission carbon capture technology. Biomass power generation capacity is expected to reach 1,550 MW by CES in 2040, representing less than 2% of overall power generation capacity. Co-firing biomass is advantageous in terms of CO_2 reduction, as it is carbon-neutral.

Thailand's power development plan projects that overall capacity will expand to 77,211MW in 2037, up from 46,090 MW in 2017. While 25 GW of plants that are somewhat older and/or smaller will be retired, another 56 GW will be commissioned. Its primary sources of energy are combined cycle and renewables. Additionally, policy support for biomass utilisation, dubbed '4D+E,' is available (Digitalisation, Deregulation, Decarbonisation, Decentralisation, and Electrification).

In 2020, a total of 700 MW of electricity generated by community-based power plants will be permitted for purchase and sale to the national grid under this new policy. Out of the 700 MW, a 'Quick Win Project' must be contracted by 2020 and must begin supplying electricity to the grid within 12 months of contract signing. Purchase of up to 100 MW of power is permitted. Mae Jam (Biomass 3 MW) in Chiang Mai Province and Thap Sakae (Biogas Energy Crop 3 MW) in Prachuap Khiri Khan Province are two of the community power plant projects of the Electricity Generating Authority of Thailand (EGAT).

Recommendations for Thailand include resource circulation to promote community sustainability, the use of municipal waste as biomass to manage municipal waste challenges, and financial assistance through bilateral collaboration.

ASEAN is predicted to undergo an energy transition, with a large increase in renewable energy. When introducing renewable energy on a large scale in ASEAN, grid flexibility is critical, as renewable energy is inherently unpredictable and intermittent. If no countermeasures are adopted, such a big introduction may result in systemic fluctuation. Additionally, coal and biomass share similar advantages in terms of their ability to operate in a flexible manner, which is critical for enabling a successful energy transition. Coal is highly reliable in terms of supply but is a significant CO_2 emitter, whereas biomass is carbon neutral but has a seasonal supply; so, both are complementary and would make an ideal combination. This complementary relationship between coal and biomass is critical for understanding biomass co-firing; Dedicated biomass firing would be an appropriate option for rural electrification and social development due to its small scale, labour-intensive but less expensive nature, and guaranteed procurement through indigenous fuel utilisation; Envisaged policy initiatives to facilitate biomass utilisation in the power sector of the ASEAN Member States.

Appendix B

Biomass Production and Supply Chain in Indonesia

ERIA-Indonesian Biomass Energy Society (IBES) Working Group Meeting

Ir Djoko Winarno, MM, IPU, AER – Chairman

14 January 2021, MS Team Platform

The Indonesian Biomass Energy Society (IBES) was declared on September 2021 with a vision to become a leading professional organisation in the development of biomass energy to support the national energy security and economy in a sustainable manner. The objectives of IBES are (1) increasing public energy access through renewable energy that can promote economic growth and environmental protection, aligning with the philosophy of pro-growth, pro-job, pro-poor, pro-environment; (2) improve the utilisation of biofuels and biomass as a source of electricity; (3) initiate the energy forest development program with government involving the community in assuring raw material availability and biomass production.

The roles and contribution of forest plants are (1) local need for diesel power plants, with its fuel converted into biomass; (2) more than 2 million people rely on biomass for cooking and heating; (3) the availability of energy from fossil fuels is limited, while forest land still quite extensive (2,245,364.00 hectares of the industrial plantaion forest (Hutan Tanaman Industry or HTI in Indonesian language) reserved and the community plantation forest (Hutan Tanaman Rakyat or HTR in Indonesian language) has 702,519.73 hectares reserved).

Additionally, the potential for crop forest development invokes the following: (1) forest area is 70% of total land area, (2) 74.44 million hectares (62.57%) of production forest, (3) permits have not been imposed on an area of 36.99 million hectares, of which 10.06 million hectares have been reserved for HT, (4) the area of HP is 28.99 million hectares, HPT is 28.41 million hectares, HPK is 18.04 million hectares, (5) plantation forest area is 5 million hectares and wood production is 21 million m^3/year.

Indonesia has a total of 32,656 MW biomass power plant and waste potential including HTI/E area, specifically Sumatra (15,588 MW); Java, Bali, Madura (9,215 MW); Kalimantan (5,062 MW); Sulawesi (1.937 MW); Nusa Tenggara (636 MW); Papua (151 MW); and Maluku (67 MW). The total area of potential energy plantation forest (HTE) is 1,292,766 hectares, with 32 total business units committed to developing energy and bioenergy plantation forests. PLN is currently preparing the new biomass power plant. In addition, biomass pellets from waste and forest products are also used as co-firing at the coal-fired power plant. Pellets from waste can generate 2,900–3,400 Cal/gr and pellets from wood can generate 3,300–4,000 Cal/gr.

Indonesia, as an agrarian country, has the capacity to produce ethanol. In Indonesia, the raw materials that are widely used are straw rice, corn stover, sago baggase, sugarcane baggase, and empty fruit bunch. The total potential of cellulosic ethanol from those raw materials is approximately 34.6 billion litres. Indonesia also has a large biomass resource. Biomass-based ethanol production could produce 34 billion litres per year. Biomass ethanol production technology is currently in its infancy; hence, the cost of biomass ethanol production is still very high. In order for Indonesia to have effective biorefinery technology and efficient biomass ethanol production at the price level of gasoline-95 in 5 years' time, it is required nationally to conduct focused research.

According to the International Renewable Energy Agency (IRENA), bioenergy must be a significant part of our energy mix by the year 2050. Renewable energy and energy efficiency are capable of reducing emissions by 90%. Modern bioenergy use must increase from 4% of the energy mix in 2017 to 16% by 2050 as part of this shift. In addition, bioenergy must play a core role in industry and transport. In the industrial sector, biomass was used at a rate of around 9% in 2017. The percentage of biomass utilisation in 2050 Planned Energy Scenario (PES) and 2050 Transforming Energy Scenario (TES) is predicted to climb to 16% and 28%, respectively. Biomass use in the transportation sector is 3% in 2017, but is expected to rise to 10% in 2050 PES and 17% in 2050 TES.

In Southeast Asia, bioenergy is expected to become the largest energy source in the total energy mix, over 40% of total primary energy supply (TPES) in 2050 under TES. The potential for sustainable biomass is estimated to be in Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam. The study revealed that by reducing waste and improving efficiency, biomass might contribute significantly to the energy mix while also freeing up space for other purposes, such as agricultural and forestry residues, reduced food waste, and sustainable timber extraction. In addition, biomass from all aspects of the oil palm industry is widely used as sources of renewable energy.

The first step is mapping bioenergy pathways in Indonesia. There are four demonstrable pathways that have potential to provide over 60% of the contestable energy mix in industry and transport by 2050. Bioenergy pathways provide an approach for quantifying available sources and potential technical routes through which they can be supplied. Out of the available primary bioenergy sources, over 40% on a petajoule (PJ) basis can be used as substitute for fossil fuel by 2050. The first pathway is direct combustion for industrial heat rising; the second pathway is direct combustion in CHP for raising steam and power generation; the third pathway is anaerobic digestion; and the fourth is refining and blending. Although there are huge bioenergy resources in Southeast Asia, a realistic view on the security of supply must recognise constraints from several key factors. The increase in collected feedstock over time is due to increasing plantation owner and farmer awareness, improvements in logistics management in the collection, stockpile management, processing and delivery, and improvements in technology.

The second step is quantifying bioenergy economics in Indonesia. A cost and benefit analysis shows significant economic benefits through developing bioenergy projects by 2050, with the benefits including avoided environmental costs and creation of resilient jobs. Total economic benefits are $55 billion, total avoided environmental costs $45 billion, and total contribution to economy from resilient jobs creation is $12 billion.

The third step is developing a bioenergy transformational roadmap in Indonesia. To unlock the significant economic benefits by 2050, key challenges around political, economic, social, technical, environmental, legal, and financing (PESTEL&F) dimensions were identified as well as short-, medium-, and long-term interventions which can tackle these challenges. The key challenges are lack of preferential regulatory framework, constraints of efficiency and replaceability, and low security of revenue.

Appendix C

Second Generation Bioethanol in Indonesia: Prospect and Challenges

ERIA-Indonesian Spirits and Ethanol Association (ASENDO) Working Group Meeting

Untung Murdiyatmo, PhD (Biotech)

29 January 2021, MS Team Platform

There are two types of bioethanol namely 1st Generation-ethanol and 2nd Generation-ethanol. The feedstocks of 1st G-ethanol include sugar-containing materials such as sugarcane juice, cane molasses, sweet sorghum juice, and starch-containing materials such as cassava (dry or fresh) as well as corn. Additionally, technology for producing 1st G-ethanol is very well established in Indonesia. Only six of the approximately 12 enterprises that are members of ASENDO, Indonesia's ethanol association, are operational. Molindo Raya Industrial, PT in Malang, East Java, is the largest ethanol producer, producing 80,000 kL ethanol per year. Only one non-ASENDO firm has existed that generated 50,000 kL of ethanol each year. However, the production cost of 1st G-ethanol is higher compared to 2nd G-ethanol. Furthermore, the price of ethanol is about double the price of gasoline-88 because the price of molasses is very high. Consequently, biofuel programmes cannot be implemented.

Indonesia is an agricultural country; therefore, biomass, including 2nd G-ethanol, biomass ethanol, and cellulosic ethanol, is readily available. Potential feedstocks for biomass ethanol are sugarcane bagasse (480 million L/year), rice straw (19.44 billion L/year), corn stover (8.271 billion L/year), sago hampass (136 million L/year), and empty fruit bunch (EFB) from oil palm (6.283 billion L/year). This total of 34,610,000 kl/year constitutes more than enough to replace gasoline imports via the 'A20' programme. This programme was initiated by PERTAMINA as an effort to reduce gasoline imports. The government has issued regulations for the mandatory use of biofuels as a vehicle fuel mixture. In the Minister of Energy and Mineral Resources Regulation 12/2005, ethanol has been required as a gasoline fuel mixture since 2015. The implementation target continues to increase to 20% in 2025. The programme is to develop bio gasoline (A20) or 15% methanol gasoline and 5% ethanol.

From the feedstock availability point of view, it can be concluded that the prospect of 2nd G-ethanol in Indonesia is very encouraging. However, the challenges to realise the prospect remain. Even in the US, which is the world's number one ethanol producer, 14 years after the Energy Independence and Security Act was signed by President Bush in 2007, cellulosic ethanol production is still less than 4% of total ethanol production. The US ethanol production by feedstock type is from corn starch (94%), with the rest from corn/ sorghum/ cellulosic biomass/ waste (3.4%); corn/ sorghum (2.1%); cellulosic biomass (0.5%); and waste sugars/ alcohol/ starch (0.1%). Furthermore, according to the USDA-GAIN report, annual European Union production of cellulosic ethanol was estimated to be around 40 kt in 2017 down to 10 kt in 2018. In Brazil, total cellulosic ethanol production is estimated to be 25 million litres (or 20 kt) for 2018, representing an insignificant share of total ethanol production. In China, 2018 cellulosic ethanol production is forecast to stop at 20 million litres (or 16 kt) as its major cellulosic project appears idle.

To comprehend the challenges, knowledge of the 2nd G-ethanol stages is required. Four steps to produce 2nd G-ethanol are (1) biomass pre-treatment; (2) hydrolysis (enzymatic) of pre-treated biomass; (3) fermentation of hydrolysis products; and (4) distillation and dehydration. Biomass pre-treatment is to make cellulose and hemicellulose free from lignin so that cellulolytic enzymes have access to contact and hydrolise cellulose to yield C6 (glucose) and xylanolytic enzymes can hydrolise hemicellulose to xylose (C5). This step should be done because feedstocks for 2nd G-ethanol cannot be fermented directly. Biomass pre-treatment technology is quite mature but is still being developed. Pre-treatment is very essential for enzymatic hydrolysis and graded according to multiple targets including degree of particle size reduction, fermentable sugar (C6/C5) recovery, inhibitor formation (e.g. fermentability), energy and water consumption, operating cost, as well as environmental footprint. The methods used for pre-treatment are alkaline, acid, ammonia, and steam explosion. Effective pre-treatment methods should have low capex, which can be accomplished by avoiding the use of costly materials (catalyst, solvents, reagents, and biomass) during pre-treatment and consequent neutralisation. Because pre-treatment uses a significant amount of energy in the ethanol process, it is critical to keep the energy demand low while preserving process performance. Inhibitors should be produced in small quantities. High pre-treatment severity can result in inefficient hemicellulose degradation and the formation of hazardous chemicals derived from sugar decomposition, which can affect the enzymatic hydrolysis and fermentation stages. The sugars content from the collective pre-treatment and enzymatic hydrolysis processes should be >10% to establish acceptable ethanol concentrations, manage recovery, and other downstream costs. Lignin should also be recoverable to be converted into important products to realise the biorefinery concept. At industrial scale, research and development is still needed to develop efficient and environmentally friendly biomass pre- treatment technology.

The second step, which is hydrolysis of pre-treated biomass is very important. Two enzymes used in this step are cellulolytic enzymes and xylanolytic enzymes. Cellulolytic will hydrolise cellulose into glucose and xylanolytic will hydrolise hemicellulose to use xylose (C5). In Indonesia, significant research effort is required to lower the contribution of enzymes to biofuel production costs. Due to the fundamental role of cellulolytic enzymes in 2nd G-ethanol production, Indonesia must develop its own technology.

Many literatures mentioned the cost of enzymes to produce one gallon of 2nd G-ethanol. The cost contribution of enzymes to the production of lignocellulosic ethanol varies widely in the literature, ranging from \$0.10/gal–\$0.40/gal. In addition, the cost of enzymes in the production of lignocellulosic biofuels is still a big challenge. Around the world, there are many studies conducted to minimise the cost of enzymes in the 2nd G-ethanol production.

China, India, and Brazil have a high number of publications in the development of Cellulolytic Enzymes Technology, most likely due to investments made on Cellulosic Bioethanol between 2015 and 2017. In order to efficiently produce 2nd G-ethanol from a mixture of glucose and xylose at once, the development of special yeast strains through genetic engineering is a must. To summarise, a large amount of study is still required in Indonesia to reduce the contribution of enzymes to the expenses of biofuel production.

Microbes such as Saccharomyces cerevisiae, S. uvarum, and Zimomonas mobilis are capable of fermenting glucose (C6) into ethanol, and the technique for doing so is well established. For the technological fermentative 2nd G-ethanol from C5 and C6, sophisticated microbial genetic engineering methods are used. However, there still no research published in Indonesia. Several 2nd G-ethanol plants are well established around the world such as GranBio in Brazil (construction start in 2014), Raizen in Piracicaba, Brazil (inaugurated in 2015), four plants in the US (two of them in Iowa, one in Kansas, one in Illinois), and one plant in Italy. However, in Indonesia, PERTAMINA will construct the 2nd G-ethanol plant with a capacity of 25,000 tonne/year by 2025.

Appendix D

Introduction to RENOVA Energy and Biomass Project Development

ERIA-RENOVA Working Group Meeting

18 March 2021, MS Team Platform

The government has a clear target of carbon neutrality by 2050 and declared that low-efficiency coal power stations must be made obsolete by biomass in tandem with its deep relation with government policy on fossil fuels, particularly coal and non-renewables. RENOVA, Inc. was established in May 2020 and specialises in the development and operation of renewable energy facilities (solar, wind, biomass, and geothermal). Its mission is to create green and sustainable energy systems for a better world with the vision to become Asia's renewable energy leader. RENOVA focuses on biomass and offshore wind power while accelerating its overseas business. This strategy includes increasing its investment in biomass, and wind power, both offshore and onshore overseas, and further strengthening cost competitiveness to achieve long-term growth.

As of February 2021, existing and pipeline RENOVA projects account for approximately 1.8 GW of power. Specifically, around 350 MW of solar, around 400 MW of biomass, around 1,000 MW of wind, and geothermal are under development. RENOVA expects to commence construction on all disclosed biomass pipeline projects over the next 1–2 years. In Japan and abroad, RENOVA has 25 projects in operation, under construction, and under development.

Construction commenced as scheduled in December 2019 for the Omaezakikou Biomass Project (74.95 MW) and in March 2020 for the Ishinomaki Hibarino Biomass Project (74.95 MW). Both projects will commence operation in FY3/2024. Furthermore, one of the large-scale biomass project developments, the Tokushima-Tsuda Biomass Project (74.8 MW) reached financial completion on 25 February 2019. RENOVA was selected by the local consortium and led its development. The business development fee was received from the special purpose company (SPC) and one of the project's co-sponsors.

RENOVA has five dedicated biomass power projects in Kanda, Tokushima, Omaezaki, Sendai, and Ishinomaki, each generating 75 MW. In Tokushima, the process is on schedule and a commercial operation date is in the middle of 2023. In the nearby prefecture of Tohoku, a power project is beginning construction. By the of 2023, five units of dedicated biomass power station will start commercial operation. By that time, RENOVA would be one of the top companies in Japan in terms of total generation capacity by biomass. Total biomass fuel consumption by RENOVA will be about 1.5 million tonnes per year in wood chips and wood pellets. For the moment, most fuel is coming from overseas. Additionally, RENOVA has one existing biomass power station of 20 MW in Akita prefecture, which has operated since 2016. It has a good reputation on the quality of its construction. In addition, Akita power station also imports briquettes from Indonesia and Malaysia to maintain constant combustion, particularly in winter.

After the commencement of commercial operation, RENOVA pays the greatest attention to stable, continuous, and safe operation of whole biomass power plant. Electricity generation has a social responsibility, and is fundamental to supporting the energy infrastructure of Japan. Furthermore, amongst renewables, biomass can constitute an important electricity baseload.

The Ministry of Economy, Trade, and Industry (METI) of Japan has a famous guideline called Energy Mix 2030. By 2030, renewables would be between 22%–24% of total energy for power generation. According to the Reuter.com (2021), this percentage has been almost attained at this moment. Amongst renewables, biomass contributes 3.7%–4.5% of total energy. To achieve this capacity, about 2.5 million tonnes of biomass per year is necessary. Meanwhile, before the energy mix was announced by METI in 2016, the feed-in tariff was introduced in 2012. It accelerated the power industry to move toward renewables. Independent power producer (IPP) has developed dedicated biomass power projects and the power measures utility company has begun to co-fire coal and biomass. Nonetheless, Japan needs to leave out fossil fuels more seriously and more quickly. The driving force was the statement of the Prime Minister in 2020, which declared that Japan will be carbon-neutral by 2050. At the same time, the minister of METI announced low-efficiency coal-fired power stations must be phased out because coal is not welcome by international society. As most European counties already planned to abandon coal dependency, Japan must go in the same direction. It has become obvious that Japan needs to leave out coal dependency as quickly as possible.

The government has started the discussion for reconsidering, revising, updating its energy mix guideline. One of the potential scenarios is making renewables 50%–60% of the total share. Hydrogen and ammonia would be made 10% of total energy. The remained is given for nuclear and thermal power with carbon capture technology. Amongst renewables, the government emphasises that offshore wind power, both embedded and floating, should be encouraged. However, biomass is important as well. It is not always necessary to have a green biomass project, which normally takes several years to build. The existing facility can be utilised, although the city modification is necessary. Coal-fired power stations cannot become renewable power stations without sacrificing the oversupply facilities.

Regarding biomass fuel procurement, there are many long-term supply and purchase contracts already existing between overseas suppliers and Japan. Many of them supply biomass fuel to dedicated projects of the capacity between 50–110 MW. Some of them have already started operation. In fact, in the case of RENOVA, only one power plant in Akita is now in operation. One power plant in Kanda is under trial run, and power plants in Tokushima, Ishinomaki, and Sendai are under construction. The other, in Omaezaki, is still in the construction preparation stage. By 2023, RENOVA will have completed six dedicated biomass power projects.

As of March 2021, RENOVA currently purchases about 100,000 tonnes a year of wood pellet equivalent biomass. However, after all power plants commence operation in 2023, RENOVA's total biomass purchase will be about 1.7 million tonnes a year of wood pellet equivalent. In addition, existing coal-fired power stations now co-firing small percentage of biomass will increase their ratio. Fuel conversion from coal to biomass will come as well.

Regarding the total demand of biomass, from Energy Mix 2030, around 25 million tonnes a year is necessary. Future demand will change upward depending on the other energy behaviour. The most difficult part of biomass is availability uncertainty. Therefore, biomass should focus on sustainability, legality, and transparency of its feedstock. Further, life cycle assessment of GHGs needs to be managed. Sustainability certification from crude palm oil mills is needed for port delivery. Simultaneously, in the context of biomass, some NGOs claim that biomass could potentially harvest native trees, which destroys rainforests and ecosystems. Therefore, it is better to distinguish between good and bad biomass, which is agreed upon by everyone, including environmental NGOs.

Biomass needs to be proven internationally as sustainable, legal, and transparent. In terms of CO_2 emissions, biomass should prove that its entire trip to the power station produces fewer greenhouse gases than fossil fuels. In addition, black pellet and torrefaction biomass will have a certain market share in Japan in the future as well. Torrefaction of biomass will increase calorific value-up, have a better handling and stockpiling efficiency, be water-resistant, and have a better grind ability.

Appendix E

Automotive Contribution to Support Oil Reduction through Biofuel Utilisation

ERIA-Toyota Daihatsu Engineering & Manufacturing (TDEM) Working Group Meeting

Indra Chandra Setiawan

19 March 2021, MS Team Platform

In 2020, the Prime Minister of Japan, Yoshihide Suga, declared the country will be carbon-neutral by 2050. To accomplish this goal, it is critical to increase the efficiency of electricity generation and transportation. In automotives, this can be accomplished by focusing on vehicle design and technology, such as reducing air drag, reducing weight, and lowering rolling resistance. On the energy and powertrain mix for sustainable mobility, the short-term issues are connected to internal combustion engines, such as increased thermal efficiency and fuel diversity, while the medium-term challenges are related to electrification, such as batteries and infrastructure.

In Indonesia and Malaysia, higher-mixed biodiesel is extensively promoted, while Thailand’s government considers E20 as the primary fuel and plans to phase out E85 through subsidy reductions. Thailand’s government has announced the implementation of Euro 5 and Euro 6 emissions regulations in 2022 and 2023, respectively. Additionally, the Indonesian government intends to research B40 in advance of its adoption in 2021, while Malaysia's government intends to do research with the Japan Automobile Manufacturers Association (JAMA) in order to prepare for B30 implementation in 2021. JAMA proposed starting in April 2020, but the Malaysian Palm Oil Board (MPOB) wants to begin when JAMA discloses the results of B20 laboratory testing.

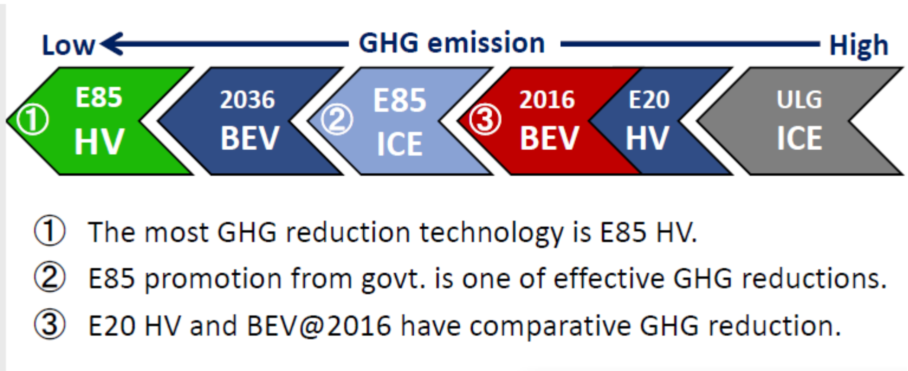
Indonesia is experiencing an oil consumption surplus, and the government has launched an ‘Energy Mix’ strategy to minimise oil consumption. According to National Energy General Plan (2018), renewable energy's proportion in Indonesia's energy mix will expand from 10% in 2018 to 23% in 2025 and 25% in 2030. According to 2018 data, 39% of total oil consumption in Indonesia comes from four wheels, including the energy mix, the oil consumption sector, transportation, and road transportation. Using the national energy mix target as a guide, the automotive sector should aim for a –20.8% reduction in oil consumption by 2030. To achieve the aim, comprehensive activities such as a Low Carbon Emission Vehicle(LCEV) or Battery Electric Vehicle (BEV) policy, compressed natural gas (CNG) vehicles, biodiesel, bioethanol, and vehicle replacement are implemented. To meet the oil consumption and CO_2 emission reduction targets, comprehensive actions are required to approach ‘New Vehicle UIO (Units in Operation),’ ‘All UIO (Fuel Usage),’ and ‘Aged Vehicle UIO.’ By implementing these efforts, it is conceivable to reduce oil consumption by 30.2% by 2030. This figure corresponds to the National Energy Mix Target. As a result, biofuels contribute significantly to Indonesia's oil reduction efforts.

Toyota is actively participating in the B40 implementation process. Currently, B40 is being investigated and tested for precipitation and material compatibility. This is expected to be completed in March 2021.

Toyota Motor Corporation developed analysis on 'Well-to-Wheel (WTW)' in regard to greenhouse gas (GHG) reduction from automotive fuels. This concept analysis can be implemented at the fuel supply cycle and operation stage of vehicle cycle, combining 'Well-to-Tank (WTT)' (fuel supply cycle) and 'Tank-to-Wheel (TTW)' (vehicle cycle) concept. In the case of ethanol, utilising a higher blend will reduce total WTW GHG emissions due to carbon balance between higher WTT and lower TTW. E85, moreover, is good for reducing GHG emissions from automotive fuels.

Toyota identified types of vehicle technologies from high to low generation of emissions, i.e. Internal Combustion Engine (ICE), Hybrid Vehicle (HV), Plug-in Hybrid Electric Vehicle (PHEV), and Battery Electric Vehicle (BEV). ICE and HV generate emissions on TTW; meanwhile, PHEV and BEV do so on the WTT stage. In the ideal scenario, BEV could be improved by using renewable energy in electricity generation to reduce WTT GHG emission. In this case, Toyota identifies scenarios for each vehicle technology as depicted on following figure D.1.

Figure D.1. Summary of Well-to-Wheel Analysis



GHG = greenhouse gases, E85: = 85% bioethanol blended to gasoline fuel, E20 = 20% bioethanol blended to gasoline fuel, ICE= internal combustion engine vehicles, HV = electric hybrid vehicles, BEV = battery electric vehicles.
Source: Toyota's Workshop Presentation, 2021.

In Thailand, the transportation sector is critical in reducing CO_2 emissions. Around 25% of emissions originate from the transportation sector, 40% from the electricity sector, 27% from industry, and 8% from other sources. The country has committed to a 25% reduction in GHG emissions by 2030. Thailand has an E85 Policy to blend ethanol to gasoline, and the National Elective Vehicle policy committee announced the country's target to have 30% of plug-in electric vehicles (xEVs) (consisting of 15% plug-in hybrid electric vehicles (PHEVs), and 15% battery electric vehicles (BEVs)) in total production by 2030.

Collaboration amongst all stakeholders, including energy suppliers, governments, customers, and automobile manufacturers, is required to meet the challenges of environmental and energy efficiency.

Appendix F

Biomass Supply Chain and Its Business Opportunity in Indonesia

ERIA- The Institute of Energy Economics, Japan Working Group Meeting

11 May 2021, MS Team Platform

From upstream to downstream, the biomass supply chain includes biomass production, pre-treatment, feedstock storage, bioenergy conversion, and bioenergy consumption. Biodiesel and bioethanol can be produced from the first generation of biomass. Biomass from all facets of the palm oil industry, including Palm Oil Mill Effluent (POME), Empty Fruit Bunch (EFB), and old palm trunks, is frequently employed as a sustainable energy source. The manufacturing procedures for the second generation of bioethanol include biomass pre-treatment, hydrolysis of pre-treated biomass, fermentation of hydrolysis products, distillation, and dehydration.

The primary business potential for biomass energy generation is related with Independent Power Producers (IPPs) that are privately developed, financed, and sell electricity to PLN under a long-term (up to 30 years) Power Purchase Agreement (PPA). The largest prospects (in terms of value) exist for foreign enterprises in consulting and engineering studies, significant electro-mechanical equipment supply, and engineering, procurement, and construction management, particularly for projects with a capacity more than 10 MW. Due to the constant changes in regulatory treatment and permissions for renewable energy IPPs, most foreign businesses established offices in Indonesia to perform market research, develop strong relationships with PLN, and evaluate possible local business partners. Market value of biomass is estimated to be around $271.5 million in 2020–21, increasing to $378.0 million in 2022–25, with a foreign share of $227.3 million.

The challenges of biomass are: 1) the high cost of transporting biomass results in these powerplants being located near the feedstock source; 2) feedstock availability is a challenge in developing and financing biomass power projects. Banks look for a feedstock supply agreement equal to or longer than the tenor of the loan; 3) the feedstock agreement should have a cap on the annual escalation, since that cost cannot be passed through to PLN; 4) in terms of commercial biomass technology, the principal is combustion for steam. Due to the size of biomass boilers, the most economic size for a biomass steam power plant is 10 MW or larger.