Chapter 2

Biomass Demand Potential up to 2040

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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.