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.

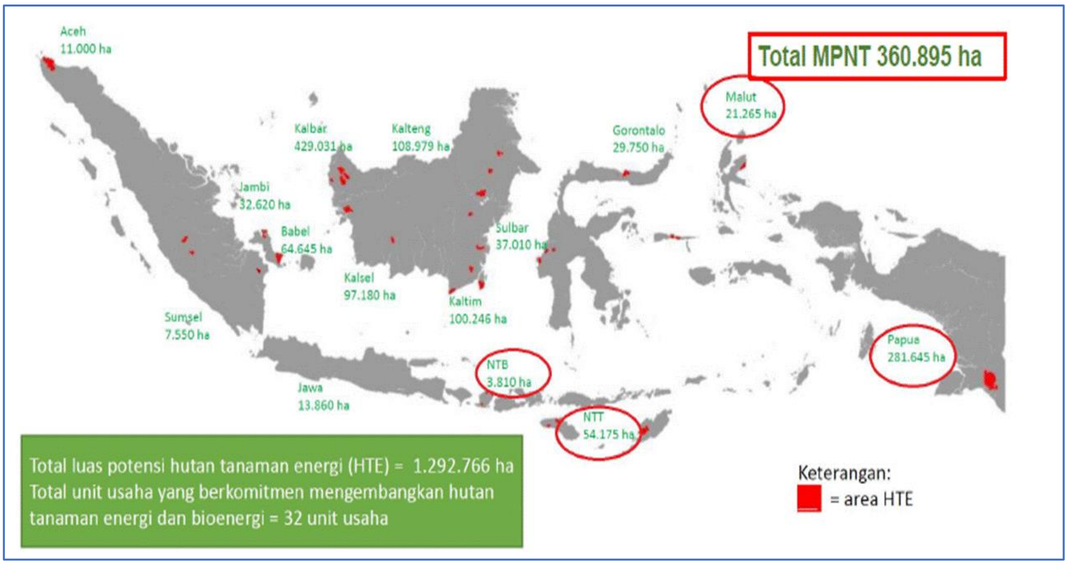
Production forest area consists of Permanent Production Forest (HP), Limited Production Forest (Hutan Produksi Terbatas, HPT), and Convertible Production Forest (Hutan Produksi yang Dapat Dikonversi, HPK). The area of HP is 28.99 million hectares, HPT is 28.41 million hectares, and HPK is 18.04 million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

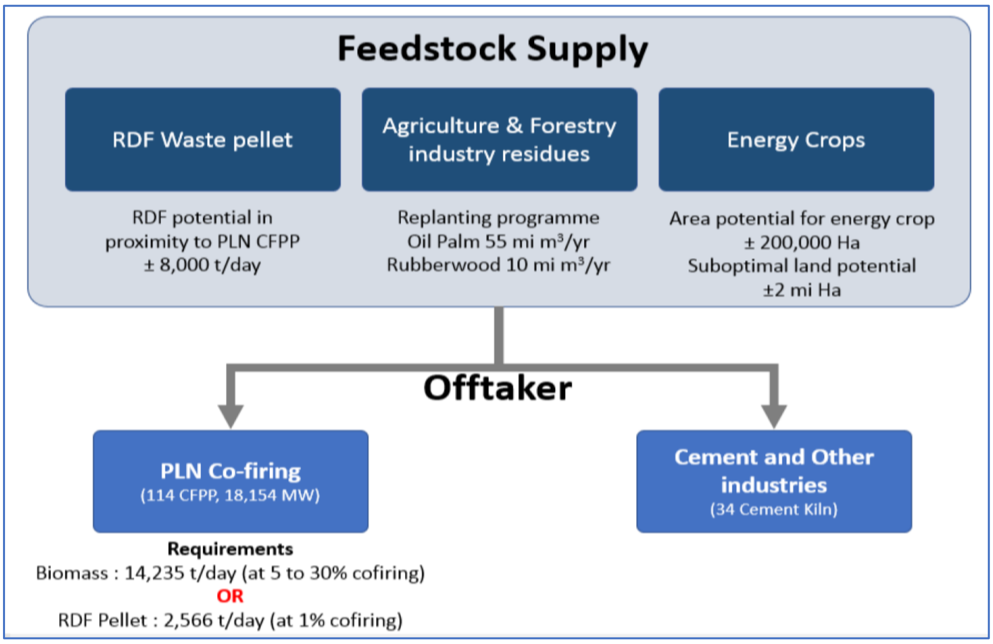
No	Kind of Agricultural Products	Harvesting area (10^3 ha)	Production (10^3 ton)	Yield Rate (quintal/ha)	Conversion Factor (ton/ha)	Potency (10^6 ton)
1	Paddy**	11,786.430	54,454.937	46.20	5.1	60.110
2	Maize	3,345.805	11,609.463	34.70	5.2	17.398
3	Cassava	1,227.459	19,986.640	163.00	6.1	7.487
4	Peanuts	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

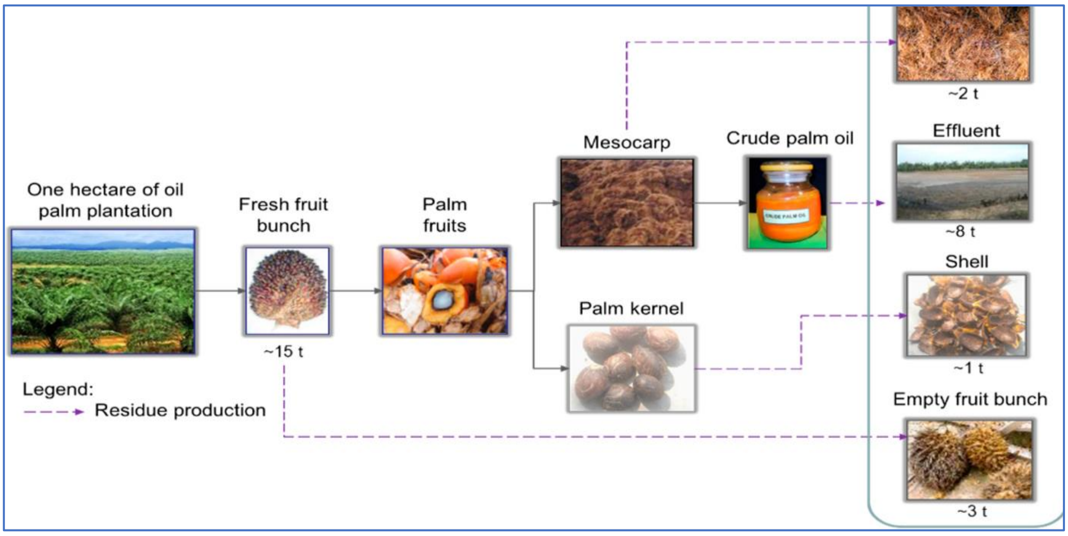
2.1. Biodiesel

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 1

Introduction

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Chapter 2

Biomass Demand Potential up to 2040

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Chapter 3

Biomass Supply Potential up to 2040

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Chapter 4

Biomass Power Generation and Wood Pellets in Japan

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Chapter 5

Wood Pellets Business Model in Indonesia

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Chapter 6

Conclusions and Recommendations

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