ERIA Research Project Report FY2025, No. 42

Development of the Bioenergy Supply Chain in AZEC Partner Countries Phase II

Economic Research Institute for ASEAN and East Asia

and

The Institute of Energy Economics, Japan

Economic Research Institute for ASEAN and East Asia

Development of the Bioenergy Supply Chain in AZEC Partner Countries

Phase II

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List of Abbreviations and Acronyms

AZEC	Asia Zero Emission Community
b/d	Barrels per day
Bio-CNG	Bio-compressed Natural Gas
BPDP	Plantation Fund Management Board (Indonesia)
BPDPKS	Oil Palm Plantation Fund Management Board (Indonesia)
CES	Clean Energy Scenario
CHP	Combined heat and power (system)
CO_2	Carbon dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CPO	Crude palm oil
DOE	Department of Energy (Philippines)
EFB	Empty fruit bunches
ERC	Energy Regulatory Commission (Philippines)
ERIA	Economic Research Institute for ASEAN and East Asia
ESDM	Ministry of Energy and Mineral Resources (Indonesia)
EU	European Union
EV	Electric vehicle
EVCS	Electric vehicle charging station
FAO	Food and Agriculture Organization of the United Nations
FFDP	Five-fuel Diversification Policy (Malaysia)
FIT	Feed-in tariff
GAIKINDO	Association of Indonesia Automotive Industries
GEF	Global Environment Facility
GDP	Gross domestic product
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GJ	Gigajoule
GW	Gigawatt

GWh	Gigawatt hour
ha	Hectare
ICAO	International Civil Aviation Organization
IEA	International Energy Agency
IEEJ	The Institute of Energy Economics, Japan
IMD	International Institute for Management Development
IPP	Independent power producer
IRENA	International Renewable Energy Agency
ISPO	Indonesian Sustainable Palm Oil
kL	Kilolitre
KPK	Ministry of Plantation and Commodities (Malaysia)
ktoe	Kilotonnes of oil equivalent
kW	Kilowatt
kWh	Kilowatt hour
LCOE	Levelised cost of electricity
LHV	Lower heating value
MBtu	million British thermal units
MEMR	Ministry of Energy and Mineral Resources (Indonesia)
MJ	megajoule
MSPO	Malaysian Sustainable Palm Oil
Mt	Million tonnes
Mt-CO_2e	Million tonnes of carbon dioxide equivalent
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
MyRER	Malaysia Renewable Energy Roadmap
NBAP	National Biomass Action Plan (Malaysia)
NBP	National Biofuel Policy (Malaysia)
NEP	National Energy Policy (Malaysia)
NETR	National Energy Transition Roadmap (Malaysia)
NREP	National Renewable Energy Program

NREPAP	National Renewable Energy Policy and Action Plan (Malaysia)
OPF	Oil palm fronds
OPT	Oil palm trunks
PBBD	Palm-based biodiesel
PBBF	Palm-based biofuel
PCA	Philippine Coconut Authority (Philippines)
PCAARD	Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development
PEP	Philippine Energy Plan
PKS	Palm kernel shells
PME	palm methyl ester
POM	Palm oil mill
POME	Palm oil mill effluent
PPA	Power purchase agreement
PSA	Philippine Statistics Authority
R&D	Research and development
RBD	Refined, bleached, and deodorised
RE	Renewable energy
REA	Renewable Energy Act (Malaysia)
RED II	Renewable Energy Directive (European Union)
REF	Reference Scenario
RPS	Renewable portfolio standards
RSPO	Roundtable on Sustainable Palm Oil
SAF	Sustainable aviation fuel
SEDA	Sustainable Energy Development Authority (Malaysia)
SEDAA	Sustainable Energy Development Authority Act (Malaysia)
Solar PV	Solar photovoltaic
SRA	Sugar Regulatory Administration (Philippines)
SREP	Small Renewable Energy Programme (Malaysia)
t	Tonne
t-CO_2e	Tonne of carbon dioxide equivalent

TJ	Terajoule
TWh	Terawatt hour
UCO	Used cooking oil
UNDP	United Nations Development Programme
USDA	United States Department of Agriculture

Executive Summary

This Phase II report by ERIA, entitled *Development of the Bioenergy Supply Chain in AZEC Partner Countries*, builds upon the earlier Phase I report to examine the non-power bioenergy sectors in Indonesia and the broader bioenergy contexts of Malaysia and the Philippines. The research emerges amidst global decarbonisation trends and increasing demand from multinational manufacturers for renewables and carbon-free energy, particularly in Southeast Asia, where solar and wind deployment remains relatively limited.

Bioenergy, being dispatchable and relatively stable, presents an essential opportunity for these countries. However, its development is impeded by high costs, regulatory fragmentation, infrastructure gaps, and sustainability concerns. Through literature reviews, site visits, stakeholder interviews, and surveys, the report evaluates the current status and development of bioenergy supply chains in the three selected countries.

As the leading bioenergy player in the Association of Southeast Asian Nations, Indonesia has made significant progress in biodiesel due to palm oil resources and crude palm oil levy incentives. However, non-power bioenergy sectors like bioethanol, biogas, and sustainable aviation fuel lag due to cost, regulatory, and infrastructure challenges. To address this, the recommendations include expanding crude palm oil levy support, reforming biomethane pricing, boosting domestic feedstock like sugarcane, and promoting advanced biofuels. Carbon pricing is also proposed to diversify funding, whilst stronger sustainability governance is urged to mitigate environmental concerns. An integrated policy approach is needed to unlock bioenergy potential, reduce fossil fuel use, and align development with climate and socio-environmental goals.

Malaysia, with a comprehensive biomass policy framework that includes the Renewable Energy Act, feed-in tariff schemes, and the National Biomass Action Plan, has achieved moderate success in harnessing palm-based biomass and exporting palm kernel shells and wood pellets. Despite strong institutional support and policy evolution towards auctions and net-zero pathways, modern bioenergy still constitutes a small share of national energy due to logistical inefficiencies, cost competitiveness issues, and capped feed-in tariff quotas. The report recommends enhancing biomass system efficiency through targeted research and development (R&D), leveraging international finance and technology partnerships, improving governance, supporting co-firing of biomass in coal plants, enhancing export certification schemes, and scaling industrial heat applications.

The Philippines possesses robust bioenergy potential due to abundant agricultural residues like rice husk, bagasse, molasses, and coconut oil, supported by policies such as the Biofuels Act and Renewable Energy Act. However, limited feedstock supply, processing challenges, high costs, and policy uncertainty have constrained its contribution to energy supply. Bioethanol production remains insufficient and biodiesel expansion faces cost barriers. Recent policy shifts and innovations, like using rice straw and non-standard coconuts for fuel, aim to diversify inputs. With improved infrastructure, coordinated farming, R&D, and greater policy stability, the country could significantly expand bioenergy use, enhancing energy security and rural development.

Across all three countries, common barriers include the economic non-competitiveness of bioenergy without subsidies, limited technological readiness for advanced biofuels, underdeveloped supply chains, and environmental trade-offs, particularly related to palm oil cultivation.

The report concludes that addressing these issues will require integrated policy reform, financial incentives including carbon pricing, regional collaboration under the Asia Zero Emission Community framework, and targeted investment in R&D and infrastructure. As a result, these Southeast Asian countries can unlock the potential of bioenergy not only to decarbonise their own energy systems but also to meet the growing decarbonised energy demands of international manufacturers operating within the region.

Chapter 1

Introduction

This report is the second in the series following *ERIA Research Project Report FY2025, No. 3, 'Development of the Bioenergy Supply Chain in AZEC Partner Countries'* (Ninomiya et al., 2025), hereafter referred to as the 'Phase I' report. Whilst the Phase I report focused on Indonesia's power sector, Thailand, and Viet Nam, this Phase II report extends its scope to Indonesia's non-power sectors, Malaysia, and the Philippines. Therefore, this report is referred to as 'Phase II'.

Amidst the global trend of economic decarbonisation, large multinational corporations are making significant efforts to decarbonise their supply chains. As a result, demand for locally generated renewable energy and carbon-free fuels is growing amongst manufacturing companies operating in Southeast Asia. However, Southeast Asian countries generally lag behind in the deployment of wind and solar photovoltaic (PV) energy, which are amongst the leading renewable energy technologies in other regions.

In these circumstances, it is crucial to consider the efficient use of Southeast Asia's potentially abundant bioenergy resources. Bioenergy[1] is an inherently dispatchable energy source that can play a key role in providing the flexibility required by power grids to accommodate the increased share of variable renewable energy, namely wind and solar PV.

On the other hand, bioenergy resources are highly diverse, requiring different approaches to their effective utilisation. Various barriers exist, such as securing land for cultivation and appropriate cooperation and collaboration amongst stakeholders, and in some cases, massive investments are required. Therefore, collecting and analysing information on bioenergy is crucial to assess the current situation and the potential for its use in Southeast Asia.

This Phase II report revisits the central question posed in Phase I: Why not use bioenergy? It follows with: Why not develop a bioenergy supply chain?

To ultimately answer these questions, the objectives of this report are the same as those of Phase I. First, the report aims to collect and analyse information and data on bioenergy resources in Southeast Asia, create an overall picture of bioenergy supply and demand in the countries of the region, namely the non-power sectors of Indonesia, Malaysia, and the Philippines, and identify areas of interest for further promoting bioenergy use. Second, in line with the results of the first objective, it aims to consider a feasible approach to developing a bioenergy supply chain for the efficient use of bioenergy in the region and to

[1] Throughout this report, bioenergy is defined as the energy in solid, liquid, and gaseous products derived from biomass feedstocks, including solid bioenergy, liquid biofuels, and biogases but excluding hydrogen produced from bioenergy and synthetic fuels made with carbon dioxide feedstock sourced from biomass.

provide specific recommendations for these countries.

This report is structured as follows. After the introduction, Chapter 2 describes the research scope and methodologies used in the report. Chapters 3, 4, and 5 constitute the core sections of the report, presenting country-specific findings for the non-power sectors of Indonesia, Malaysia, and the Philippines, respectively.

These chapters are divided into several sections. The first section provides a general mapping of the current bioenergy supply and demand landscape, covering the policy and regulatory framework, resource availability, current commercial production, existing supply chains, costs, advantages of bioenergy compared to other available energy sources, and bioenergy selection, which are the focus of the following sections. As a prologue, this section informs readers of these nations' existing bioenergy circumstances and the significance of bioenergy. The 'expected supply and demand of the target bioenergy in 2030' is the subject of the second section, which also identifies the anticipated discrepancies between the supply and demand of bioenergy in that year. A cost estimate for bioenergy, if any, may also be included in this section to draw attention to the supply-demand imbalance and the problem of bioenergy's economic competitiveness.

The third section outlines the requirements for supply chain development to close the supply-demand gap for each country, taking into account the anticipated supply-demand gap in 2030. As a major component of the research, it outlines how to overcome the three primary obstacles of market/investment, policy/regulatory, and technological barriers in order to establish the bioenergy supply chain in the countries.

These barriers differ greatly based on the unique conditions of each country. However, it can be broadly stated that the technical barriers pertain to the cost, workforce, maturity, availability, and compatibility of the various technologies at every stage of the bioenergy supply chain, including collection, transportation, storage, conversion, and end-use. A lack of strong policies with precise quantitative goals supported by policy incentives to advance bioenergy under appropriate legal and regulatory frameworks within an integrated energy system may be the main cause of the policy and regulatory obstacles. Consequently, the existing policy and regulatory frameworks themselves might be an obstacle to the development of bioenergy, requiring regulatory reform. Issues related to sustainable/quality standards certification could also be considered. Finally, market/investment barriers could be highly related to the existing market structure and the associated financial uncertainties of the existing business model for bioenergy.

Chapter 6 concludes the report by presenting recommendations in two parts. The first part briefly summarises the country-specific recommendations. The second part presents a synthesised assessment of bioenergy supply chain development across all the countries considered throughout the series of this study, specifically Indonesia, Malaysia, Thailand, the Philippines, and Viet Nam, encompassing the three countries analysed in this Phase II report and those examined in the Phase I report.

Chapter 2
Scope and Methodology

The formal scope of this study series is the development of the bioenergy supply chain in Asia Zero Emission Community (AZEC) partner countries: Australia, Brunei Darussalam, Cambodia, Indonesia, Japan, the Lao People's Democratic Republic, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam. However, due to limited resources, the Phase I report (FY 2023) focused on Indonesia's power sector, Thailand, and Viet Nam. Phase II (FY 2024) extends the analysis to Indonesia's non-power sectors, Malaysia, and the Philippines. Together, the Phase I and Phase II reports complete the research scope for this study series.

Throughout this report, bioenergy is defined as the energy in solid, liquid, and gaseous products derived from biomass feedstocks, including solid bioenergy, liquid biofuels, and biogases but excluding hydrogen produced from bioenergy and synthetic fuels made with carbon dioxide (CO_2) feedstock sourced from biomass.

The approach employed in the report is mostly a literature evaluation, which entails a thorough examination of all published reports, official documents, books, data, and other bioenergy-related documents. Site visits were carried out when necessary to understand the true conditions of supply and demand for bioenergy in the relevant countries. Additionally, in some instances, questionnaire surveys were carried out by emailing questionnaires to bioenergy stakeholders directly to bolster and support the literature review. Concurrently, a number of stakeholders were interviewed to incorporate their opinions into this report. Producers and traders of bioenergy, as well as developers and operators of biomass power plants, were amongst the stakeholders.

To ensure balanced findings that reflect diverse national perspectives, an expert group of bioenergy specialists from Indonesia, Malaysia, and the Philippines was formed to regularly review and comment on the study's outputs.

Chapter 3

Findings Indonesia (non-power sectors)

Indonesia is the largest consuming and producing country of bioenergy in the Association of Southeast Asian Nations (ASEAN) region. Bioenergy is important to the country, especially for energy self-sufficiency and decarbonisation. Backed by abundant palm oil resources and aggressive policy incentives, Indonesia achieved a rapid expansion of biodiesel over the past 10 years. Since bioenergy for the power sector was covered in the Phase 1 report (Ninomiya et al., 2025), this section focuses on bioenergy for non-power sectors in Indonesia, including overall mapping of bioenergy supply and demand at present, expected supply and demand in 2030, and the requirements and recommendations for the development of the bioenergy supply chain.

1. Overall mapping of bioenergy supply and demand

1.1. Policy and regulatory framework

Indonesia has a long history of utilising bioenergy, mainly in the form of non-commercial primary solid biomass. However, modern commercial bioenergy became increasingly necessary due to the rising cost of imported fossil fuels in the 2000s. Through a series of regulations, decrees, and instructions over the years, Indonesia developed a policy framework to accelerate the use of bioenergy for non-power sectors in the country, as presented in Table 3.1.

Table 3.1. Major Regulations, Decrees, and Instructions Concerning Bioenergy in Non-power Sectors in Indonesia

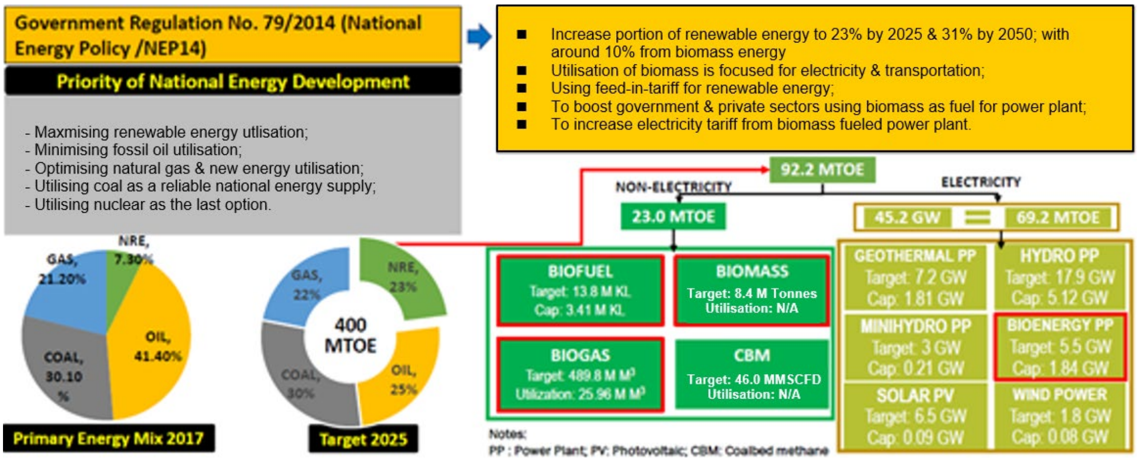
Year	Title	Content in Terms of Bioenergy
2006	Presidential Instruction No. 1	Establishing a framework for coordination amongst ministries to promote the supply and use of biofuel
2014	Government Regulation No. 79	Renewable energy target shares of 23% by 2025 and 31% by 2050; with around 10% from bioenergy
2015	Ministry of Finance Ministerial Regulation No.113/PMK.01	Establishing the BPDPKS (Oil Palm Plantation Fund Management Board) to incentivise biodiesel use through export levies
2024	Presidential Regulation No. 132	BPDPKS renamed as the BPDP (Plantation Fund Management Board) to cover not only palm oil but also cocoa, coconut, and rubber

2025	Ministry of Energy and Mineral Resources Regulation No. 4	Business and utilisation of biofuels as a strategic step to support energy independence and the transition to more environmentally friendly fuels
2025	Ministry of Trade Regulation No.2	Export restrictions on palm oil mill effluent, high acid palm oil residue, and used cooking oil

Source: Personal communication with the Ministry of Energy and Mineral Resources (Indonesia).

Under the National Energy Policy, the 2025 target volumes were set at 13.8 million kilolitres (kL) for biofuel, 489.8 million cubic metres (m^3) for biogas, and 8.4 million tonnes (t) for biomass, as presented in Figure 3.1.

Figure 3.1. Bioenergy Policy Targets in Indonesia



Source: Personal communication with the Ministry of Energy and Mineral Resources (Indonesia).

Bioenergy use for power generation and biogas fall short of their targets, although the biofuel (mainly biodiesel) utilisation target in 2025 was almost achieved in 2023, as presented in Table 3.2.

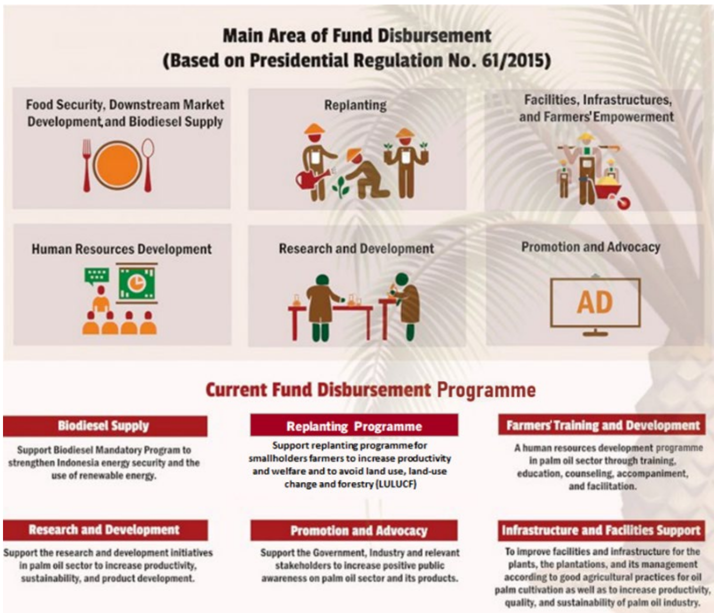
Table 3.2. Bioenergy Utilisation and Realisation in Indonesia

Programmes	2020	2021	2022	2023	2024	2025	Realisation 2023	GAP
Bioenergy Power Plants (MW)	2,500	2,900	3,400	4,000	4,700	5,500	3,257	2,243
Biofuel (Million KL)	8.0	8.9	10.0	11.2	12.5	13.9	13.1	0.8
Biomass (Million Tonnes)	6.7	7.0	7.4	7.7	8.0	8.4	7.5	0.9
Biogas (Million M3)	131.9	171.5	222.9	289.8	376.8	489.8	143.3	346.5

Source: Personal communication with the Ministry of Energy and Mineral Resources (Indonesia).

Behind the great success of biodiesel is an incentive scheme called the crude palm oil (CPO) export levy, which is managed by the Oil Palm Fund Management Agency (BPDPKS). BPDPKS was established in 2015 to 'foster development and sustainability of the palm oil sector through prudent, transparent, and accountable funds management' (BPDP 2025). BPDPKS oversees a wide range of activities, not only supporting mandatory biodiesel programmes but also replanting, farmer training and development, research and development, promotion and advocacy, and infrastructure and facilities in support of the palm oil sector, as presented in Figure 3.2 (BPDP 2025).

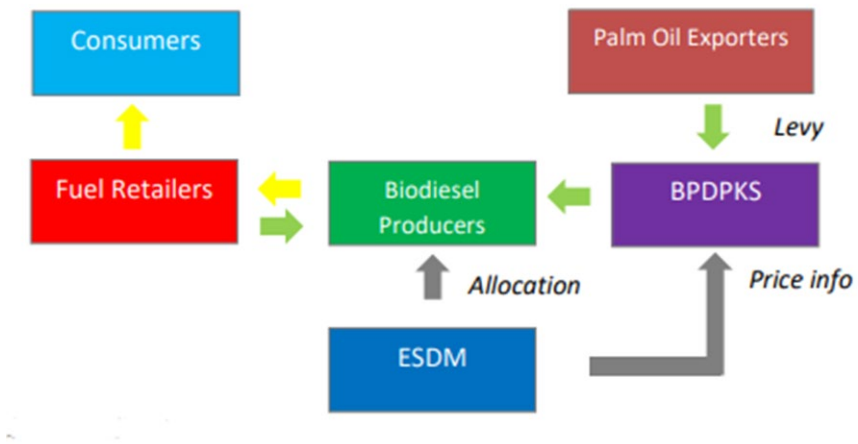
Figure 3.2. Activities of the BPDPKS



Source: BPDP (2025).

Put simply, the agency collects palm oil export levies and distributes the funds to offset the price gap between biodiesel and fossil diesel, as well as cover other activities. In 2024, the BPDPKS was renamed as the BPDP to add cocoa and coconut under its authority, as illustrated in Figure 3.3.

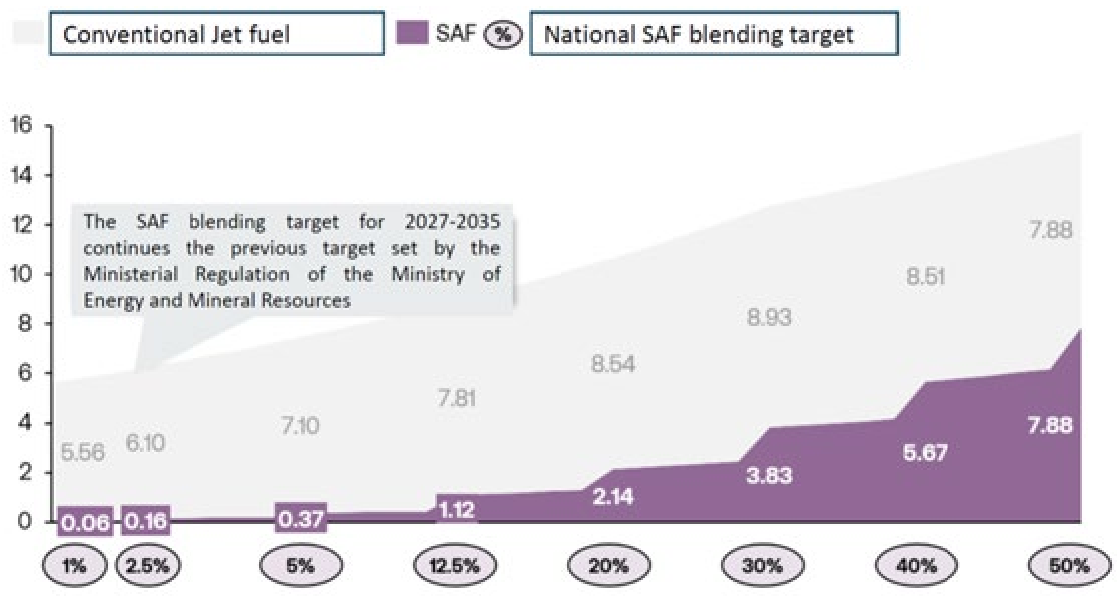
Figure 3.3. Profile of the Crude Palm Oil Export Levy



Source: Ministry of Energy and Mineral Resources (Indonesia), cited in USDA (2024a).

As for sustainable aviation fuel (SAF), the government formulated a roadmap in late 2024 under which 1% SAF blending will start in 2027, gradually increasing to 50% (7.88 million kL) by 2060[2], as seen in Figure 3.4.

Figure 3.4. Indonesia's Sustainable Aviation Fuel Targets



Source: ICAO (2024a).

[2] The blending target is still under discussion as of July 2025.

1.2. Resource availability

Indonesia is known for its abundant bioenergy resource base. With 56 million hectares of agricultural land and 90 million hectares of forest area as of 2022, plentiful rainfall, and a warm climate, the value of Indonesia's agricultural production was US$126 billion in 2019, by far the largest in the ASEAN region and the fifth largest in the world (FAOSTAT, 2025).

In terms of bioenergy feedstocks, Indonesia is the largest palm oil producer in the world, producing 46.8 million tonnes in 2022 (FAOSTAT, 2025). In the same year, 8.842 million tonnes of crude palm oil (CPO) were used to produce biodiesel (GAPKI 2023). Whilst CPO is expected to remain the main feedstock for bioenergy in the country, its production is estimated to be sufficient for B50 but could disrupt other uses, particularly exports, according to the Ministry of Energy and Mineral Resources (MEMR). By contrast, bioethanol production faces a shortage of feedstock, particularly sugar molasses.

As presented in Table 3.3, IRENA (2022) assesses supply potential of other feedstocks, namely, palm oil residues, rice (husks and straw), sugarcane (bagasse, tops, and leaves), rubber, palm oil mill effluent (POME), and cassava pulp, and estimates that this supply potential will expand from 363.3 petajoules (PJ) in 2025 to 2,594.6 PJ in 2050 (IRENA 2022). However, POME is likely the only feedstock amongst these suitable for biodiesel production. For bioethanol, other feedstocks can generally be utilised, though often only through second-generation (cellulosic) processes.

Table 3.3. Indonesia's Potential Primary Bioenergy Supply: Selected Collectible Feedstocks

Type of Feedstock	Primary Bioenergy Supply (PJ)		
	2025	2030	2050
Palm oil residues (palm kernel shells, empty fruit bunches, old trunk)	197.1	624.5	657.6
Rice husks, rice straw	62.4	187.2	467.9
Sugarcane bagasse, tops, and leaves	11.3	35.8	95.1
Rubber	69.9	123.0	235.0
Acacia	25.5	44.9	85.9
Palm oil mill effluent	4.9	15.4	40.8
Cassava pulp	1.2	3.9	12.3
Total	**363.3**	**1,034.7**	**2,594.6**

Source: IRENA (2022).

More specifically, for crop waste, Widodo and Rahmarestia (2021) estimate the potential at 45.6 million tonnes/year. However, further study is needed to assess its suitability for non-power sector bioenergy, as presented in Table 3.4.

Table 3.4. Estimation of Estates' Crop Waste Potency

No	Kind of Waste	Area (ha)	Conversion Factor (%)	Potency (m3/ha)	Total Potency (tonnes/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	16,277,868
	Shell		5		593,080
	EFB		20		2,372,323
	Ditch CPO		15		1,779,242
3	Coconut	38,036,014			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

Source: Widodo and Rahmarestia (2021).

As for bioethanol feedstocks, ERIA (2022) estimates the total potential at 34.6 million kL per year, as presented in Table 3.5, which would be sufficient to implement E20 (a 20% blend with conventional gasoline). However, a second-generation process would be required to utilise these feedstocks to produce bioethanol.

Table 3.3. Potential of Second-generation Bioethanol Production from Feedstocks in Indonesia

Feedstock	Bioethanol Production Potential (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

Source: ERIA (2022).

As for used cooking oil, Pertamina (2024) estimates that used cooking oil (UCO) collection could reach 1.24 million kL annually, which is enough to reach the SAF blending target of 1.12 million kL in 2040.

1.3. Commercial production

According to statistics from the MEMR (2024), biodiesel production in Indonesia increased dramatically from 2.1 million kL in 2013 to 13.2 million kL in 2023. The majority of this production is for domestic consumption. Biogas production has also increased rapidly over the past 3 years, reaching about 111 million m^3 in 2023, as described in Table 3.6.

Table 3.6. Bioenergy Production in Indonesia

Year	Biodiesel			Biogas
	Production	Export	Domestic	Production
	1,000 kL			1,000 m^3
2013	2,085	1,757	1,048	n.a.
2014	3,961	1,629	1,845	n.a.
2015	1,620	328	915	18,953
2016	3,656	477	3,008	22,800
2017	3,416	187	2,572	24,786
2018	6,168	1,803	3,750	25,670
2019	8,399	1,319	6,396	26,277
2020	8,594	36	8,400	27,856
2021	10,240	133	9,294	28,390
2022	11,836	372	10,449	32,521
2023	13,151	188	12,290	110,792

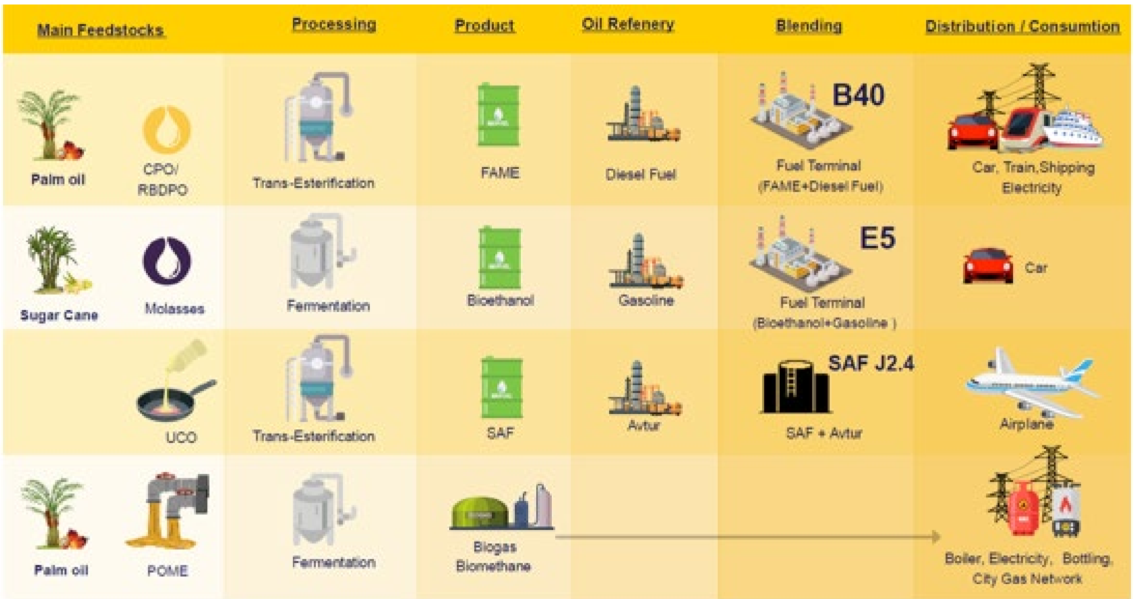
Source: MEMR (2024).

The MEMR statistics do not include bioethanol production but note a production capacity of 40,000 kL/year in East Java. International Energy Agency (IEA) statistics, on the other hand, show no biogasoline (including bioethanol) production in 2022. As for SAF, as of March 2025, Pertamina reportedly will start trial production of 9,000 barrels per day (b/d) in the second quarter of 2025 (Petroleum Argus, 2025).

1.4. Existing supply chains

The utilisation of bioenergy for non-power sectors in Indonesia is currently dominated by biodiesel, although biogas production has been rising rapidly since 2021. The utilisation of bioethanol remains limited, and SAF production is still in its infancy. The existing (or near existing, in the case of SAF) supply chains for these four products in non-power generation sectors are summarised in Figure 3.5.

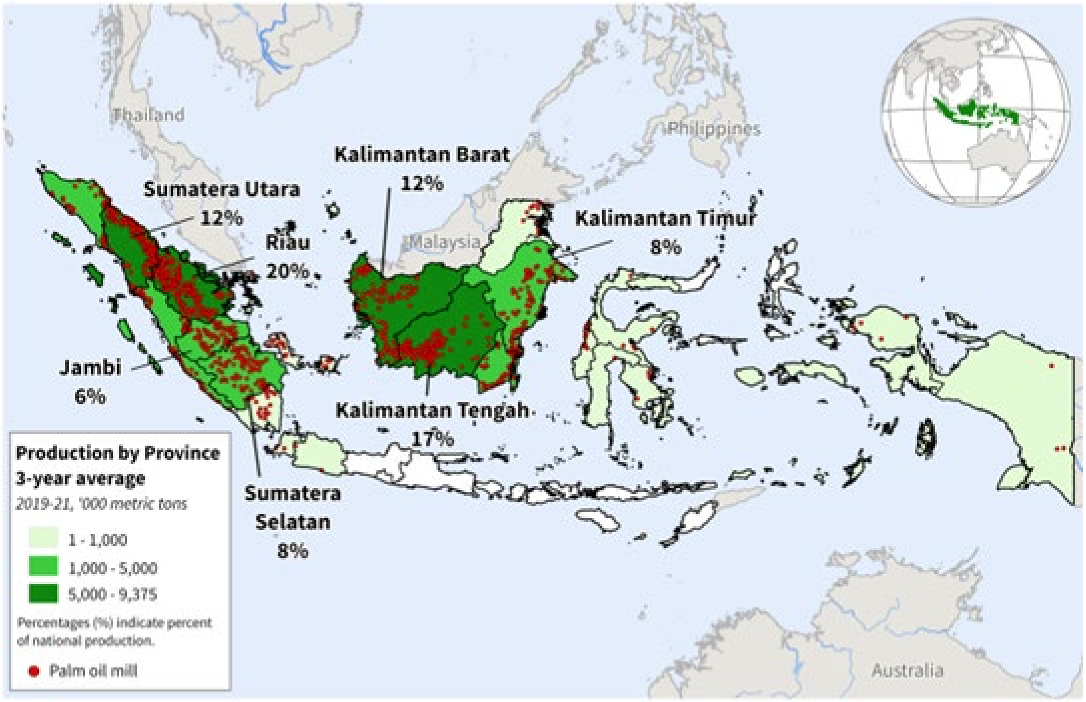
Figure 3.5. Simplified Existing Supply Chains of Bioenergy for Non-power Generation Sectors in Indonesia



CPO = crude palm oil, FAME = fatty acid methyl ester, POME = palm oil mill effluent, RBDPO = refined, breached, deodorised palm oil, SAF = sustainable aviation fuel, UCO = used cooking oil.
Source: Personal communication with the Ministry of Energy and Mineral Resources (Indonesia).

Palm oil, specifically CPO, has so far been by far the main feedstock for biodiesel. Palm oil production is centred in Sumatra and Kalimantan, as indicated in Figure 3.6. In 2024–2025, Indonesia produced 46,000 million tonnes of palm oil, according to the USDA (2025a).

Figure 3.6. Palm Oil Production in Indonesia



Source: USDA (2023a).

The production of CPO-based biodiesel usually involves a transesterification process, in which the triglycerides in the oil react with alcohol in the presence of a catalyst. After the reaction and subsequent treatments, fatty acid methyl ester is extracted and blended with fossil diesel. POME, currently the main feedstock for biogas, is liquid waste product from palm oil processing. After pretreatment, POME is fed into a sealed tank, or anaerobic digester, for fermentation. The resulting biogas is collected and treated before utilisation either for power generation or industry.

In 2023, sugarcane production reached 2.23 million tonnes, with about three-quarters of it produced in Java (BPS-Statistics Indonesia, 2024). Sugarcane molasses, a by-product of sugarcane production, serves as the main feedstock for bioethanol. After pretreatment, such as dilution and pH adjustment, fermentation takes place, followed by distillation and dehydration to raise the ethanol content. The resulting ethanol is then blended with gasoline for distribution.

For UCO-based SAF, Pertamina has initiated steps to collect UCO from households, restaurants, and food processing industries (Pertamina, 2024). Considering collection efficiency, collections can be centred in urban areas. Pertamina reportedly operates six collection points in Jakarta, Tangerang, and Bandung (Tanahair.net, 2025). Like CPO-based biodiesel, UCO undergoes a transesterification process, and the resulting fatty acid methyl ester is blended with fossil jet fuel for utilisation as SAF.

1.5. Cost

Whilst production cost data for bioenergy feedstocks are not available to the public, costs are assumed to differ significantly depending on various factors like agricultural productivity, labour costs, processing efficiency, and transportation. For CPO-based biodiesel, both CPO and biodiesel prices are not regulated. The CPO price in the biodiesel formula is based on the average price of the CPO auction conducted by Kharisma Pemasaran Bersama Nusantara in a particular month. The Ministry of Trade sets a reference price for CPO every month, which determines export taxes and levies . MEMR issues the Biofuel Market Price Index (HIP) as a reference for parties involved in the mandatory biofuel programme. As of June 2025, the HIP for biodiesel, for instance, is Rp12,890 per litre plus transportation costs, and the HIP for bioethanol is Rp13,356 per litre, as presented in Table 3.7.

Table 3.7. Biofuel Market Price Index (HIP) Formula

Biodeisel					
Average CPO KPB Price (Rupiah/kg)		Formula	HIP Biodiesel (Rupiah/liter)		
24 April 2025 to 24 May 2025	13,408	HIP = (Average CPO KPB Price + 85 USD/tonne) x 870 kg/m3 + Transportation Cost	June 2025	12,890	+ Transportation Cost
Bioethanol					
Average Sugarcane Molassses KPB Price (Rupiah/kg)		Formula	HIP Bioethanol (Rupiah/liter)		
24 April 2025 to 24 May 2025	2,225	HIP = (3 Month Average Sugacane Molasses KPB Price x 4.125 kg/liter) + 0.25 USD/liter	June 2025	13,356	

Source: Personal communication with the Ministry of Energy and Mineral Resources (Indonesia).

Biogas market prices are determined through business-to-business (B2B) agreements and producers' internal cost estimations. Producers are required to upgrade biogas to biomethane, such as by removing impurities and adjusting its heating value.

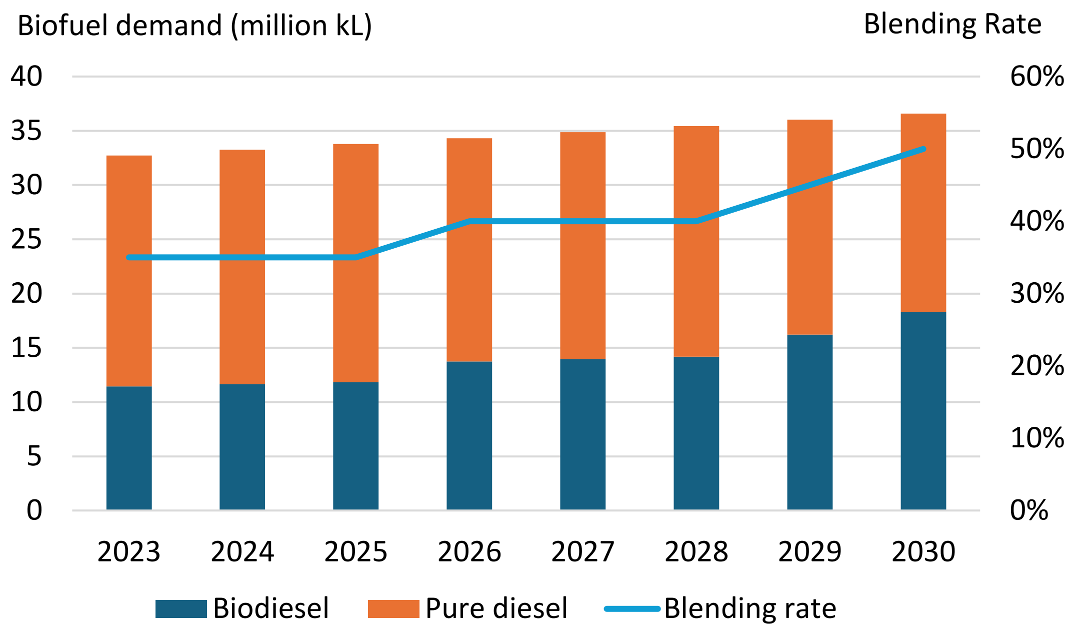
2. Expected supply and demand of bioenergy in 2030

2.1. Biodiesel

According to MEMR (2024), combined demand for diesel and biodiesel (hereafter, biogasoil) grew rapidly at 3.5% per year between 2013 and 2023. Thanks to an aggressive blending programme, the blending rate increased from 10% (B10) in 2013 to 35% (B35) in 2023.

With economic growth, rising energy demand for transportation, and plans to increase the biodiesel blend to B50, biodiesel demand is expected to continue increasing. Assuming biogasoil demand will grow at 1.6% per annum until 2030,[3] and that B50 will be fully introduced in 2030,[4] biogasoil demand will reach 41.9 million KL in 2030. As a result, biodiesel demand will increase at 7.5% per annum, and will reach 21.0 million kL in 2030. CPO requirements in 2030 will be 19.0 million tonnes, as presented in Figure 3.7.

Figure 3.7. Scenario of Diesel-related Biofuel Demand



Source: Authors' estimation.

2.2. Bioethanol

Gasoline demand in Indonesia grew steadily at 1.9% per annum between 2013 and 2023, reaching 35.8 million kL in 2023 (MEMR 2024). Despite efforts by the government and industry, bioethanol blending remains negligible, with MEMR statistics not reporting supply or demand figures. According to MEMR, bioethanol supply was a mere 30 kL in 2023 and 357 kL in 2024, even though an E5 market trial began in 2023. MEMR plans to introduce E10 in 2029, but only in specific areas. Therefore, until 2030, bioethanol demand is expected to remain very limited.

2.3. Biogas

Biogas development in Indonesia is focused on sustainable solutions in the household, industrial, and transportation sectors. Whilst the government targets 489.8 million cubic

[3] This growth rate is adopted from the reference scenario of IEEJ Outlook 2025.

[4] MEMR plans to start introducing B50 in 2029. Here we assume a blending rate of 45% in 2029 and 50% in 2030.

metres of biogas supply in 2025, actual production in 2023 reached only 110.792 million cubic metres.

2.4. SAF

As mentioned previously, Indonesia intends to start 1% blending of SAF in 2027 and increase the blending to 50% in 2060. For 2030, the planned blending rate is set at 2.5%, which is equivalent to 0.16 million kilolitres (2,756 b/d). Pertamina is in the process of producing 9,000 b/d of SAF at its Cilacap refinery, based on UCO feedstock. Additionally, Italy's NextChem plans to construct an SAF plant in North Sumatra that will use POME as the main feedstock (NEXTCHEM, 2024). The plant's capacity is 60,000 tonnes (1,295 b/d), though the start date for commercial operation has not yet been announced. As mentioned above, Pertamina (2024) estimates UCO collection could reach 1.24 million kilolitres annually, which is enough to support the 2040 blending target of 1.12 million kilolitres.

3. Requirements for development of the supply chain (to fill the supply-demand gap)

3.1. Cost barriers

The cost of bioenergy is generally considered higher than that of competing conventional fuels such as fossil fuels, and this is also the case with bioenergy in Indonesia. Even with the abundant palm oil resource base, the sector's rapid expansion would not have been possible without the CPO levy. A lack of infrastructure, feasible technologies, and adequate government support would further worsen the economics of bioenergy for bioenergy industries. Additionally, a decrease in the price of competing fuels, fossil fuels in particular, could hinder bioenergy adoption. Overall, cost remains the largest barrier for bioenergy in Indonesia's non-power sectors.

A literature survey reveals the vulnerability of bioenergy's competitiveness in Indonesia. Whilst the CPO levy has been effective in increasing CPO-based biodiesel, ERIA (2024c) notes that the price disparity between bioethanol and gasoline remains one of the primary bottlenecks for bioethanol. Interviews with anonymous industry sources in Indonesia confirm that cost barriers are the main obstacle to the expansion of bioethanol and biogas use. For example, although the price of biomethane is regulated at US$6 per million British thermal units (MBtu) (ex-pipe), anonymous industry sources claim the actual biogas cost is around US$12/MBtu.

The cost issue also prevents the commercialisation of second-generation bioenergy. For example, high capital costs are one of the main hindrances to the rapid penetration of advanced drop-in biofuels (ERIA, 2024c).

3.2. Policy and regulatory barriers

Since cost is the biggest barrier, and given policy objectives such as self-sufficiency, greenhouse gas (GHG) emission reduction, and bioindustry development, government intervention is generally justified to fill the gap and accelerate bioenergy use in the country.

Although the CPO levy provides a powerful incentive for biodiesel, IRENA (2022) argues that policy incentives are still not strong enough to decarbonise the industrial heat generation process in Indonesia. More specifically, interviews with anonymous industry sources in Indonesia reveal that a lack of financial support has resulted in major bottlenecks, such as feedstock shortages for bioethanol, grid development for biogas, and UCO collection for SAF.

Although the government plays an important role in R&D, the USDA (2024a) argues that strong support for the biodiesel mandate programme has not translated into support for the development of an advanced biofuels programme that would include widespread use of hydrogenation-derived renewable diesel or SAF. Nor are there incentives to lower the carbon intensity of biodiesel currently supplied to the market. ERIA (2024a) meanwhile points out that the current luxury sales tax considers only future passenger flex-fuel engine vehicles, not commercial vehicles, such as trucks and vans.

Expanding government support to increase bioenergy usage in the country requires a substantial amount of funding. According to the USDA (2024a), the government plans to expand the carbon pricing mechanism to non-power sectors, including transportation. Carbon pricing could potentially help finance low-carbon fuels like bioethanol, biogas, and SAF, but there is no certain timeline for carbon pricing in the country.

3.3. Feedstock shortage for conventional (first-generation) bioenergy

Indonesia's success in biodiesel is partly due to the country's abundant palm oil resources. As the world's largest palm oil producer, Indonesia is capable of B40 implementation. However, the Indonesia Biofuel Producer Association argues that current production capacity is not sufficient for the mandate beyond B40 (Indonesia Biofuel Producer Association, 2025).

The lack of feedstock is a serious bottleneck to expanding bioethanol production. ERIA (2024c) attributes the shortage of sugar molasses, the main feedstock, to competition with other sectors like food processing, monosodium glutamate production, and exports. Whilst corn is one of the possible alternative feedstocks for bioethanol, IEA Bioenergy (2024) considers corn in Indonesia unsuitable due to high aflatoxin content caused by weather conditions and inadequate grain storage and handling. Various other feedstocks are available in the country, but such alternatives usually require costly cellulosic processes.

3.4. Engine applicability

Whilst the government is pursuing higher biodiesel blending rates, the Association of Indonesia Automotive Industries (GAIKINDO) has raised concerns that B30 and higher blends could potentially damage diesel engines and lead to suboptimal combustion (GAIKINDO, 2024). Similarly, ERIA (2024c) refers to some original equipment manufacturers that have suggested engine modifications would be necessary for vehicles to safely operate on biofuels above B30. Whilst flexible-fuel engines could accommodate higher blends, engine development is a time-consuming process that could require 7–8 years (ERIA, 2024c).

3.5. Infrastructure bottleneck

An infrastructure bottleneck is evident, especially in the case of biogas, which requires pipelines for transportation. Although some natural gas pipelines exist in Sumatra and Java, the World Biogas Association (2022) notes that pipeline grids are underdeveloped outside these regions, and most palm oil mills consume biogas internally.

3.6. Environmental barriers

Sustainability issues related to land use are controversial in palm oil production in Indonesia. Despite conservation measures, the conversion of large areas of natural regenerating forests into plantations has raised concerns about environmental degradation and climate change (IRENA, 2022). Widodo and Rahmarestia (2021) argue that bioenergy production may also cause harmful environmental effects, such as deforestation and loss of biodiversity. For SAF feedstock, CPO has the highest availability in Indonesia, but its life cycle emissions exceed ICAO and key market standards, limiting its global marketability (ICAO, 2024a). Various other studies also argue that biodiesel mandates have resulted in deforestation, significant GHG emissions, and local air pollution (Mongabay, 2021; Wahyono et al., 2020; Dharmawan et al., 2020). If these environmental concerns are not properly addressed, bioenergy developments could face strong opposition domestically or internationally, leading to delays or even cancellations.

4. Recommendations for the Development of the Bioenergy Supply Chain

4.1. Wider application of the CPO levy for bioethanol, biogasoline, and biogas

Literature reviews and interviews reveal that cost remains the biggest barrier to bioenergy in Indonesia. Assuming there will be no dramatic cost reductions that would improve the competitiveness of bioenergy in the country, the availability and scope government incentives, especially financial ones, are crucial. Indeed, whilst the powerful CPO levy has enabled rapid biodiesel expansion, bioethanol and biogas continue to lag behind without such incentives. It is too early to judge whether SAF supply can grow as planned, but anonymous industry sources are not optimistic about its economics without subsidies.

If the government wishes to expand bioethanol, biogas, and possibly SAF, it is therefore essential to provide adequate financial incentives for these products. If direct subsidies are not realistic due to budget constraints, it is worth looking into the possibility of utilising the CPO levy for bioethanol.

Bioethanol is an alcohol produced by fermenting sugars or starch-rich biomass such as molasses. CPO, which lacks fermentable sugars, cannot be used as a feedstock for bioethanol. However, empty fruit bunches (EFB), a lignocellulosic waste from palm oil mills, contain fermentable sugars and could be used as a feedstock for bioethanol, though EFB-based bioethanol is still at the R&D stage.

Another possibility is to produce biogasoline from CPO through a series of conversion processes, such as hydrodeoxygenation and cracking or hydrocracking, to convert the triglycerides and free fatty acids in CPO into hydrocarbons. The government and the Bandung Institute of Technology produced CPO-based biogasoline at a pilot plant in 2022 (MEMR, 2022), but commercialisation remains unclear.

The government should accelerate support for programmes that use CPO or palm-oil-related waste as feedstock for bioethanol or biogasoline. If successfully commercialised, EFB-based bioethanol or CPO-based biogasoline could be eligible for CPO levy incentives, improving the competitiveness and reducing pure gasoline demand.

As for biogas, the regulated price of US$6/MBtu is not adequate for producers to sell their biogas. Given that this price has been fixed since 2020, the government should consider adopting more cost-oriented and flexible pricing regulation that is revised periodically to reflect cost fluctuations. Moreover, since POME is the main feedstock for biogas in the country, the government should investigate the possibility of expanding the applicability of the CPO levy to cover POME.

4.2. Carbon pricing as another financial source to incentivise bioenergy use

Whilst the CPO levy has been very effective in boosting biodiesel supply in Indonesia, another financial source may be needed to support bioenergy, given the levy is exposed to international palm oil market fluctuations. Since replacing fossil fuels with bioenergy contributes to lower emissions, carbon pricing instruments such as carbon taxes, emissions trading schemes, and carbon offset credits could incentivise broader bioenergy use. Under Presidential Regulation No. 98, Indonesia established a framework for carbon pricing in 2021, and in 2023, the Indonesia Stock Exchange launched, IDX Carbon, trading platform for emissions allowances and offsets.

Carbon pricing mechanisms in the country are in their infancy. As of July 2025, emissions allowance trading covers only the power sector, and a carbon tax has not yet been introduced. The government should accelerate its efforts to expand carbon pricing to facilitate the growth of bioenergy. Once fully implemented and adequate market liquidity is achieved, carbon pricing could facilitate greater supply of bioethanol, biogas, and SAF by improving the economics of these products.

4.3. Feedstock development for bioethanol

Indonesia consumes more pure gasoline than pure diesel, with about 60% of gasoline demand met by imports in 2022. To reduce dependency on imported fuel and lower GHG emissions, the country needs either to control gasoline demand, boost alternative fuels like bioethanol and biogasoline, or accelerate the transition to electric vehicles. Focusing on bioethanol, one part of the problem is the feedstock (sugar molasses) shortage. Unlike palm oil, Indonesia is a net importer of sugar cane, which makes it harder for the bioethanol industry to procure adequate sugar molasses. In 2022, the government launched the Sugarcane Bioethanol Programme for Energy Security, targeting sugar self-sufficiency and bioethanol production of 1.2 billion litres by 2030, by expanding sugarcane cultivation to 700,000 hectares from the current 450,000 hectares (USDA, 2023b). Achieving this target will be crucial to alleviating the shortage of molasses and increasing bioethanol production.

4.4. R&D on second-generation bioenergy

The first-generation bioenergy such as biodiesel and bioethanol is already well-established technologically. However, since blending beyond B40 may cause engine damage and suboptimal combustion (GAIKINDO, 2024), the government should accelerate the development of second-generation drop-in biodiesel, known as green diesel or hydrotreated vegetable oil. With almost the same chemical properties as diesel, hydrotreated vegetable oil is produced through hydrodeoxygenation and cracking or hydrocracking using a variety of feedstocks, including CPO and UCO, and can completely replace pure diesel without harming vehicles.

SAF, biogasoline, and other oil-related products can also be produced by the same processes. As mentioned above, Pertamina is nearing commercial production of SAF through a hydrogenation process. The government should accelerate its support for the second-generation bioenergy. In the case of biogasoline, the support should include flexible application of the CPO levy to cover CPO-based feedstock.

4.5. Minimising environmental and social impacts

The Government of Indonesia is aware of the potential adverse environmental and social impacts associated with bioenergy development. Presidential Regulation No. 22 of 2017 emphasises sustainability and community involvement in bioenergy. Programmes like Indonesian Sustainable Palm Oil (ISPO) and Roundtable on Sustainable Palm Oil (RSPO) aim to reduce deforestation and protect biodiversity. Presidential Regulation No. 16 of 2025 expands the scope of ISPO to include downstream palm oil industries and bioenergy operations, and it also enhances the legal framework and institutional support for all stakeholders, especially smallholders. A moratorium on developing primary forests and peatland has been in place since 2011. Despite these efforts, environmental and social concerns over bioenergy developments have not been eliminated completely. The government should continue to monitor the situation and implement policies to minimise adverse impacts. Effective monitoring and implementation are also crucial from an international perspective, especially if Indonesia wishes to promote bioenergy development by leveraging carbon offset schemes involving foreign investors.

Chapter 4
Findings: Malaysia

1.Overall Mapping of Bioenergy Supply and Demand

1.1.Bioenergy development policy framework

Malaysia's energy sector has undergone a significant transformation over the past two decades, driven by the need for diversification, sustainability, and environmental conservation. Facing depleting fossil fuel reserves and rising energy demand, the government introduced a series of renewable energy (RE) policies to lay the foundation for a low-carbon energy transition, with policies aimed at leveraging abundant biomass resources, especially those derived from oil palm.

Table 4.1. Bioenergy Development Policy Framework in Malaysia

Year	Policy Name	Main Goals	Outcome/Status
2000	Five-fuel Diversification Policy (FFDP)	Introduce renewable energy (RE) as the fifth fuel to diversify the energy mix	Marked RE's entry into national energy planning; limited implementation, but foundational
2001	Small Renewable Energy Programme (SREP)	Support small-scale RE projects (≤10 MW), target 500 MW by 2005	Less than 3% of target achieved due to bureaucratic and technical issues
2006	National Biofuel Policy (NBP)	Promote palm-based biodiesel to reduce diesel dependence	Laid groundwork for blending mandates; limited by cost, infrastructure, and price volatility
2010	National Renewable Energy Policy and Action Plan (NREPAP)	Target 20% RE in the capacity mix by 2025; provide strategic RE development framework	Influential policy; led to REA 2011 and measurable RE growth
2011	Renewable Energy Act (REA)	Establish feed-in tariff (FIT) to incentivise RE generation	Boosted bioenergy investments
2011	Sustainable Energy Development Authority Act (SEDAA)	Create the Sustainable Energy Development Authority to administer RE programmes and FIT	Strengthened institutional coordination and policy continuity

2021	Malaysia Renewable Energy Roadmap (MyRER)	Set 31% RE capacity by 2025, 40% by 2035; modernise biomass use	Promoted auctions, biomass co-firing, Bio-compressed Natural Gas
2022	National Energy Policy 2022–2040 (NEP)	Provide long-term energy blueprint, 18.4 GW RE by 2040	Aligned bioenergy with sustainability and green economy goals
2023	National Biomass Action Plan (NBAP)	Utilise palm biomass for energy; build 20 hubs	Focused on biomass innovation, export, and value-added use
2023	National Energy Transition Roadmap (NETR)	Achieve 70% RE in electricity by 2050; operationalise net-zero vision	Biomass as key transition fuel; supported co-firing, deployment

Source: Compiled by authors based on Sovacool and Drupady (2011), Energy Commission (2011, 2023), SEDA (2021), and Economic Planning Unit (2022).

Key policies shaping Malaysia's bioenergy landscape as listed in Table 4.1 include:

1. Five-fuel Diversification Policy (FFDP, 2000): This policy officially added RE as the fifth fuel in Malaysia's energy mix alongside oil, gas, coal, and hydro, aiming to reduce reliance on traditional fuels and promote efficient energy use. By incorporating RE into the national agenda, it marked an important initial step towards a diversified, sustainable energy sector. Although implementation was limited, the FFDP was a cornerstone in integrating cleaner energy options into Malaysia's energy framework.

2. The Small Renewable Energy Programme (SREP, 2001): This programme was launched in 2001 to promote small-scale RE projects, integrating RE as the 'fifth fuel' in the nation's energy mix. The programme allowed RE projects with capacities up to 10 megawatts (MW) to sell electricity to the national utility company. Despite its ambitious target of achieving 500 MW of RE capacity by 2005, the SREP faced challenges such as capacity caps, lengthy approval processes, lack of monitoring, exclusion of stakeholders, and inadequate feasibility studies, resulting in less than 3% of the target being met by 2005. These challenges highlighted the need for more effective policy frameworks to support RE development in Malaysia (Sovacool and Drupady, 2011).

3. National Biofuel Policy (NBP, 2006): This policy promoted the use of palm-based biodiesel (PBBD) to reduce dependence on petroleum diesel. It sought to capitalise on Malaysia's abundant palm oil resources for a sustainable transport fuel. The policy set the stage for biodiesel blending mandates and encouraged investments in palm biodiesel production. However, high production costs, fluctuating palm oil

prices, and inadequate infrastructure, such as blending facilities and distribution networks, hindered large-scale implementation. Despite these challenges, the policy demonstrated Malaysia's commitment to exploring alternative fuels for long-term energy security.

4. National Renewable Energy Policy and Action Plan (NREPAP, 2010): This plan was a pivotal moment in Malaysia's energy transition, setting a target for 20% RE share in the power capacity mix by 2025. It provided a comprehensive framework to develop the RE industry, reduce renewable technology costs, and raise public awareness. By coupling environmental goals and industrial growth, the NREPAP created measurable targets for RE deployment. Achieving these targets has required consistent policy support, and NREPAP's influence is evident in subsequent specific measures like the Renewable Energy Act (REA, 2011).

5. Renewable Energy Act (REA, 2011): Enacted in 2011, the REA introduced a feed-in tariff (FIT) system to incentivise electricity generation from renewable sources, including biomass. Under the FIT, qualified producers receive 16-year power purchase agreement (PPAs) with rates up to RM0.3800/kWh (as of 2024), guaranteeing long-term revenue. This greatly improved financial viability and spurred investment, especially in the solar and biomass energy (bioenergy) sectors, and is regarded as one of the country's most successful RE policies, as it successfully drove the ratio of RE contribution in annual power generation from 0.4% in 2012 to 1.3% in 2016 (Muaz et al., 2022). By 2017, FIT quotas for biomass power plants were largely subscribed, reflecting investor interest, though capped quotas and dependence on the Renewable Energy Fund, which is financed by a surcharge on electricity bills, constrained further growth and required adjustments (Energy Commission, 2011, 2023).

6. Sustainable Energy Development Authority Act (SEDAA, 2011): This Act created the Sustainable Energy Development Authority (SEDA) as a dedicated agency to implement RE policies and manage incentive programmes, including FITs. SEDA centralised and streamlined RE governance, facilitating efficient inter-agency coordination and long-term continuity in RE initiatives. Its establishment underscored Malaysia's institutional commitment to RE adoption and allowed more effective administration of FIT quotas, technical guidelines, and stakeholder engagement.

7. Malaysia Renewable Energy Roadmap (MyRER, 2021): Launched in 2021, MyRER outlined a strategic framework for Malaysia's energy transition up to 2035. It set ambitious targets of 31% RE share by 2025 and 40% by 2035 in terms of power

capacity. MyRER outlined key strategies for various RE technologies, notably bioenergy, solar, hydro, and new solutions, to achieve these goals. Pertinent to biomass, MyRER emphasised enhancing the regulatory framework through innovative procurement, e.g. auctions and competitive bidding, to replace fixed FIT rates with market-discovered tariffs, driving down costs, rewarding efficient developers and attracting private investment. It also highlighted modernising biomass utilisation, such as co-firing in coal power plants and developing Bio-compressed Natural Gas (Bio-CNG) (SEDA, 2021).

8. National Energy Policy 2022–2040 (NEP, 2022): The NEP, released in 2022, provided a blueprint for Malaysia's energy sector, with goals of sustainability, affordability, and energy security. It envisioned Malaysia as a regional leader in the green economy by 2040, aligning with a low-carbon future. The NEP set an even more ambitious renewable capacity target of 18.4 GW by 2040. Whilst it covers all energy forms, it reinforced commitments to bioenergy by encouraging value-added utilisation of biomass for domestic energy and industrial applications. It also underlined the importance of land-use planning and sustainable practices to support bioenergy growth in synergy with food and environmental priorities (Economic Planning Unit, 2022)

9. National Biomass Action Plan (2023–2030) (NBAP, 2023): The NBAP, released in 2023, set up detailed measures to leverage the country's abundant biomass resources. It included initiatives like converting palm biomass into biofertilisers, animal feed, biomass co-firing, and fuel pellets for energy generation and export. Additionally, the government aimed to establish 20 biomass hubs nationwide to streamline the collection and supply chain (Ministry of Plantation and Commodities, 2023). The initiatives were designed to enhance economic growth, sustainability, and industry exports, thereby positioning Malaysia as a global leader in biomass innovation.

10. National Energy Transition Roadmap (NETR, 2023): The NETR, released in 2023, operationalised the NEP's vision with actionable pathways for reaching net-zero emissions by 2050. For the power sector, it targeted a 70% renewable share in electricity generation by 2050. Biomass was identified as a key contributor, particularly via co-firing in existing coal plants and new high-efficiency bioenergy plants. The NETR explicitly promoted co-firing of coal with biomass pellets as a near-term measure to cut coal's carbon footprint. Through the NETR, the government also signalled support for emerging technologies like bioenergy with carbon capture and storage, a technology that combines biomass energy production with carbon capture and storage to achieve negative emissions (Ministry of Economy, 2023).

Overall, Malaysia's biomass policy framework reflects a progressive strengthening of support mechanisms – from early strategic inclusion of the FFDP (2000) to the specific incentives of FIT and institutional setups (SEDA), and now to long-term roadmaps of MyRER (2021), NEP (2022), NBAP (2023) and NETR (2023). There are also other supportive policies or incentives like the National Green Technology Policy (NGTP, 2009) which was launched in 2009 to promote sustainable development and reduce carbon emissions; the Green Technology Financing Scheme (2010), which was launched in 2010 to promote the development and adoption of green technologies in the country; and the Green Technology Master Plan (GTMP, 2017–2030) which was introduced as part of the Eleventh Malaysia Plan and aligned with the NGTP (2009) to support the energy transition up to 2050. This comprehensive policy framework has enabled steady growth in bioenergy in Malaysia.

Malaysia's progressive bioenergy policy framework has resulted in tangible achievements on the ground. Palm oil biomass and agricultural residues are now extensively harnessed for power and heat, with many companies integrating these resources into mill operations and exporting surplus electricity to the grid. The FIT mechanism, administered by SEDA, has been instrumental in accelerating the commercialisation of bioenergy. New applications – such as biomass co-firing pilots and Bio-CNG production – are emerging, demonstrating the sector's ongoing innovation. Strong institutional coordination, particularly through SEDA and the Malaysian Palm Oil Board, coupled with strategic plans, such as MyRER, NEP, NBAP, and NETR, has established a robust foundation for a diversified and sustainable bioenergy sector. Malaysia's active collaboration with international partners, including the United Nations Development Programme and Global Environment Facility, further underscores its commitment to a low-carbon energy transition and green innovation.

1.2. Resource availability

Oil palm biomass is by far the dominant resource, reflecting Malaysia's status as a top palm oil producer. The NBAP estimates a total technical biomass production of approximately 163.58 million tonnes (Mt) per annum, of which about 95.1% comes from the oil palm sector, as described in Table 4.2. In terms of energy, total bioenergy production is 35.22 million tonnes of oil equivalent (Mtoe), and oil palm bioenergy accounts for 91.4%, as illustrated in Figure 4.1.

Table 4.2. Biomass Production in Malaysia, 2022

Category	Biomass Type	Annual Production (Mt)	Annual Production (Mtoe)	Coefficient (toe/tonne)
Plantation biomass	Oil palm fronds	59.59	23.43	0.393
	Oil palm trunks	10.55	1.90	0.180
	Empty fruit bunches	7.30	1.26	0.173
	Mesocarp fibres	7.68	2.16	0.282
	Palm kernel shells	4.43	1.79	0.404
	Palm kernel cake	2.47	0.71	0.286
	Palm oil mill effluent	63.53	0.93	0.015
	Other plantation biomass	0.20	0.08	0.402
Woody biomass	Forest residues	1.49	0.60	0.400
	Other woody biomass	2.15	0.90	0.417
Agricultural biomass	Rice straw and husk	1.84	0.52	0.284
	Other agricultural biomass	2.34	0.94	0.402
Total		163.58	35.22	0.215

Note: Values of Mt are the original values. Values of Mtoe are converted from Mt based on the coefficients calculated from the study on Thailand (Ninomiya et al., 2025). Some biomass types in the original source are excluded due to potential double counting or the focus of this study.
Source: Ministry of Plantation and Commodities (KPK) (2023).

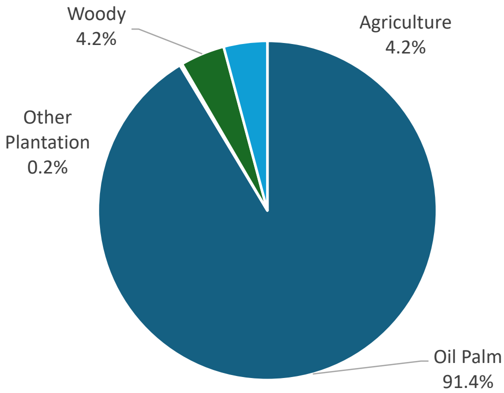
According to the NBAP, major biomass categories include:

Plantation biomass (156 Mt, or 32 Mtoe): Primarily derived from oil palm plantations in the form of pruned fronds, trunks from replanting, EFB, palm kernel shells (PKS), mesocarp fibres, palm kernel cake, and POME. Oil palm biomass constitutes the largest share of plantation biomass.

Woody biomass (3.6 Mt, or 1.5 Mtoe): Forestry residues and wood-processing wastes form another source. Logging activities and forest management produce about 1.5 Mt of residual wood, whilst wood-based industries such as sawmills, plywood, wood off-cuts, and sawdust, etc. add up to 2.15 Mt.

Agricultural biomass (4.2 Mt, or 1.5 Mtoe): Beyond palm and rubber, other crops generate significant residues, the largest being paddy harvesting residues of straw and husk, amounting to approximately 1.84 Mt.

Figure 4.1. Composition of Biomass Potential in Malaysia



Source: Ministry of Plantation and Commodities (KPK) (2023).

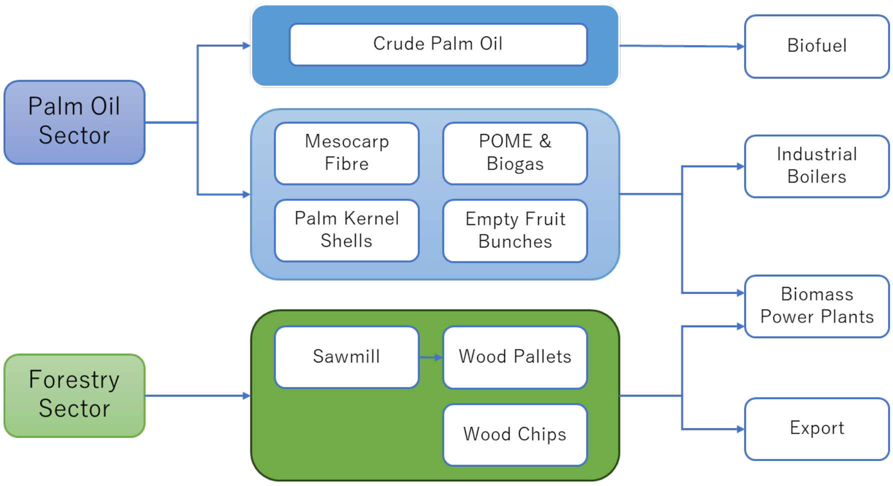
1.3. Existing supply chains

Malaysia's biomass supply chains are largely shaped by the palm oil industry and forestry sector, with emerging linkages to power producers and biofuel markets, as illustrated at Figure 4.2. The supply chain for palm-based biodiesel (PBBD) in Malaysia begins with the cultivation of oil palm trees, predominantly in large plantations across the country. EFB are harvested and transported to nearby palm oil mills (POMs). Within these mills, the crucial step of extracting CPO takes place. This CPO then becomes the primary feedstock for biodiesel production. Biodiesel plants, which may be integrated with or located near the POMs or refineries, process the CPO through transesterification to produce palm methyl ester (PME), also known as palm biodiesel. This biodiesel is then stored and distributed via tankers and pipelines to blending facilities or directly to end users in the transportation and industrial sectors. The efficiency and sustainability of this supply chain are influenced by factors such as transportation infrastructure, logistics management, and adherence to environmental regulations.

As of 2023, there were 451 POMs across the country (Ministry of Plantation and Commodities (KPK), 2023), most of which are strategically located within or near plantation estates to maintain EFB quality and reduce transport costs. These mills are often situated in off-grid areas and rely on cogeneration systems powered by solid biomass combustion to produce both heat and electricity for internal operations.

Oil palm biomass in Malaysia is primarily derived from the by-products of the palm oil milling process, including EFB, mesocarp fibres, PKS, and POME. These residues are generated in large volumes during the extraction of CPO and palm kernel oil from EFB at POMs.

Figure 4.2. Biomass Supply Chain In Malaysia



Source: Compiled by authors based on various sources.

Specifically, EFB are generally returned to plantations for mulching because of their limited economic value and nutrient-recycling benefits. Some mills have invested in EFB processing facilities (shredders and dryers) to either use EFB as boiler fuel or to sell EFB fibres and compost. A few dedicated biomass power plants also source EFB from surrounding mills, but collection is labour-intensive and the high moisture content of EFB complicates combustion without drying. Studies show that, for palm mills, selling EFB to third parties is only marginally profitable, whereas simply returning it to fields incurs minimal cost. This explains why the market for EFB remains underdeveloped – it is logistically easier and economically safer for plantation operators to dispose of EFB on-site rather than transport it off-site for energy use. To make EFB-based energy viable at scale, the supply chain will need improved aggregation, such as central collection centres, and value addition through pelletisation or briquetting.

For POME and biogas, the supply chain is typically on-site and in-situ. Hundreds of POMs have installed biogas capture facilities on POME ponds, allowing methane to be recovered. The biogas is either used in gas engines to generate electricity, with some mills exporting power to the grid under the FIT for biogas, or flared to reduce emissions. This supply chain does not involve biomass transport but rather the deployment of digesters and gas utilisation equipment at the waste source. Pilot projects are also upgrading biogas to Bio-CNG for use as vehicle fuel or as diesel replacement in industrial factories. This could form a new supply chain where biogas is purified on-site and then trucked as CNG cylinders or fed into local gas grids.

In the forestry sector, biomass supply chains are more export oriented. Sawmill residues and offcuts are collected and processed into wood pellets or wood chips by pellet manufacturers concentrated in Peninsular Malaysia and Sarawak. A notable portion of Malaysia's pellet output goes to Japan and the Republic of Korea (henceforth, Korea), where demand for industrial wood pellets for power generation is growing. Similarly, some forestry companies supply wood chips for biomass power plants or export. The supply chain for wood pellets typically involves aggregating biomass from multiple sawmills to ensure consistent feedstock for pelletisation, followed by bulk shipment of the finished pellets. Infrastructure such as drying kilns, pellet mills, and storage silos are key elements. By 2022, Malaysia's pellet exports had reached nearly RM958 million in value, according to the *National Biomass Action Plan 2023-2030* (Ministry of Plantation and Commodities (KPK), 2023), indicating a maturing supply chain connecting domestic wood waste to overseas energy markets.

1.4. Bioenergy utilisation and current energy contribution

Despite the substantial biomass resource base, bioenergy currently plays a modest role in Malaysia's overall energy supply. Based on the National Energy Balance 2021, the primary energy production of biomass as modern bioenergy was relatively small, being about 150 ktoe of solid biomass, 99 ktoe of biogas, and 1,001 ktoe of biofuels (biodiesel) in 2021, as shown in Table 4.3. This totals around 1.25 Mtoe, accounting for 1.17% of the total primary energy supply, which stood at 107.3 Mtoe in 2021. However, when compared with the estimated bioenergy production of 35.22 Mtoe, only 3.5% is captured in official statistics as modern energy utilisation. Although conducting a strict international comparison is challenging, and interpreting the results requires caution, given the comparable ratio of 34.5% in Thailand in 2022 (Ninomiya et al., 2025), this implies a significant underutilisation of biomass resources in the form of modern energy.

Table 4.3. Bioenergy Balance Table, 2021 (ktoe)

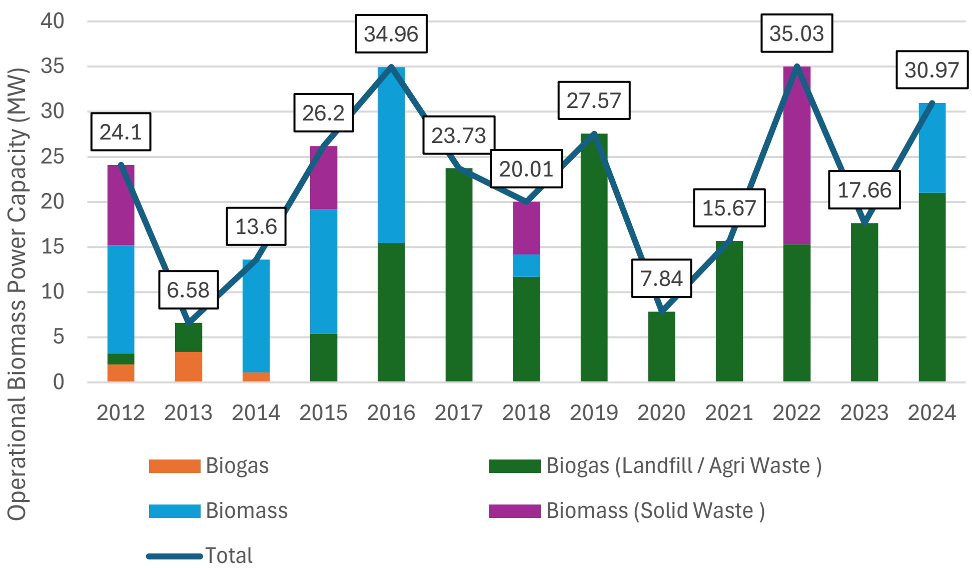
Energy Source	Biomass	Biogas	Biodiesel	Total
Primary production	150	99	1,001	1,250
Exports (-)	0	0	246	246
Primary supply	150	99	827	1,076
Power generation (-)	150	99	0	249
Transport	0	0	827	827
Gross electricity generation (GWh)	160	440	0	600

Source: Energy Commission (2024a, p.75).

In fact, total electricity generated from biomass and biogas was 600 GWh in 2021, which was only around 0.4% of Malaysia's total electricity generation. In terms of capacity, as of 2021, Malaysia had 411.5 MW of installed biomass power capacity and 129.4 MW of biogas power capacity. Together, biomass, biogas, and other types of renewable power capacity accounted for about 2.0% of the nation's total generation capacity of 37.42 GW in 2021 (Energy Commission, 2024a; 2024b). These numbers have remained relatively flat in recent years (IRENA, 2024a), indicating that no large new biomass plants have come online after the initial FIT-driven projects.

Biomass power generation in Malaysia is anchored by projects developed under supportive policy mechanisms like the FIT. Figure 4.3 highlights the historical trends in biomass and biogas capacity additions under the FIT scheme. Over the years, there has been significant growth in biogas capacity, particularly from landfill and agricultural waste, which cumulatively reached 165.76 MW by 2024. Biomass power has also expanded, with cumulative capacity additions of 70.2 MW, alongside 41.48 MW from solid waste sources. The total operational capacity of biomass (including solid waste) and biogas (including landfill and agricultural waste) under the FIT scheme stands at 283.92 MW, reflecting Malaysia's continued efforts to harness RE sources from organic waste materials. However, the annual additions have been inconsistent, with notable peaks in 2016 and 2022, suggesting varying project implementation rates and policy-driven influences.

Figure 4.3. Operational Biomass Power Plant Development Under the Feed-in Tariff Scheme



Source: SEDA (2025).

Under the FIT scheme, dozens of small- to medium-scale biomass power projects were developed during 2011–2017. Typical plant sizes range from about 5 MW to 20 MW for most biomass independent power producers (IPPs) (Salleh et al., 2021). Common feedstocks for biomass IPPs include EFB and PKS, often supplemented by mixed agricultural waste depending on local availability. Several sugar mills and timber mills also operate cogeneration plants using bagasse and wood residues to supply both their own process heat and surplus power to the grid.

Malaysia's biogas power plants are primarily located at POMs (capturing POME methane) or at landfills (capturing landfill gas). These facilities are usually smaller (0.5–2 MW each), but they contribute to rural electrification and emissions reduction by capturing methane. By 2020, biogas accounted for roughly 0.3% of generation capacity, reflecting a still-developing sector.

The introduction of the FIT programme in 2011 was a game-changer for biomass power. The FIT guaranteed renewable power producers a premium tariff for electricity fed into the grid, with 16-year power purchase agreements, thereby reducing market risk. The FIT rates for biomass have evolved to balance investment incentives and cost adjustments. Initially set in 2012 at RM0.3100/kWh for plants up to 10 MW and RM0.2700/kWh for those above 20 MW, the rates saw a decline in 2022, with a range of RM0.235–RM0.290/kWh for capacities up to 30 MW. By 2023, the structure reverted to fixed values similar to 2012, with RM0.3085/kWh for up to 10 MW and RM0.2687/kWh for above 20 MW. A major shift occurred in September 2024, when the rate was significantly increased to RM0.3800/kWh for capacities up to 30 MW, indicating stronger policy support. In addition to these base rates, Malaysia's FIT programme includes a bonus incentive rate of RM0.0199/kWh for gasification technology, RM0.0100/kWh for high-efficiency steam systems, and RM0.0500/kWh for locally manufactured equipment.

In general, the FIT's generous pricing and must-take grid access attracted many investors, resulting in a surge in biomass IPP proposals. Consequently, between 2012 and 2017, Malaysia's biomass power capacity grew steadily.

The FIT's impact on biomass was significant in building early capacity and financing projects that would otherwise have been marginal. However, there were inherent challenges and limitations. One issue was the FIT quota system – only a certain aggregate capacity could be awarded FIT contracts. Biomass quotas were often fully subscribed quickly, leaving other willing developers without incentive support. Another challenge was the 30 MW cap on project size to qualify for the FIT (projects above 30 MW required special approval). This cap prevented the construction of larger, potentially more cost-effective biomass plants under the programme, keeping average plant sizes smaller and perhaps less economical. Additionally, as solar PV costs plummeted in the 2010s, a growing share of the RE fund and quotas went to solar projects. Biomass, being less rapidly scalable and having higher upfront costs, saw slower growth. By the late 2010s, Malaysia transitioned new large-scale solar projects to a competitive bidding model and simultaneously phased out the traditional fixed-rate FIT scheme for new biomass and biogas projects, replacing it with an auction-based system.

Economically, biomass power faces a higher levelised cost of electricity (LCOE) than some alternatives. The need to gather and transport fuel, operate fuel-handling systems, and manage more complex operations and maintenance (O&M) has led to higher costs than solar PV in recent years. This cost gap means that without incentives or carbon pricing, biomass struggles to compete with other generation sources, especially cheap natural gas. Indeed, natural gas and coal have long benefited from subsidised pricing in Malaysia's regulated tariff system, posing a competitiveness challenge for biomass. In response, Malaysia has begun exploring new mechanisms beyond the FIT, such as RE auctions that include biomass, as well as renewable portfolio standards and green certificates that could give biomass a market-based boost.

Biofuels in Malaysia are almost synonymous with PBBD, given the country's large palm oil industry and the focus of the NBP (2006). On the other hand, ethanol as a biofuel is negligible in Malaysia – limited sugarcane cultivation and high production costs make fuel ethanol uncompetitive, and no ethanol blending mandate exists.

Table 4.4. History of Biodiesel Development in Malaysia

Biodiesel Blend	Implementation Timeline
B5	Launched under the National Biofuel Policy (2006) Began in 2011 for the transport sector; implemented nationwide by 2014
B7	Introduced in 2015 for transport sector, implemented nationwide by 2017
B10	Mandated for the transport sector in 2019 (B7 remained for industrial use)
B20	Partially implemented regionally starting in 2020 (nationwide rollout delayed due to various factors, including infrastructure and economic considerations, and COVID-19)
B30	Planned for 2030

Source: Compiled from various sources by authors.

As illustrated in Table 4.4, Malaysia's biodiesel programme initially introduced B5 (a 5% biodiesel blend) for the transport sector in phases starting in 2011, followed by B7 nationwide by 2015. The mandate was later raised to B10 for the transportation sector in 2019, with B7 remaining for certain segments such as industrial or Euro 5 diesel. Plans were made to roll out B20 for transport, and whilst partial implementation began in 2020 in some regions, full nationwide implementation has been delayed due to facility upgrades, infrastructure investments, and COVID-19-related issues. As of 2023, B10 remains the standard for retail diesel, whilst B7 is used in sensitive applications. The consumption of biodiesel for transport has reached roughly 0.8–0.9 Mt annually in recent years.

Malaysia currently has a sizable biodiesel production capacity of approximately 2.25 Mt per year across 19 plants, as reported by the Malaysian Palm Oil Board in 2022. However, actual output varies with mandates and export demand. For instance, in 2022, Malaysia produced about 1.4 Mt of biodiesel, of which roughly 0.3 Mt was exported (mainly to the European Union (EU) and a small amount to China), with the remained consumed domestically. The EU has been the largest importer of Malaysian biodiesel, but under the Renewable Energy Directive (RED II), palm oil biofuels are now classified as high indirect land-use change risk and are being phased out. Consequently, Malaysian biodiesel exports to the EU have declined (USDA, 2023c), creating potential surplus capacity if domestic use is not ramped up or alternative markets found.

Domestically, the biodiesel programme's viability has been maintained through government support, particularly a subsidy mechanism funded by the Palm Oil Cess. A small levy of RM16 per tonne of CPO (as of 2021) contributes to a fund, with around 15% allocated to subsidise biodiesel blending costs and support the programme (USDA 2023c). This is crucial because biodiesel production costs are often higher than petroleum diesel, especially when crude oil prices are low or palm oil prices spike. As palm oil prices can be volatile, the subsidy ensures biodiesel remains financially feasible for fuel distributors.

To address environmental concerns, Malaysia has developed and continuously upgraded its own certification scheme, Malaysian Sustainable Palm Oil (MSPO), to promote sustainable palm oil production. Furthermore, ongoing research aims to develop advanced biofuels to diversify beyond conventional biodiesel. In 2023, Malaysia announced initiatives to explore the production of SAF from palm-based waste and to upgrade biogas to biomethane for use in transportation. These efforts reflect a growing push to broaden the role of biomass in the transport fuel sector.

In summary, the biofuel sector in Malaysia is currently a one-product story focused on PBBD, which has been successfully integrated into the national fuel supply. The economic feasibility of this programme is bolstered by government subsidies and the co-benefit of supporting the palm oil industry. The main challenges ahead are improving the sustainability of PBBD to maintain export markets and public confidence and ensuring sufficient feedstock availability for higher blends such as B20 and B30.

Biomass also contributes to heating fuel markets in Malaysia and abroad, as shown in Table 4.5. One direct use is by industry for process heat. For example, manufacturers use PKS and wood waste as boiler fuel to replace coal or natural gas. PKS, with its high energy content and granular form, is particularly popular. However, significant quantities of PKS are exported – since around 2010, Malaysia has been exporting PKS to Japan, where power producers co-fire it in coal power stations. Whilst not processed like pellets, PKS export involves a supply chain of drying, sizing, and bulk shipping.

Table 4.5. Biomass Pellets and Uses

Biomass Fuel	Main Use	Domestic Demand	Export Markets
Palm kernel shells	Boiler fuel in manufacturers and power plants	Moderate	Japan
Wood pellets	Biomass power plants	Low	Japan, Republic of Korea
Empty fruit bunch pellets	Industrial biomass fuel	Limited	Some exports
Rice husk/coconut shells	Biomass boilers	Limited	Limited

Source: compiled by authors.

A major growth area has been the wood pellet industry. Malaysia has rapidly become a notable exporter of wood-based pellets, ranking as the eighth largest wood pellet exporter in the world in 2023 (Gilbert et al., 2024). The wood pellet sector utilises sawmill residues, forest residues, and unused timber to produce standardised fuel pellets. These pellets are primarily shipped to East Asian markets (Japan and Korea), which have high demand due to RE policies that incentivise biomass power generation.

Most Malaysian pellet plants are located in Sabah, Sarawak, and Peninsular Malaysia's timber-rich states (Pahang, Johor, etc.), often near ports. They produce both wood pellets and EFB pellets. Malaysia's pellet exports have grown rapidly due to investments from both domestic firms and foreign joint ventures aiming to supply long-term offtake agreements in Japan and Korea. The supply chain for pellets involves securing consistent feedstock, operating pellet mills, and logistics to port.

For domestic industrial heat applications, beyond captive use in agro-industries, uptake of biomass remains limited. Many industries still rely on natural gas or coal, especially in Peninsular Malaysia, where gas is subsidised for industrial users. However, there is potential and interest to use more biomass as a decarbonisation strategy. For instance, some food processing factories use biomass boilers fuelled by rice husks or coconut shells, and there is growing awareness that switching to biomass for heat can reduce a factory's carbon footprint. Government incentives like the Green Technology Financing Scheme (2010) have been extended to biomass and biogas projects, which could include industrial energy systems.

One emerging opportunity lies in producing biomass pellets specifically for co-firing in power plants within Malaysia. The NBAP highlights co-firing as a way to achieve RE targets, envisioning the use of locally produced and imported wood pellets to blend with coal. Currently, Malaysia's coal power plants do not significantly co-fire biomass, but trials have been conducted using palm biomass.

For instance, Tenaga Nasional Berhad conducted a major trial in September 2023 at Unit 2 (1,000 MW) of the Stesen Janakuasa Sultan Azlan Shah in Lumut, Perak. This was Malaysia's first biomass co-firing test for a supercritical boiler, using EFB pellets. The trial achieved observable reductions in emissions, demonstrating the feasibility of biomass co-firing. Further studies are planned to test higher biomass concentrations (3%–5%). From an economic standpoint, biomass pellets and briquettes are more expensive per unit of energy than coal, so without a carbon incentive or policy requirements, industries have been slow to switch. Thus, demand for pellets exists primarily where there are RE incentives or carbon pricing (as in export markets). To stimulate industrial use of pellets locally, measures like carbon credit trading, green procurement, or direct subsidy for biomass fuel might be needed to improve competitiveness.

In conclusion, the pellet industry presents a significant opportunity for Malaysia to transform biomass waste into high-value products and foster a circular economy. However, stringent sustainability requirements from key importers – such as Japan and the EU – mandate certifications such as the Forest Stewardship Council for wood-based biomass and MSPO or RSPO standards for palm-based biomass. This demand for proof of responsible sourcing compels Malaysian exporters to prioritise sustainable practices, safeguarding forests and food resources. Consequently, the industry is driving a shift towards greater sustainability throughout the industrial biomass supply chain.

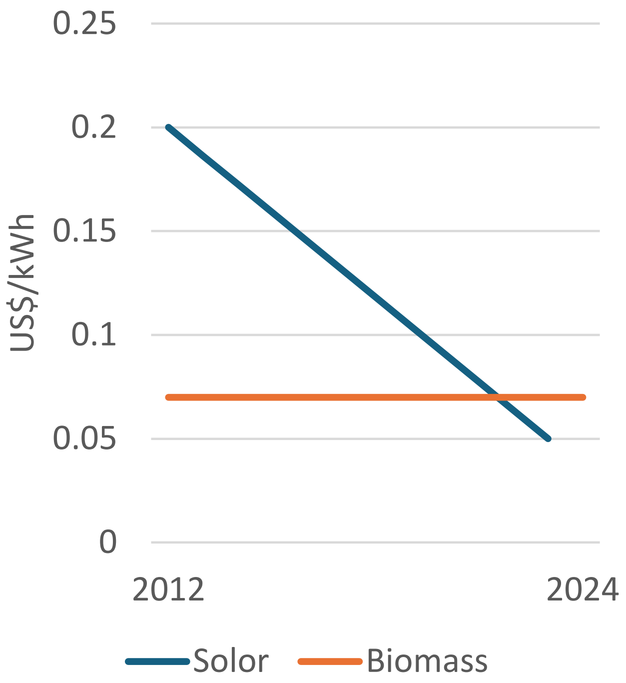
1.5. Production and supply costs

The economic feasibility of biomass utilisation in Malaysia hinges on production and supply chain costs, which vary by feedstock and end-use. A critical factor is that many biomass resources, whilst abundant, are low in energy density and geographically dispersed, leading to high collection and transport costs per unit of energy. For instance, transporting bulky EFB or straw over long distances can quickly erode project economics, as the delivered fuel cost to a plant might double or triple relative to its field-side cost.

In the biomass power sector, high capital and operating costs remain major challenges. According to Muaz et al. (2022), building a 10–50 MW biomass combined heat and power (CHP) plant typically requires a capital investment of US$3,550– US$6,820 per kW, depending on equipment origin and system design. These plants often rely on imported equipment, further raising costs. The fuel cost of high-quality biomass pellets is also significantly higher than coal, which directly affects its competitiveness in the power section. When deploying stoker boilers, the expected payback period is 6.7 years, whilst circulating fluidised bed systems stretch the payback to 9.7 years, making private sector investment unattractive without incentives. Whilst the FIT programme offers between RM0.2687–RM0.3800/kWh depending on capacity and technology bonuses, these rates are still higher than solar PV. A US dollar-based analysis shows that the FIT auction rate for biomass power generation has remained unchanged at US$0.07/kWh between 2012 and 2024, whilst the rate of solar PV fell from US$0.2/kWh in 2012 to US$0.05/kWh in

2023, as illustrated in Figure 4.4. (EMBER, 2024).

Figure 4.4. Feed-in Tariff Auction Rate in Malaysia



Source: EMBER (2024).

In the biofuel sector, biodiesel production is tightly linked to the price of refined palm oil, particularly refined, bleached, and deodorised (RBD) olein, which is the primary feedstock. The average price of RBD olein was recorded at RM4,257/tonne. Given that producing 1 tonne of biodiesel typically requires about 1.1 tonnes of palm oil, this implies a substantial feedstock cost per litre of biodiesel.

As shown in Table 4.6, B10 biodiesel is more expensive than fossil diesel at the production level. The difference of RM0.21/litre is absorbed via a government subsidy to ensure that consumers pay comparable prices at the pump. The 8.6% subsidy helps stabilise the market, especially when global palm oil or crude oil prices fluctuate. Historically, fossil fuel prices in Malaysia have been subsidised to support economic growth. However, the comprehensive subsidy for RON95 gasoline ended in 2024, and subsidies for diesel in Peninsular Malaysia were also removed (USDA, 2024b). The government is transitioning to targeted subsidies, which may affect the competitiveness of biodiesel.

Table 4.6. Biodiesel Costs in Malaysia

	Average Cost
RBD olein (RM/Mt)	4,257
Average crude oil price (RM/barrel)	296
Estimated diesel price (RM/litre)	2.27
Estimated B10 biodiesel price (RM/litre)	2.43
B10 price at local petrol station (RM/litre)	2.22
Subsidy (%)	8.6

RBD = refined, bleached, and deodorised.
Source: USDA (2023c).

The biomass pellet industry also faces cost competitiveness challenges. The cost to produce wood pellets in Malaysia includes feedstock expenses, which might vary widely depending on the type and other conditions, as described in Table 4.7. The pellet industry also faces competition for feedstock – for example, sawdust can be used in particleboard or left for local use – so pellet producers must secure long-term agreements. Any rise in domestic wood residue prices or restrictions on wood waste exports due to environmental rules can also increase costs. On the other hand, Malaysia has strong potential to expand exports of PKS and PKS pellets to other countries such as Japan. Japan's import price for PKS has increased from around RM360 per tonne in 2001 to around RM720 in 2023, before decreasing to around RM600 in 2024.

Table 4.7. Acquisition Cost of Biomass in Malaysia

Biomass Type/Product	Value (RM/tonne, wet)
Empty fruit bunches	40–85
Oil palm trunk	13.5
Palm kernel shells	400–600
Sawdust	120–150
Municipal solid waste	10.0

Source: Malaysian Industry-Government Group for High Technology (2020).

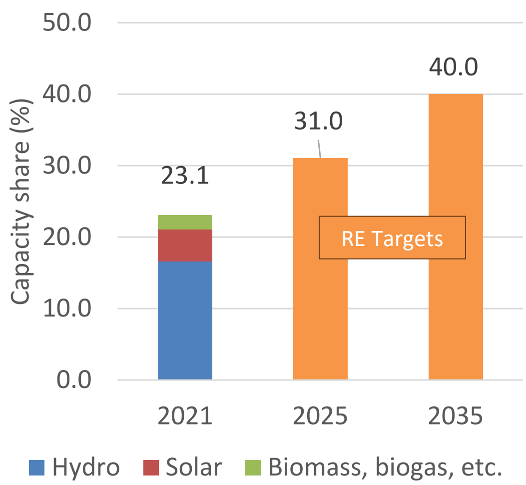
In summary, the cost profile of biomass utilisation in Malaysia still requires policy support or niche markets to be attractive. Production costs are coming down gradually with technological improvements and scale. For instance, newer boiler designs can handle EFB more efficiently, reducing downtime costs. Since the gap with conventional fuels remains in many cases, the government's role in mitigating these costs through FIT, subsidies, tax preference, grants, or enabling carbon finance remains crucial to expand biomass use further.

2. Expected Supply and Demand of Bioenergy in 2030–2040

2.1. Biomass development targets and forecasted demand

Looking ahead, Malaysia has established clear RE targets, indicating an increasing role for bioenergy by 2030 and beyond. Under MyRER, the country aims to achieve a 31% RE capacity mix by 2025 and 40% by 2035, representing a significant expansion from the 2021 level of 23.1%, as shown in Figure 4.5. Whilst a large share of this will come from solar PV due to its cost competitiveness and hydropower, the biomass power sector is expected to contribute several gigawatts. MyRER's bioenergy pillar calls for increasing biomass, biogas, and waste-to-energy capacity through new business models like auctions and co-firing initiatives.

Figure 4.5. Renewable Energy Gap Between Current Level and Targets (Capacity Base)



Source: Actual data from National Energy Balance (2021); target data from MyRER (2021).

The NBAP provides more specific direction for biomass, framing it as a key part of Malaysia's energy transition and industrial strategy. One of its notable targets is the implementation of biomass co-firing in coal power plants. By blending biomass pellets with coal, Malaysia aims to reduce coal usage and increase renewable generation without the need to build entirely new dedicated RE plants. This approach would supplement domestic biomass resources to ensure consistent fuel supply for co-firing. Using such quantities of pellets, in addition to domestic biomass, implies a significant increase in biomass consumption within the biomass power sector. Such an initiative could raise biomass's share in the electricity mix markedly by 2030.

The demand for biofuels in Malaysia by 2030 is also expected to grow significantly if the country adopts higher biodiesel blends. A nationwide transition from the current B10 blend to B20 by 2030 would effectively double biodiesel consumption. This growth is further underscored by the recent removal of comprehensive subsidies for RON95 gasoline in 2024 and for diesel in Peninsular Malaysia, which may enhance the competitiveness of biodiesel relative to unsubsidised fossil fuels.

There is also potential growth in demand for biomass as an industrial feedstock. The NETR (2023) identifies opportunities for biomass-based hydrogen and biofuels for aviation. These remain nascent, but by 2040, Malaysia envisions having some advanced biofuel production capacity, e.g. using biomass to produce SAF or biohydrogen for potential integration into green ammonia production. Such developments, if realised, would add to domestic biomass consumption.

Another important aspect is the regional and global market: As part of the Asia Zero Emission Community (AZEC) initiative, Malaysia could export biomass-derived energy or carbon credits to other countries, such as through the Joint Crediting Mechanism, under which Japan finances Malaysian biomass projects and in return counts reduced emissions as Japan's reduction. If such international collaboration deepens, Malaysia's biomass could contribute more extensively to regional energy systems, as is already the case with pellets exports to Japan.

In summary, the 2030–2040 horizon for Malaysia's biomass utilisation points to significant expansion in all major use cases of power, fuels, and heat usage if policy and market drivers align. Official roadmaps and plans foresee biomass playing a key role in meeting RE and emission targets through measures such as co-firing, higher biofuel blends, waste-to-energy plants, and possibly new bioproduct industries. These plans are ambitious but realistic given Malaysia's resource base.

2.2. Gaps between supply and demand

Despite Malaysia's optimistic targets, there are clear gaps between biomass supply and projected demand that must be addressed. Theoretically, the country's biomass potential exceeds even aggressive demand scenarios. However, practical supply is constrained by collection capability, seasonality, competing uses, and sustainability considerations. This creates a gap between theoretical abundance and accessible biomass. A large portion of biomass may remain unavailable for energy due to scattered locations or necessary soil return. Consequently, the effective supply of biomass for energy could be much lower than the total biomass produced each year, unless significant investments are made in the supply chain.

Another gap arises between policy-driven demand and market-driven demand. Malaysia's targets (e.g. RE capacity share, co-firing rates, and biofuel blends) create a demand pull for biomass that the market by itself might not fulfil. For example, if coal plants are required to co-fire 20% biomass by 2030, they will demand millions of tonnes of pellets or PKS, which the domestic biomass industry might not be able to supply reliably at competitive cost. Thus, Malaysia may need to import biomass even though it has huge domestic resources.

There is also a timeline gap. Establishing new biomass projects and supply chains can take years, whereas some policy goals (like 31% RE by 2025) are imminent. In the short term, quicker-to-deploy renewables like solar might fill the gap whilst biomass projects catch up later. This suggests biomass's role may ramp up more slowly than hoped, potentially leading to a shortfall in contribution towards near-term targets.

A further critical gap exists in sustainability and acceptance. Whilst Malaysia has a ready supply of oil palm biomass, there is global demand for sustainable biomass. Bridging this gap means implementing robust sustainability certification and traceability for biomass supply – a challenge that involves training smallholders and monitoring land use, etc.

In summary, Malaysia faces a dual challenge: scaling up demand for bioenergy to meet RE targets whilst simultaneously strengthening the supply chain to meet that demand. Any mismatch could either result in unmet renewable goals (if the supply chain constrains projects) or under-utilised biomass (if projects are not there to use it). The current trajectory shows gaps, but with appropriate measures, as discussed next, these gaps can be narrowed.

3. Requirements for Development of the Biomass Supply Chain

Malaysia's biomass supply chain, primarily supported by the expansive palm oil industry, holds substantial potential for energy production and industrial applications. Yet, as highlighted above and in recent studies (Muaz et al., 2022; Rashidi et al., 2022; Salleh et al., 2021; Zahraee and Assadi, 2017), a number of persistent and interlinked challenges continue to hinder its full development. These obstacles can be categorised into three broad areas, as summarised in Table 4.8: (i) technical barriers, (ii) policy barriers, and (iii) market barriers. Addressing them requires systemic improvements in technology deployment, policy coherence, market structure, and financial mechanisms.

Table 4.8. Challenges for Biomass Development in Malaysia

Category	Challenges
Technical barriers	1. Geographic dispersion and supply chain complexity
	2. Technological limitations and feedstock dependence
Policy barriers	3. Inconsistencies in policy framework
	4. Compliance challenges with international standards
Market barriers	5. Immature market structure and financial barriers
	6. Market confidence and public awareness

Source: Compiled by authors.

3.1. Technical barriers

1. Geographic dispersion and supply chain complexity

Malaysia's biomass resources, although abundant, are geographically dispersed across Peninsular Malaysia, Sabah, and Sarawak, making collection and transportation costly and logistically complex (Muaz et al., 2022; Rashidi et al., 2022). Rashidi et al. (2022) note that many palm mills are located in remote areas – often more than 10 km from the nearest grid connection – thereby increasing power losses and deterring investment. Transportation challenges are further compounded by the use of low-capacity tanker lorries, which require multiple trips for large-scale operations, significantly raising operational costs and carbon emissions. In contrast, biodiesel blending facilities and infrastructure are mostly concentrated in specific regions, restricting the nationwide rollout of higher biodiesel blends such as B20 or B30.

Furthermore, Malaysia's biomass supply chain is inherently complex, involving multiple interconnected stages, such as feedstock collection, preprocessing, conversion, and final energy distribution. Coordinating these processes across diverse stakeholders poses logistical and organisational challenges. Zahraee and Assadi (2017) highlight the difficulty of managing the full supply chain from agricultural source to energy plant, particularly given the lack of integration and coordination amongst actors. In addition, feedstock availability is subject to significant uncertainty due to seasonal fluctuations, over-reliance on a narrow range of sources (such as EFB), and increasing competition from alternative uses, including soil mulching and pellet exports (Salleh et al., 2021; Rashidi et al., 2022). These factors not only complicate supply planning but also raise concerns about the long-term reliability of biomass as an energy resource.

2. Technological limitations and feedstock dependence

Malaysia remains reliant heavily on foreign technology for biomass conversion, which increases capital and maintenance costs (Rashidi et al., 2022). Local expertise in technology design, plant operations, and maintenance remains limited, partly due to a lack of targeted technical training and education. As highlighted by Zahraee and Assadi (2017), most existing facilities are not equipped with advanced conversion systems or optimised logistics solutions, leading to inefficiencies and reduced energy recovery. Salleh et al. (2021) also highlight the underutilisation of biomass due to inadequate resource planning and a lack of trust in technology from investors. Similarly, the absence of pelletisation or briquetting facilities near many biomass sources means raw residues cannot be economically transported. The biodiesel sector remains heavily dependent on CPO and lacks alternative feedstocks, making it vulnerable to price fluctuations and international scrutiny.

3.2. Policy barriers

3. Inconsistencies in policy framework

Although Malaysia has many policies promoting bioenergy, implementation gaps and misalignments persist. Zahraee and Assadi (2017) discuss how the NBP (2006) and other frameworks sometimes face challenges aligning with other regulations and international norms. For instance, permitting processes for new biomass plants can be cumbersome, involving several government agencies (energy, environment, and local authorities) with sometimes conflicting requirements. Despite the biodiesel sector's early progress, its roadmap has faltered. Nationwide rollout of B20 and future targets such as B30 have been delayed due to shifting political priorities, infrastructure bottlenecks, and a lack of investment. This inconsistency creates uncertainty for investors and undermines industry confidence. For biomass power development, the FIT scheme is helpful but is still insufficient under current finite quota and FIT rates. Policy instruments such as carbon pricing and a renewed feed-in premium have been proposed but are yet to be implemented (Zahraee and Assadi, 2017). Salleh et al. (2021) also note that a lack of support from electricity supply stakeholders is a further reason that the programme has fallen short of achieving its goal.

4. Compliance challenges with international standards

As Malaysia eyes export markets and global partnerships, meeting international sustainability regulations becomes crucial. The EU's RED II and the new Regulation on Deforestation-free Products (EUDR) impose stringent criteria on biomass imports, requiring proof that products are not linked to deforestation. For smallholders and smaller companies in Malaysia, compliance is challenging due to limited resources and technical expertise to meet RSPO standards. Furthermore, RED II, which aims to phase out PBBF by 2030 due to concerns over deforestation and environmental sustainability, presents a significant long-term challenge to Malaysia's biodiesel export potential.

3.5. Market barriers

5. Immature market structure and financial barriers

Malaysia's biomass industry remains in a developmental phase, lacking full commercialisation, which undermines both operational efficiency and investor confidence. As Muaz et al. (2022) highlight, the market's early stage is characterised by a limited number of established players, poor price discovery mechanisms, and inefficient supply chains. For instance, there is no robust biomass commodity market or exchange in the country, and transactions are typically bilateral and short-term. Zahraee and Assadi (2017) further emphasise the need for a mature industrial chain encompassing feedstock sourcing, energy generation, sales, and waste processing to unlock economies of scale and minimise inefficiencies.

Compounding these structural issues are significant financial hurdles. Biomass projects, such as power plants and pellet mills, demand high capital expenditure, which is often difficult to secure. Financial institutions frequently perceive these ventures as riskier than conventional energy projects due to uncertainties surrounding fuel supply and technological reliability. As Salleh et al. (2021) observe, the limited familiarity amongst lenders with biomass technologies contributes to higher perceived risks, thereby restricting access to financing.

6. Market confidence and public awareness

Market confidence in Malaysia's bioenergy sector remains fragile, with investors and project developers often exhibiting caution towards biomass and biodiesel ventures. This hesitance stems from various factors, including inconsistencies in policy implementation, increasing global environmental stringency, limited local experience, and strong competition from conventional energy sources. For instance, frequent delays in the implementation of biodiesel blending mandates have weakened investors' confidence, as they signal a lack of policy continuity and long-term commitment from the government. Moreover, growing international scrutiny over sustainability standards, particularly from major export markets like the EU, has introduced additional compliance risks that complicate project viability.

Biomass is also perceived as complex and capital-intensive compared to more familiar renewable options like solar, which has gained broader acceptance amongst private investors for its simplicity and lower perceived risk. Additionally, the continued presence of subsidised fossil fuels and limited RE incentives make biomass and biodiesel less competitive on a pure cost basis, despite their systemic advantages. One such overlooked benefit is grid stability: unlike intermittent sources such as solar and wind, biomass power plants provide stable, dispatchable energy, which is critical for maintaining a balanced grid, especially as Malaysia moves towards a more renewable-intensive energy mix.

Public awareness and acceptance present an additional challenge. General understanding of bioenergy remains low amongst both the public and businesses. Misconceptions persist, particularly around its environmental impact – such as concerns over air pollution from biomass combustion – despite improvements in emissions control technologies and sustainability certification. The lack of visibility of successful bioenergy projects, in contrast to high-profile solar installations, further limits public engagement.

3.6. Policy recommendations and strategies

Building on the identified challenges, Malaysia can implement a comprehensive set of policy measures and strategic initiatives to enhance biomass utilisation, as summarised in Table 4.9. International best practices offer valuable lessons, from policy frameworks that successfully scaled bioenergy in other countries to market mechanisms that ensured sustainability and investment. The following key recommendations combine global insights with Malaysia's domestic context to provide actionable strategies for policymakers and industry stakeholders.

Table 4.9. Policy Recommendations for Biomass Development in Malaysia

Category	Policy Recommendations
Technology and sustainability	1. Improve the efficiency of biomass utilisation systems
	2. Utilise international climate finance and partnerships
Regulatory and policy frameworks	3. Strengthen policy coordination and governance
	4. Enhance sustainability standards and certification for biomass
Infrastructure and market development	5. Establish a long-term expanded and stable market
	6. Support end-use development and raise public awareness

Source: Compiled by authors.

1. Improve the efficiency of biomass utilisation systems

Malaysia can improve the efficiency of biomass utilisation systems by strengthening investment in research and development to enhance biomass yield and improve the efficiency of both collection and conversion systems. This includes innovations such as mechanised harvesters for oil palm fronds and advanced POME digestion systems that increase biogas output. Public funding and targeted incentives should support not only advanced conversion technologies but also the development and demonstration of efficient biomass collection systems, which are essential for reducing supply chain costs and increasing feedstock availability. Pilot projects should cover a range of innovations –

from automated or modular collection technologies suited to different feedstocks, to second-generation biofuels, biomass-to-hydrogen, and SAF. Success in these areas can significantly reduce overall costs, unlock the viability of currently uneconomic feedstocks, and create new high-value markets, strengthening both the resilience and sustainability of Malaysia's biomass supply chain.

As a first step towards achieving this goal, the government can take the lead in establishing strategically located biomass hubs in key production regions, as already envisioned in current planning. These hubs would serve as centralised facilities where biomass is collected, pre-processed, and distributed to domestic end-users or export markets. Public investment should focus on developing shared infrastructure within these hubs, such as storage warehouses, weighbridges, pellet mills accessible to smallholders, and road networks linking plantations to processing sites. By reducing supply chain fragmentation, these hubs can help ensure consistent feedstock quality and volume, ultimately lowering logistical costs and improving supply reliability. Operations can follow a public–private partnership model, where local cooperatives, producer associations, or private consortia manage day-to-day activities under government oversight and with appropriate regulatory support.

2. Utilise international climate finance and partnerships

Malaysia can leverage international support through mechanisms like the Joint Crediting Mechanism with Japan and the Green Climate Fund, which offer concessional financing and technical assistance for biomass projects – particularly those with high upfront costs, such as retrofitting coal plants for co-firing or converting them into 100% biomass power plants. By actively engaging in initiatives like the Asia Zero Emission Community, Malaysia can position itself as a biomass hub for the ASEAN region, attracting regional demand and investment. These partnerships not only help de-risk early projects but can also draw more foreign companies to invest, bringing in financial capital, advanced technologies, and international expertise whilst aligning with increasing international environmental stringency. In turn, this helps to boost local capacity, accelerate technology transfer, and align Malaysia's biomass strategy with proven global best practices.

3. Strengthen policy coordination and governance

Malaysia should establish a dedicated Bioenergy Development Committee to serve as the central coordinating authority for all biomass and bioenergy-related initiatives. The committee would bring together representatives from key government ministries, private sector stakeholders, research institutions, and civil society to ensure coherent and integrated policy implementation.

Its core functions would include:

- Overseeing the execution of the NBAP and related strategies;
- Monitoring progress towards national bioenergy targets and regularly publishing transparent performance reports;
- Advising on the design and recalibration of fiscal incentives, R&D support, and market mechanisms to ensure responsiveness to industry needs; and
- Acting as a single-point body to reduce fragmentation, streamline decision-making, and enhance accountability across agencies currently involved in the sector.

By establishing this dedicated and focused entity, Malaysia can improve policy consistency, accelerate project delivery, and build investor confidence in the biomass sector.

4. Enhance sustainability standards and certification for biomass

To guarantee long-term market access and environmental integrity, Malaysia must prioritise the establishment, rigorous enforcement, and continuous improvement of comprehensive sustainability standards for all biomass sources. This necessitates expanding and detailing MSPO certification to explicitly cover the entire supply chain of palm oil residues, including EFB, PKS, and OPF, with a strong emphasis on transparent collection methodologies and traceability with verifiable mechanisms.

Furthermore, Malaysia should develop clear and adaptable sustainability criteria for other significant biomass feedstocks, ensuring alignment with internationally recognised best practices and frameworks, such as the EU's RED II. Facilitating accessible and cost-effective certification schemes, including group certification for smallholders, is crucial to ensure broad participation and compliance across the sector. The implementation of digital verification and tracking systems, such as blockchain or QR codes, throughout the biomass supply chain will enhance transparency, verify sustainability claims, and build consumer trust. Actively engaging in dialogue and collaboration with key international markets, including the EU and Japan, is essential to ensure the mutual recognition and acceptance of Malaysian sustainability standards, thereby securing vital export opportunities and enhancing global competitiveness.

5. Establish a long-term expanded and stable market

To create a robust and predictable environment for biomass investment and deployment, Malaysia can establish an expanded and stable market supported by long-term policy instruments. This includes a combination of regulatory mandates, financial incentives, and transparent market mechanisms:

- Introduce a Renewable Portfolio Standard (RPS) or Bioenergy Obligation, requiring utilities to source a defined percentage of electricity from biomass, ensuring guaranteed demand and providing long-term market signals for project developers and investors;

- Mandate biomass co-firing in coal power plants and establish a Biomass Innovation Fund to co-finance demonstration projects with the private sector to accelerate commercialisation and de-risk emerging technologies;
- Introduce long-term feed-in premium or contracts-for-difference mechanisms, similar to those used in European countries, to offer revenue stability over 15–20 years, promote cost-efficiency, provide price certainty, and reduce investor risk;
- Revise and enhance the FIT programme for biomass by increasing FIT rates to improve the financial viability of biomass projects, allocate larger quotas specifically for biomass, and even implement differentiated FIT pricing based on feedstock type and conversion technology to incentivise sustainable practices and innovation; and
- Strengthen fiscal incentives for bioenergy market development by extending relevant green tax exemptions or offering tax incentives or preferences to support the full biomass value chain, from raw material production and technology development to processing and power generation.

6. Support end-use development and raise public awareness

Not all biomass utilisation should aim for export or grid power; there is much to gain by promoting local use of biomass for rural energy and industrial heat. The government can revive or bolster initiatives like the Biogas for Rural Electrification programme (which previously installed small biogas gensets in off-grid villages) to use agricultural waste for community power. Incentives could also be introduced for industries, such as brick kilns and food processing, to convert boilers from diesel or gas to biomass. An industrial boiler replacement subsidy or low-interest loans for buying biomass boilers could catalyse switching. These measures would create immediate local demand for residues like rice husk in rice mills or coconut husk in copra drying and reduce fossil fuel use.

To ensure the long-term uptake of bioenergy, end-use measures must be supported by comprehensive awareness and capacity-building initiatives. Public education campaigns can play a key role in highlighting the climate and rural development co-benefits of bioenergy whilst addressing common misconceptions related to emissions, land use, and deforestation. Simultaneously, targeted training for rural communities, cooperatives, and small and medium-sized enterprises can foster local entrepreneurship across the bioenergy value chain – for example, in biomass fuel supply, waste collection, aggregation, and system installation or maintenance. Embedding bioenergy modules into technical and vocational education and training programmes will help develop the skilled workforce needed to support a distributed, inclusive, and resilient bioenergy economy.

By executing the above strategies, Malaysia can not only emulate but potentially leapfrog international best practices. Countries with notable biomass success typically combined clear targets, stable incentives, strong sustainability governance, and investment in technology and infrastructure – all underpinned by political will and stakeholder buy-in. Malaysia has already demonstrated such resolve through its rapid solar PV deployment and the sustained growth of its palm oil industry. Applying the same strategic focus and determination to biomass will enable the country to fully unlock its vast resource potential in a sustainable manner.

This transition will not only support Malaysia's RE and climate ambitions but also deliver broader socio-economic benefits, such as rural job creation, the emergence of new bio-based industries, and greater resilience through a diversified energy mix. Ultimately, Malaysia can position biomass as a core pillar of its energy and industrial ecosystems, emerging as a regional leader and a global example in biomass development.

Chapter 5
Findings: The Philippines

With a population of approximately 115 million, the Philippines is an island nation comprising 7,641 islands, geographically divided into three major regions: Luzon, the Visayas, and Mindanao. The Philippines has experienced steady economic growth. Following a swift recovery from the COVID-19 downturn, the country reported a higher annual gross domestic product (GDP) growth rate of 5.5% in 2023 compared to other ASEAN member nations, such as Indonesia at 5.0% and Malaysia at 3.6% (World Bank, n.d.). Supported by strong domestic demand, the country's robust economic activity continued in 2024 with GDP growth of 5.6%, although this was below the anticipated growth range of 6.0%–6.5% (Philippines Department of Finance, 2025). Regarding the country's economic outlook, the government has set GDP growth targets of 6.0%–8.0% for 2025–2028 (Philippines Department of Budget and Management, 2024).

1. Overall Mapping of Bioenergy Supply and Demand at Present

1.1. Policy and regulatory frameworks

Biofuels Act of 2006 (Republic Act No. 9367)

The Philippines enacted the Biofuels Act of 2006 to reduce dependence on imported oil and greenhouse gas (GHG) emissions and to increase local employment opportunities and farmers' income by utilising locally produced biofuels. The Act mandates that liquid fuels for motors and engines sold in the country be blended with biofuels made from local agricultural resources. Feedstocks specified in the Act are organic sources, such as molasses, sugarcane, cassava, coconut, jatropha, and sweet sorghum. No biodiesel imports are allowed by law. For bioethanol, however, oil companies are permitted to import bioethanol for fuel use only if there is a shortage of local feedstocks to meet bioethanol demand in compliance with the mandate.[5]

Biofuel blending targets have been revised upward, as presented in Table 5.1. Initially, the biodiesel blend was mandated at a minimum of 1% biodiesel (B1) within 3 months and increased to 2% (B2) within 2 years after the Act took effect. Similarly, the bioethanol blend was required at a minimum of 5% (E5) within 2 years and 10% (E10) within 4 years from the implementation of the Act. The Philippine National Standards, technical standards developed by the government, for biodiesel 5% (B5) and bioethanol 20% (E20) were promulgated in 2015 and 2023, respectively (USDA, 2024c).

[5] Oil companies need to follow the guidelines set forth by the Department of Energy and Department of Finance – Bureau of Internal Revenue under DC 2006-08-0011 and Revenue Regulation No. 8-2006, respectively.

Tablr 5.1. Biofuel Blending Targets in the Philippines

Year	Bioethanol	Biodiesel
2007	-	1% (B1)
2009	5% (E5)	2% (B2)
2011	10% (E10)	2% (B2)
2015	10% (E10)	5% (B5)
2020	20% (E20)	10% (B10)
2025	20% (E20)	20% (B20)

Source: Compiled by the Institute of Energy Economics, Japan (IEEJ).

The current blending mandates are biodiesel 3% (B3) and bioethanol 10% (E10). The biodiesel blend was expected to be ratcheted up from B2 to B3, B4, or B5 but remained at B2 until 2024. In May 2024, the Philippines Department of Energy (DOE) released new guidelines for adopting a higher biofuel blend (DOE, 2024a). Fuel retailers are required to blend 3% biodiesel with all diesel fuel sold nationwide. The B3 mandate took effect in October 2024, with plans to increase the blend to 4% (B4) in October 2025 and further to 5% (B5) in October 2026. However, on 29 May 2025, the National Biofuel Board, through Resolution No. 2025-01, Series of 2025, agreed to suspend the implementation of 4% biodiesel blend (B4) and 5% biodiesel blend (B5) mandates scheduled for 1 October 2025 and 1 October 2026, respectively. The suspension was due to their expected significant impact on pump prices and potential inflationary effects on the economy. For bioethanol, a 20% blend (E20) with gasoline is allowed, but remains optional, left to the discretion of oil companies.

Renewable Energy Act of 2008 (Republic Act No. 9513)

The Renewable Energy Act of 2008 aims to accelerate renewable energy development and encourage the utilisation of renewable resources, including biomass. The Act provides a list of non-fiscal incentives to support on-grid renewable energy development, such as RPS, an FIT system, a Green Energy Option programme, and net-metering for renewable energy.[6]

In compliance with the Act, which supports policy framework to facilitate the development and use of renewable energy resources and technologies, the DOE (2022) formulated the National Renewable Energy Program (NREP). The latest NREP 2020-2040 sets targets of at least a 35% renewable share in the power generation mix by 2030 and at least 50% by 2040. To help achieve these goals, the RPS was increased from 1.0% to 2.52% in 2023.

The FIT system ensures a guaranteed purchase of electricity generated from renewable energy sources – run-of-river hydropower, solar, wind, and ocean – at a fixed rate for 20 years (DOE, 2022). FIT-approved projects have priority connections to the national grid and

[6] A Green Energy Option programme allows end-users to choose renewable resources.

are prioritised in the purchase, transmission, and payment of renewable electricity by grid system operators. In 2012, the Energy Regulatory Commission (ERC) approved the FIT rates and installation targets for renewable technologies.[7] The FIT rate for biomass was revised from an initial ₱6.63 per kilowatt-hour (kWh) to ₱6.5959/kWh in 2017, and further to ₱6.19/kWh in 2021. The installation target of 250 MW for biomass projects under the FIT scheme has already been fully subscribed.

Under the Renewable Energy Act, various fiscal incentives are provided to developers of renewable energy facilities upon certification by the DOE (Table 5.2.). For farmers engaged in the cultivation of biomass resources, the Act grants duty-free importation and exemption from value-added tax on all types of agricultural inputs, equipment, and machinery for 10 years after its enactment.

Table 5.2. Fiscal Incentives Under the Renewable Energy Act

• Income tax holiday for the first 7 years of its commercial operation	• Accelerated depreciation if a project fails to receive an income tax holiday before full operation
• Duty-free importation of renewable machinery, equipment, and materials	• 0% value-added tax rate on the sale of fuel or power generated from renewable sources
• Special realty tax rates on equipment and machinery	• Cash incentive for renewable energy developers for Missionary Electrification
• Net operating loss carry-over	• Tax exemption on carbon credits
• Corporate tax rate of 10% on net taxable income after the seven-year income tax holiday	• Tax credit on domestic capital equipment and services

Source: Compiled by the IEEJ based on Section 15 of the Renewable Energy Act.

Investment environment

The Philippines has established a policy framework to improve the investment environment for renewable energy development. In 2022, the DOE amended the implementing rules and regulations for the Renewable Energy Act to remove a 40% foreign ownership cap for renewable energy projects.[8] Accordingly, 100% foreign ownership is allowed for renewable energy technologies, including biomass, solar, wind, hydro, geothermal, and ocean energy.

In addition, the Philippines set up the Green Lanes for Strategic Investments to attract foreign direct investment.[9] Strategic investments are defined as one of the following: (i)

[7] The Energy Regulatory Commission determined the FIT rates under the ERC Resolution No. 10 Series of 2012, the ERC Resolution No.1 Series of 2017, and the ERC Resolution No.6 Series of 2021, respectively (DOE, 2022).
[8] Department Circular No. DC2022-11-0034.
[9] Executive Order No. 18 Constituting Green Lanes for Strategic Investments.

highly desirable projects recommended by the Fiscal Incentives Review Board to the Office of the President; (ii) foreign direct investments endorsed by the Inter-Agency Investment Promotion Coordinating Committee; and (iii) priority projects under the Strategic Investment Priority Plan, one of which is clean energy sources (Green Lanes for Strategic Investments, n.d.). The Green Lanes initiative simplifies and streamlines procedures for the entry of strategic investments and expedites application processing, supported by a One-Stop Action Center. In 2024, 141 out of 176 certified strategic projects were renewable energy projects amounting to ₱4.13 trillion, accounting for about 91% of all strategic investments (Power Philippines News, 2025).

Climate change policy

The Philippines is highly vulnerable to the severe impacts of climate change. The country enacted the Climate Change Act of 2009 (Republic Act No. 9729) to strengthen, integrate, consolidate, and institutionalise government initiatives for coordinating climate change programmes. The Climate Change Commission was established under the Act as an independent and autonomous policy-making body tasked with coordinating, monitoring, and evaluating these programmes. Furthermore, the Act, amended in 2011 (Republic Act No. 10174) to establish the People's Survival Fund, which supports local governments and community organisations carrying out climate change adaptation projects to improve resilience against climate-related impacts.

Having submitted its first Nationally Determined Contribution in 2021, the Philippines is committed to a 75% reduction in GHG emissions compared with the business-as-usual scenario for the period 2020–2030, of which 2.71% is unconditional and 72.29% is conditional (UNFCCC, 2021).

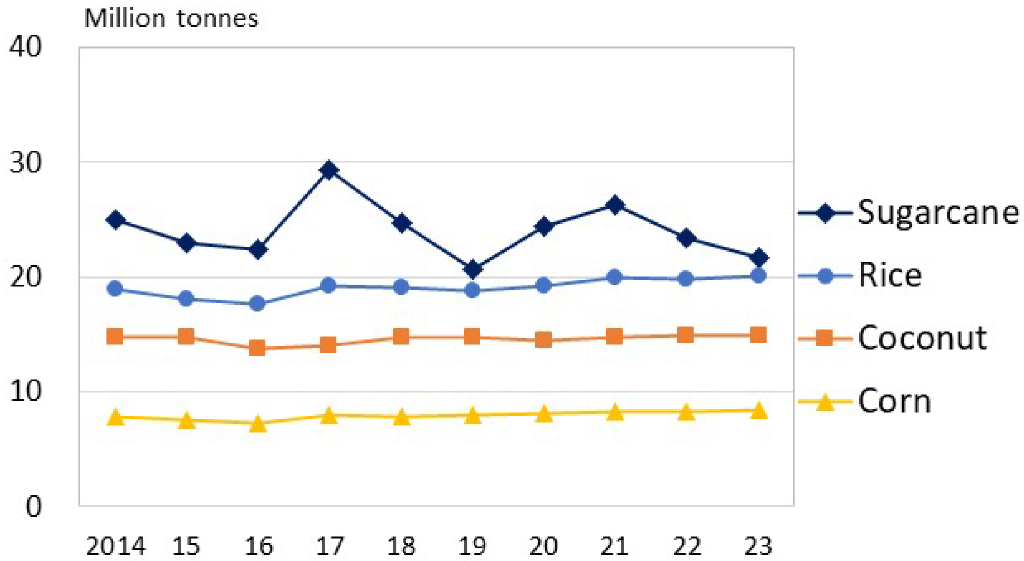
i. Resource availability

The Philippines is endowed with diverse biomass resources from agricultural products and residues. The agriculture industry is one of the country's essential sectors. In 2022, the agriculture, forestry, and fishing sectors contributed 9.5% to GDP at current market prices, whilst the agriculture, hunting, and forestry industries accounted for 20.4% of the employed workforce (Philippine Statistics Authority (PSA), 2024b). About 42.5% of the total land area of 298,170 km^2 was dedicated to agricultural production in 2022 (World Bank, n.d.).

The top five agricultural products by value are rice, banana, corn, coconut, and sugarcane (PSA, 2024c). These crops generate large amounts of residues or wastes left in the field after harvest or collected during processing at mills or plants. Although some of these by-products have low or no commercial value, they can be useful for bioenergy. Importantly, they do not compete with food security, which has been prioritised in the country. Agricultural residues are often assessed to determine their suitability as feedstocks for bioenergy.

Figure 5.1. shows the production trends of the main crops with potential for energy use in the Philippines. Crop production is a critical factor affecting the availability of agricultural residues for bioenergy resources. Rice, coconut, and corn production are relatively stable. However, sugarcane production has decreased in recent years along with a declining trend in the sugarcane harvested area, owing to land conversion and the closing of mills (USDA, 2025c). The average annual yield of sugarcane production in the Philippines is relatively low compared with other sugar-producing countries. In 2023, the average yield of sugarcane production was 52.9 tonnes/hectare (t/ha) in the Philippines, compared with 67.8 t/ha in Viet Nam (PSA, 2024c; General Statistics Office of Viet Nam, 2024). The low yield observed in sugarcane production in the Philippines is attributed to factors such as soil acidity, low soil organic matter content, soil erosion, and limited access to new high-yielding varieties (Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD), n.d.).

Figure 5.1. Major Crop Production in the Philippines, 2014–2023



Source: Compiled by the IEEJ based on data from the PSA (2024c).

In the Philippines, by-products of sugarcane and residues from the production of rice and coconut are used for energy production. Bagasse, the material left after crushing sugarcane, is primarily used as a feedstock for CHP in sugar mills and bioethanol refineries. Rice husk is burned to provide heat for drying and power in rice mills (Elepaño et al., 2015; Go et al., 2019). Coconut shells are also made into charcoal, though in limited quantities (Go et al., 2019).

Coconut and sugarcane serve as the main raw materials processed into biofuels for the transport sector in the Philippines. Molasses, a by-product of sugar processing, is primarily used to produce bioethanol, whilst sugarcane is also used to a lesser extent. In

2023, the Visayas accounted for 72.1% of sugarcane production, followed by Mindanao with 19.3% and Luzon with 8.6% (PSA, 2024c). For biodiesel, coconut methyl ester made from coconut oil is the primary feedstock. Coconuts are grown nationwide, with 69 out of 82 provinces being coconut-producing provinces (Philippine Coconut Authority (PCA), n.d.). Production is concentrated in Mindanao, which accounted for 60.1% of national coconut production in 2023 (PSA, 2024c). The number of bearing coconut trees stood at 345 million in 2023, though the average annual growth rate slightly declined by 0.2% from 2019 to 2023 (PSA, 2024a). To mitigate the downward trend, the Philippines has committed to planting 100 million coconut trees by 2028 (PCA, 2024b).

A renewable energy resource assessment study supported by the Philippine government estimated the potential of bagasse and rice husk for energy use (Ang et al., 2017). Bagasse potential is observed in a limited number of provinces, whereas rice husk is found across the country with different degrees of potential amongst provinces. However, these potential sources from agricultural residues do not necessarily equate to their availability for energy use, considering that other factors would limit availability. For example, the distance between collection points and the facilities where fuels are in demand should be assessed, as this affects transportation costs. Long-distance delivery is not cost-efficient for agricultural residues with low bulk density.

1.2. Commercial production

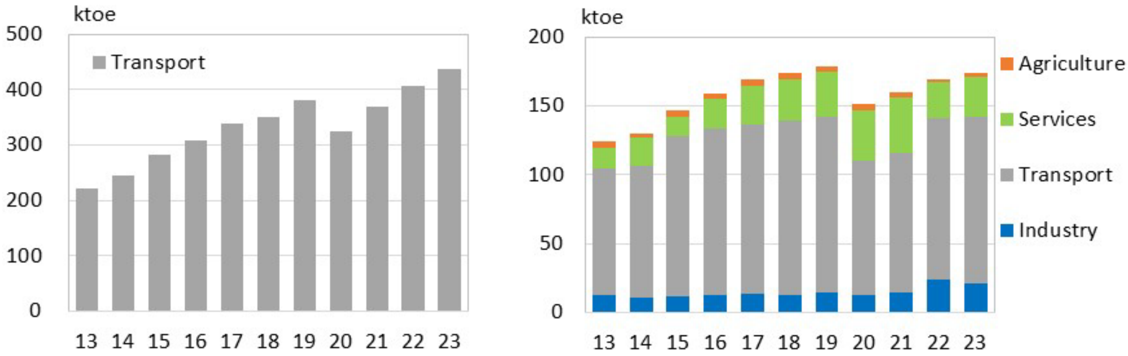
The total energy supply of the Philippines was 65.3 million tonnes of oil equivalent (Mtoe) in 2023, of which oil, coal, and renewable energies (including hydro) occupied approximately one-third each (DOE, 2024b). The share of biomass resources has gradually decreased from 16.1% in 2013 to 12.0% in 2023, reflecting a shift from traditional biomass (fuelwood and agricultural wastes) towards commercial energy sources. Despite their relatively small shares of total energy supply, biodiesel and bioethanol have shown substantial average annual growth rates of 4.1% and 19.7%, respectively, between 2013 and 2023.

Bioethanol and biodiesel

Since the Biofuel Act mandated the blending of biofuels with gasoline and diesel, consumption of bioethanol and biodiesel has steadily increased in the transport sector, except for a drop in 2020 due to the economic slowdown caused by COVID-19 (Figure 5.2). Whilst bioethanol is in demand in the transport sector, specifically in the road subsector, biodiesel is primarily consumed in the transport sector and is used moderately in the industry, services, and agriculture sectors.

Figure 5.2. Biofuel Consumption in the Philippines, 2013–2023

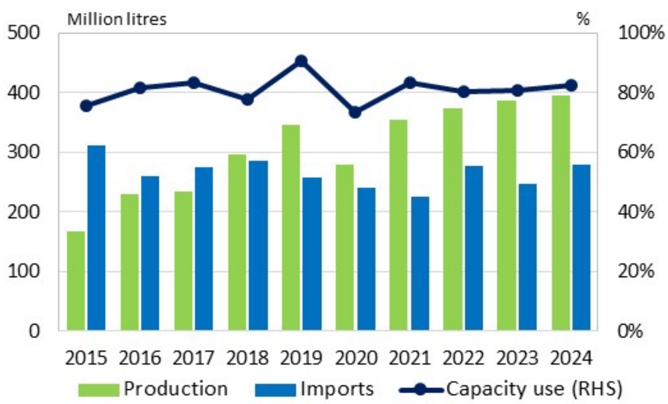
(i) Bioethanol (ii) Biodiesel



ktoe = thousand tonnes of oil equivalent.
Source: Compiled by the IEEJ based on data from the DOE (2024b).

There are 14 accredited bioethanol producers in the Philippines with a total rated production capacity of 508 million litres per year as of March 2025 (DOE, 2025b). Local bioethanol producers can supply approximately 63% of the requirement for a 10% ethanol blend in gasoline (E10).[10] Most facilities use molasses as the primary feedstock to produce ethanol, with only three plants using sugarcane (USDA, 2024c). Although the use of locally produced biofuels is encouraged, domestic bioethanol production has not been sufficient to meet national requirements due to feedstock supply constraints. In 2022, domestic ethanol production for fuels met just 51% of demand, necessitating ethanol imports to fill the gap, mostly the United States and Brazil (International Energy Agency (IEA), 2024b; USDA, 2024c). Figure 5.3. shows that ethanol production for fuel has increased, and capacity use has remained high, at around 80%, although ethanol imports have not decreased.

Figure 5.3. Production and Imports of Ethanol for Fuel in the Philippines, 2015–2024



RHS = right-hand scale.
Source: Compiled by the IEEJ based on data from the USDA (2024c).

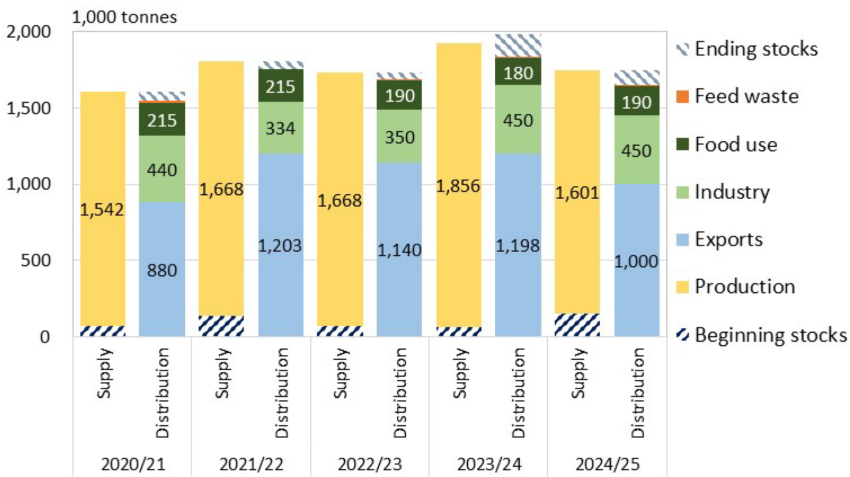
[10] Comments by an expert from the Philippines' DOE at an online meeting held on 16 April 2025.

For biodiesel, 14 plants are certified for operation, with a total rated production capacity of 815.33 million litres per year as of March 2025 (DOE, 2025a). The capacity utilisation rate was 32.2% in 2023 (USDA, 2024c). Production capacity has been expanded to accommodate the blending mandate increasing to B5. However, the extra capacity is expected to tighten once demand increases in line with higher blending mandates.

The coconut industry is one of the country's most vital economic sectors. The Philippines is the world's second-largest coconut producer after Indonesia and the leading producer of coconut oil. A sizable amount of coconut oil, a biodiesel feedstock, is exported (Figure 5.4). In 2023, most coconut oil exports from the Philippines were destined for European countries and the United States (Figure 5.5).

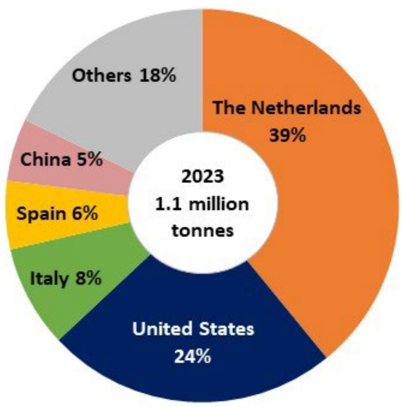
Coconut oil has multiple uses in the oleochemical, food, and feed industries. For instance, oleochemicals from coconut oil are processed into consumer goods, such as laundry detergent, shampoo, and soaps (FAO, 2019). These multiple uses increase overall demand for coconut oil, driving up its price.

Figure 5.4. Coconut Oil Production and Exports in the Philippines



Source: Compiled by the IEEJ based on data from the USDA (2025b).

Figure 5.5. Coconut Oil Export Destinations, 2023

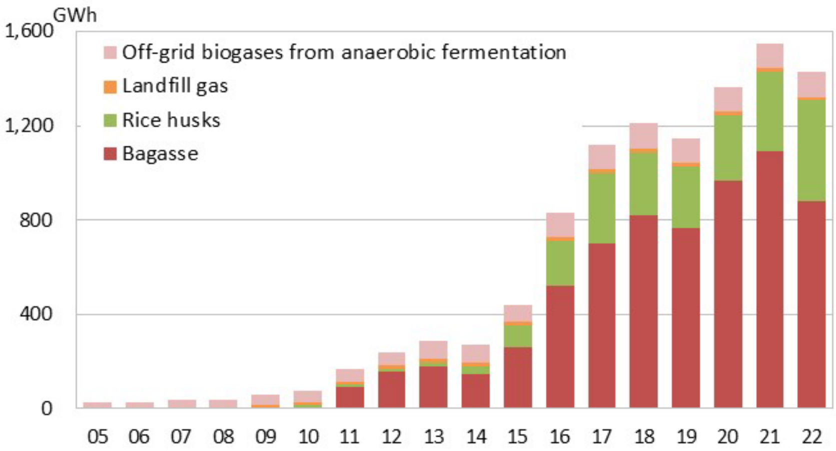


Source: Compiled by the IEEJ based on data from PSA (2024c).

Bioenergy in the power sector

In the Philippines, fossil fuels, particularly coal, dominate power generation, accounting for 78% of total output in 2023 (DOE, 2024b). Biomass-fuelled power generation has significantly increased, from 212 GWh in 2013 to 1,409 GWh in 2023, yet biomass accounts for only 1% of total power generation. Bagasse is the main feedstock for power generation, followed by rice husk (Figure 5.6) (IRENA, 2024a). Both are residues collected from processing in the sugarcane and rice mills. Biogas power generation is used in off-grid energy systems, contributing to electrification in remote areas.

Figure 5.6. Biomass Power Generation in the Philippines, 2005–2022



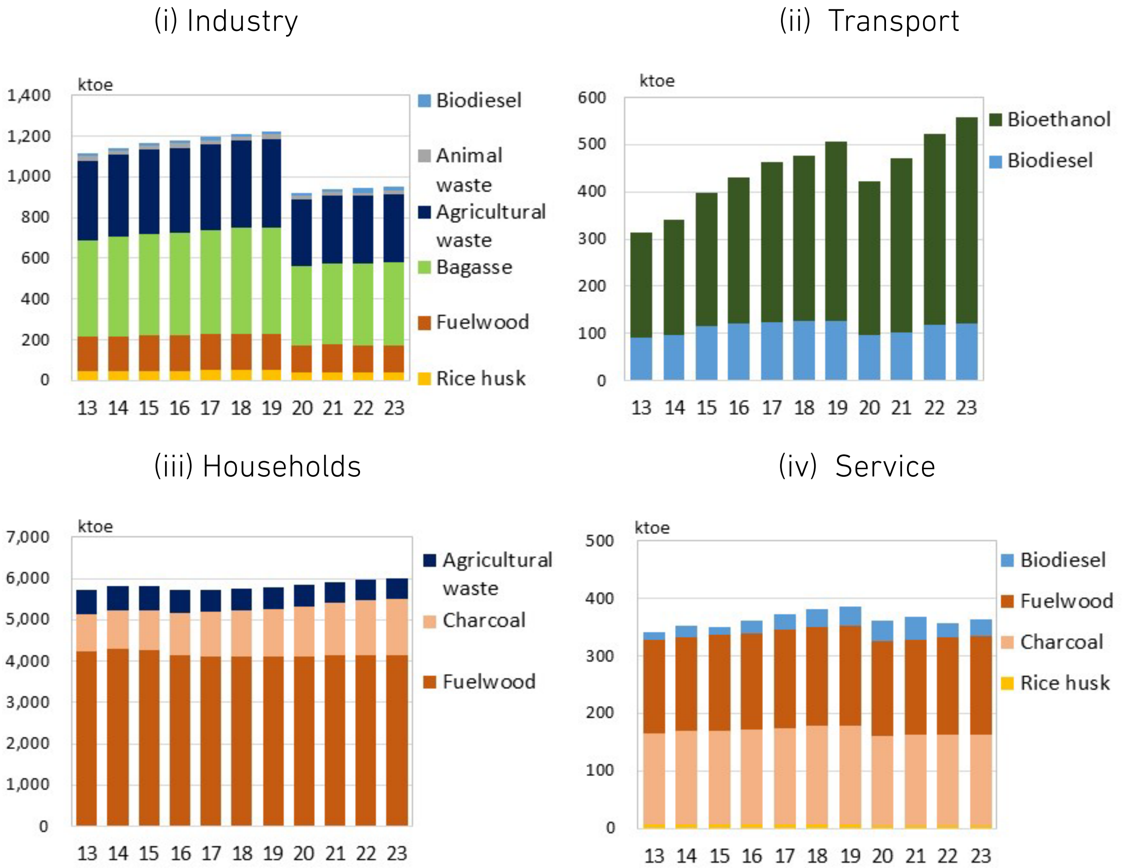
GWh = gigawatt-hour.
Source: Compiled by the IEEJ based on data from IRENA (2024a).

Bioenergy in the end-use sectors

Bioenergy is utilised across all end-use sectors (Figure 5.7). The industry sector demonstrates steady demand for agricultural residues and biodiesel, particularly within food processing and sugar manufacturing (DOE, 2023b).

Traditional biomass resources remain prevalent in the residential sector, accounting for approximately three-quarters of total bioenergy consumption in the end-use sectors. Households have increasingly shifted towards modern energy, such as electricity and liquefied petroleum gas, whereas traditional biomass resources, mostly fuelwood and charcoal, are used primarily for cooking and heating. However, demand for traditional biomass resources is projected to decline towards 2050 as preferences for clean and efficient energy spread as incomes increase (DOE, 2023b).

Figure 5.7. Bioenergy in the End-Use Sectors in the Philippines, 2013–2023



ktoe = thousand tonnes of oil equivalent.
Source: Compiled by the IEEJ based on data from DOE (2024b).

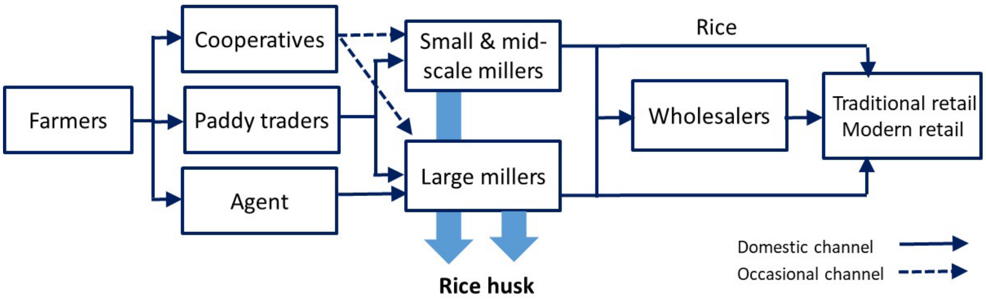
1.3. Existing supply chains

Rice

The Philippines has around 2.4 million rice farmers, with an average farm size of 1.3 ha (Briones, 2019; Philippine Rice Research Institute, n.d.). Rice is typically delivered to millers through traders, agents, and occasionally cooperatives (Figure 5.8). More than 8,000 rice mills operate across the country, mainly in the private sector. Of these, approximately 7,000 are small-scale mills with a production capacity of less than 2 tonnes per hour (World Food Programme, 2022).[11] Despite the potential use of rice husk for bioenergy, many rice mills treat their piles as waste and consider them a disposal problem (FAO and GIZ, 2019).

[11] Large rice mills have a production capacity of more than 5 tonnes per hour, and medium mills operate at a milling capacity of 2–5 tonnes per hour (World Food Programme, 2022).

Figure 5.8. Rice Supply Chain in the Philippines



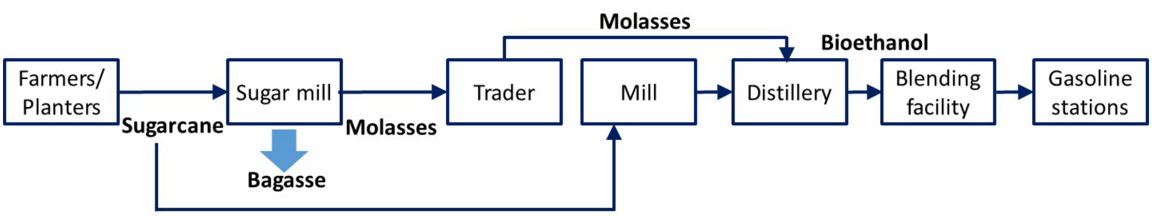
Source: Adapted by the IEEJ from World Food Programme (2022, Figure 10, p.20).

Sugarcane

There are approximately 88,000 sugarcane farmers in the Philippines, of which 84% have landholdings of less than 5 ha (PCAARRD, n.d.). Only 3% of the total harvested area is allocated for bioethanol production, whereas the remaining 97% is for centrifugal sugar (USDA, 2025c). The Sugar Regulatory Administration (SRA) has registered 25 sugar mills (Luzon – 4, the Visayas – 17, Mindanao - 4) and 10 sugar refineries (Luzon – 2, the Visayas – 7, Mindanao – 1) for crop year 2024–2025 (Sugar Regulatory Commission, n.d.-a; n.d.-b).

Bioethanol is produced from molasses and sugarcane (Figure 5.9). To secure feedstock, bioethanol refineries need to bid for molasses provided by sugar mills, planters, and traders in most cases (Briones, 2020). In 2023, 0.69 million tonnes of sugarcane and 1.35 million tonnes of molasses were allocated to produce fuel ethanol (USDA, 2024c). Since the feedstock supply for bioethanol production is insufficient to meet domestic demand, importing ethanol is necessary. Twenty-three accredited companies – including major oil companies such as Petron, Shell, and Chevron – and several traders are engaged in fuel ethanol imports (USDA, 2024c). The use of imported molasses as a feedstock for biofuel production is legally prohibited (USDA, 2024c).[12]

Figure 5.9. Bioethanol Supply Chain in the Philippines



Source: Adapted by the IEEJ from Demafelis et al. (2020, Figure 1, p.98).

[12] Imported molasses are used to produce denatured alcohol for industrial use (USDA, 2024c).

Sugar mills and bioethanol refineries generally use the bagasse they generate as fuel for CHP. However, 30%–50% of it is left unutilised and is often piled up in open fields (Go et al., 2019). The seasonal nature of bagasse availability, dependent on the sugarcane crushing season, poses challenges to the efficient operation of CHP facilities.

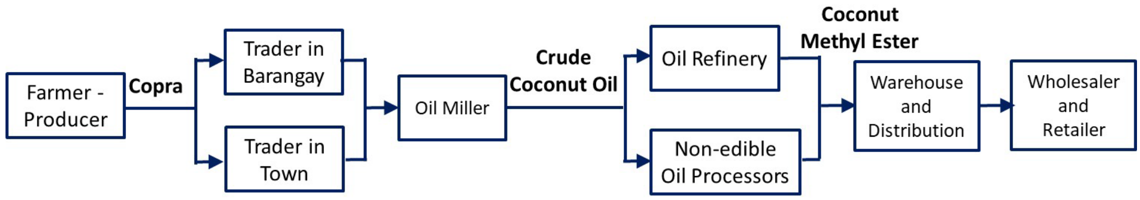
A distinctive feature of the Philippine sugar industry is the *quedan* system, a sharing arrangement established under the Sugar Act of 1954 (Republic Act No. 809). The Act mandates the sharing of raw sugar and by-products, such as molasses, between farmers/planters and sugar mills. Under this system, planters give 30%–35% of their sugar to the mill as payment for processing the sugarcane (USDA, 2025c). After the sugarcane is processed, the miller issues a *quedan*, a warehouse receipt representing the farmer's 65%–70% share, which can be traded or used to withdraw sugar stocks at any time.

Coconut oil

Amongst the country's agricultural exports, crude coconut oil ranked second in both volume and value after fresh bananas in 2023 (PSA, 2024c). Coconuts are mainly produced on small- and medium-sized farms. About 1.4 million farmers are coconut growers, mostly smallholders with an average farm size of 0.5–5 ha (Moreno et al., 2000).

Biodiesel (coconut methyl ester) from coconut is derived from the extracted oil from copra.[13] Farmers process coconuts into copra, which is mainly delivered to oil millers through traders (Figure 5.10). In the biodiesel supply chain, stakeholders such as mills, refineries, and biodiesel plants operate separately (FAO, 2019). This high level of fragmentation presents challenges in coordinating the entire supply chain.

Figure 5.10. Coconut Oil Supply Chain



Source: Adapted by the IEEJ from Moreno et al. (2020, Figure 4, p.S535).

1.4. Cost

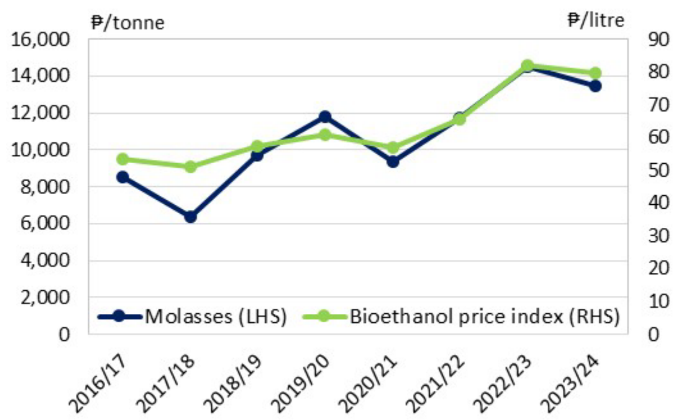
High procurement costs for feedstock used in bioethanol and biodiesel production remain one of the major challenges faced by biofuel refineries in the Philippines.[14] The high

[13] About 80% of total coconut production (coco meat) is processed into copra, and the remainder is made into desiccated coconut and other coconut products, such as coconut milk (USDA, 2024d; PCA, n.d.).
[14] According to the questionnaire survey conducted for this study.

feedstock costs of molasses and coconut oil result in high production costs, leading to high selling prices for biofuels.

Domestic bioethanol is generally more expensive than imported bioethanol. As of the first half of April 2024, the bioethanol reference price was ₱84 per litre, compared to ₱41.54 per litre for imported ethanol (USDA, 2024c). The domestic bioethanol price is largely affected by molasses prices (Figure 5.11). Demand for molasses is high due to its multiple uses, which pushes up prices. Furthermore, domestic bioethanol does not compete with imported ethanol because, under current regulations, local supply must be fully utilised before imports are allowed. In contrast, countries such as the United States and Brazil, benefiting from economies of scale, produce bioethanol at lower costs.

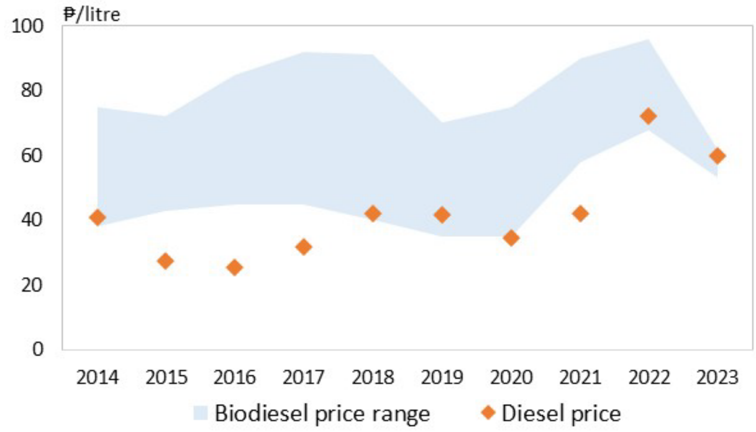
Figure 5.11. Molasses Price and Bioethanol Price Index in the Philippines



LHS = left-hand scale, RHS = right-hand scale.
Source: Compiled by the IEEJ based on data from USDA (2024c, Table 9, p.14).

The price range of biodiesel has remained higher than that of petroleum-based diesel in the Philippines (Figure 5.12). The high biodiesel prices can be attributed to high production costs, with feedstock accounting for 70%–80% of the total production cost (Landoy et al., 2022). As a major coconut oil exporter, the Philippines' biodiesel producers must deal with the impacts of price volatility in the international coconut oil market. This is a hurdle to reducing the domestic price of coconut oil. As previously noted, the suspension of the required biodiesel blending schedule from B3 to B4 in October 2025 and to B5 in October 2026 is under consideration due to the high coconut oil price. Increasing biodiesel blend mandates would lead to higher diesel pump prices. It is important to mitigate the impacts on the diesel price because diesel is the major transport fuel in the Philippines.

Figure 5.12. Diesel Price and Biodiesel Price Range in the Philippines



Source: Compiled by the IEEJ based on data from USDA (2024c, Table 12, p.18).

The Philippines' coconut oil market has been impacted by the European Union Regulation on Deforestation-free Products, which entered into force in June 2023. This regulation requires any operator or trader who places commodities such as soy and palm oil on the EU market 'to prove that the products do not originate from recently deforested land or have contributed to forest degradation' (European Commission, n.d.).[15] Since coconut oil is not subject to this regulation, preference for this product over soybean and palm oil has led to a stock increase globally in anticipation of higher demand. This situation tightened the supply of coconut oil in the domestic market in the Philippines, which led to a price surge in the fourth quarter of 2024.[16]

1.5. Advantages of bioenergy (in comparison to other energy resources)

Tapping into bioenergy offers significant advantages for the Philippines, which has high potential to use its abundant agricultural residues. There are two main advantages of using biomass resources for energy.

First, energy security will be enhanced by incorporating more biomass resources into energy systems. The Philippines' energy self-sufficiency declined to 46% in 2023, a significant drop from 57% in 2013 (DOE, 2024b). In particular, the country relies heavily on imported petroleum products and has no oil refinery, leaving it highly exposed to supply disruptions and price fluctuations in the international market. As noted in the Philippine Energy Plan (PEP) 2023-2050, increasing energy self-sufficiency is critical to ensuring a reliable and resilient energy supply system, which can be achieved by utilising domestic resources. Bioenergy is expected to help reduce dependence on energy imports. The

[15] The targeted commodities include cattle, wood, cocoa, soy, palm oil, coffee, rubber, and some of their derived products, such as leather, chocolate, tyres, and furniture. The law will be applicable on 30 December 2025 for large and medium companies and 30 June 2026 for micro and small enterprises (European Commission, n.d.).

[16] Comments by an expert from the Philippines' DOE at an online meeting held on 16 April 2025.

Biofuels Act also promotes the use of biofuels as a way to develop and utilise domestic renewables. Hence, making use of biomass resources will be effective in improving the country's energy security.

Second, bioenergy will contribute to the decarbonisation of the economy. In the Philippines, fossil fuels dominate the primary energy supply, accounting for 68.5% in 2023 (DOE, 2024b). Committed to advancing its Nationally Determined Contribution of a 75% reduction and avoidance of GHG emissions by 2030, the Philippines must take steps to mitigate emissions. The country's total GHG emissions were 150.6 million tonnes of CO_2 equivalent (Mt-CO_2e) in 2023 (DOE, 2024b). Since the electricity and transport sectors are the major emitters, accounting for 59.4% and 24.5%, respectively, utilising biomass resources in these sectors is an effective way to reduce GHG emissions. In 2023, bioethanol and biodiesel reduced emissions by 843,110 tonnes of CO_2 equivalent (t-CO_2e) and 575,910 t-CO_2e, respectively (USDA, 2024c).

Furthermore, proper management of agricultural waste can help minimise environmental harm. Current practices of burning crop residues in open fields release toxic air pollutants. Converting unutilised biomass waste from fields or mills into usable fuels will help decarbonise the energy system and improve air quality.

1.6. Selected bioenergy resources

This study focuses on the main biomass resources currently used for energy in the Philippines, i.e. rice husk and bagasse for CHP, and molasses, sugarcane, and coconut oil for biofuels, as these are likely to continue being utilised.

On the other hand, biomass resources not examined in this study include corn, used cooking oil, and wood products such as wood pellets and chips. Given the priority for food security, corn, a possible feedstock for ethanol production, is excluded as it is the second most important crop and the main staple food for many people in the Philippines. Regarding used cooking oil, it was reported that the Philippines will not pursue its use for biodiesel production due to concerns about quality and the adequacy of supplies of domestic vegetable oil feedstock (Moffitt, 2023). Similarly, wood products are not desirable for bioenergy, given that deforestation remains a serious issue in the Philippines. A total of 1.42 million ha of tree cover was lost from 2001 to 2022, a 7.6% decrease from the total tree cover of approximately 18.7 million ha (Climate Change Commission, 2024). According to a study by Martinez and Lopez (2017), the technical potential of forest residues as feedstock for co-firing is found to be zero due to the legislation on biodiversity protection that prohibits the collection of stemwood.

2. Expected Supply and Demand of Selected Bioenergy in 2030

2.1. Identifying the gap between supply and demand

The Philippine Energy Plan (PEP) 2023–2050 serves as the basis for analysing the projected gap between bioenergy supply and demand in 2030. In the PEP 2023-2050, the energy supply and demand outlook portrays two possible paths towards 2050: the Reference Scenario (REF) and the Clean Energy Scenario (CES), based on the different assumptions specified in Table 5.3. The REF is the business-as-usual case, assuming that current energy policies are continuously implemented. The CES, on the other hand, sets more ambitious targets for the energy sector, particularly for renewables and biofuel blending. In addition, the CES includes two options for offshore wind development: CES1 with 19 GW of awarded offshore wind by 2050, and CES2 with 50 GW by 2050.

Table 5.3. Major Assumptions in the Philippine Energy Plan 2023–2050 by Scenario

(i) Reference Scenario (REF)

Demand	Supply
- Electric vehicle penetration rate: 10% by 2040 - Biofuels blending: B2 and E10 - Current energy efficiency and conservation	- Renewable share in generation mix: at least 35% by 2030 and 50% by 2040 and onwards - Liquefied natural gas imports starting in 2023

(ii) Clean Energy Scenario (CES)

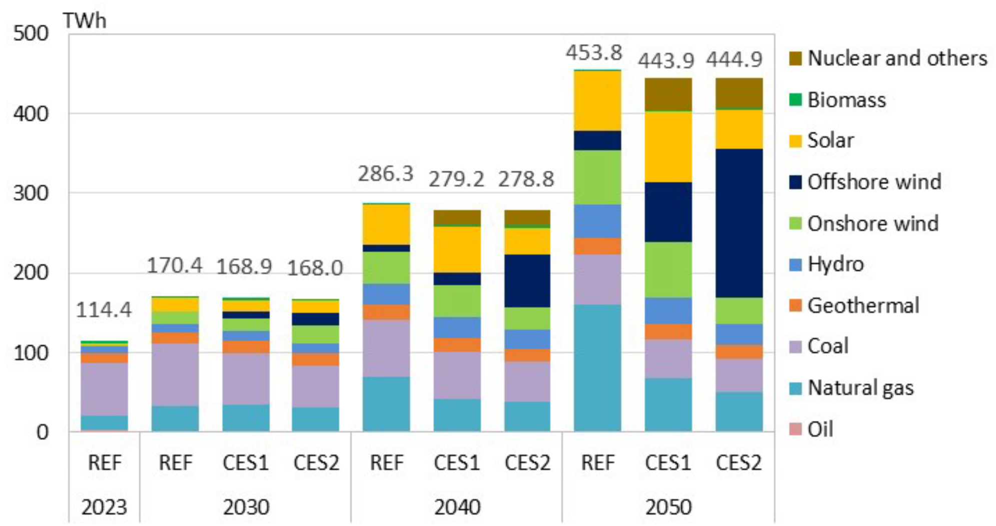
Demand	Supply
- Electric vehicle penetration rate: 50% by 2040 - Biofuels blending: B5 starting in 2026 - Improvement in energy savings from oil products and electricity use by 10% in 2040–2050	- Renewable share in generation mix: 35% by 2030, 50% by 2040, and more than 50% by 2050 - 40-year technical life for coal plants - Nuclear capacity: 1.2 GW by 2032, 2.4 GW by 2035, and 4.8 GW by 2050
	- CES1: 19 GW of offshore wind by 2050
	- CES2: 50 GW of offshore wind by 2050

GW = gigawatt.
Source: Compiled by the IEEJ based on DOE (2023b).

Power generation

According to the PEP 2023–2050, power generation is expected to grow annually at an average rate of 5.14% under the REF, 5.06% under CES1, and 5.07% under CES2 from 2022 to 2050 (Figure 5.13). Solar and wind, especially offshore wind, will play a key role in decarbonising the power sector through 2050, and natural gas is considered a transition fuel to support these variable renewable energy sources, thus making the power system more reliable and stable.

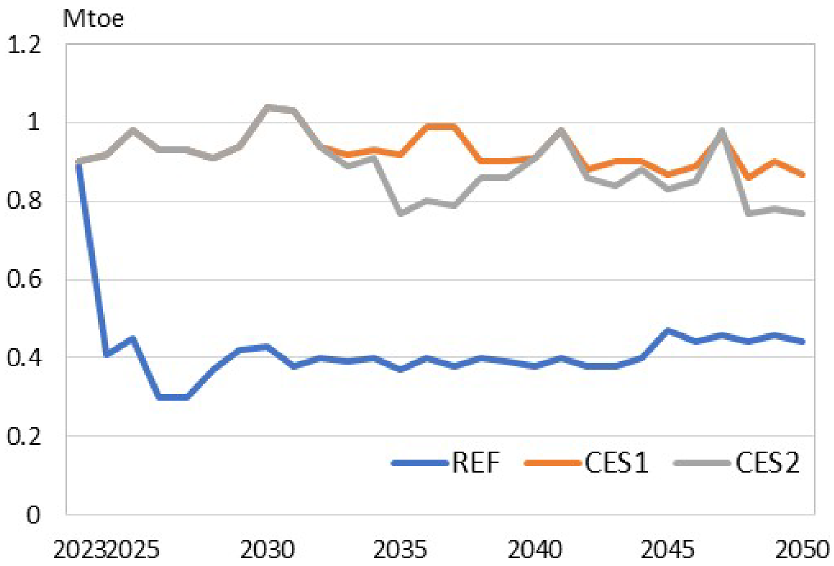
Figure 5.13. Power Generation Outlook by Scenario



CES = Clean Energy Scenario, REF = Reference Scenario, TWh = terawatt hour.
Source: Compiled by the IEEJ based on data from DOE (2023b).

However, the share of biomass resources will remain minimal in power generation. Biomass is projected to account for 0.7% under the REF and 1.7% under CES1 and CES2 in 2030, gradually decreasing towards 2050. The outlook indicates that biomass input to power generation is not likely to increase regardless of the scenario (Figure 5.14). This implies that demand for bagasse and rice husk will remain steady and can be adequately met for CHP by 2030.

Figure 5.14. Biomass Inputs for Power Generation by Scenario



CES = Clean Energy Scenario, Mtoe = million tonnes of oil equivalent, REF = Reference Scenario.
Source: Compiled by the IEEJ based on data from DOE (2023b).

Bioethanol and biodiesel

Higher biofuel blending requirements will drive up demand for bioethanol and biodiesel. Meanwhile, these biofuel blending mandates will encourage the development of production capacity and feedstock to satisfy the growing demand.

Biodiesel production is expected to meet blending requirements by 2030. The industry has already expanded its production capacity in anticipation of the shift to B5 (USDA, 2024c). Furthermore, three biodiesel production plant projects with a combined capacity of 201.45 million litres per year are accredited for construction as of March 2025 (DOE, 2025a). However, securing sufficient coconut oil remains a critical challenge to sustaining production that fulfils the mandated blending. The DOE estimates that an additional 900 million coconuts are required for 100 million–120 million litres of coconut methyl ester in compliance with a 1% mandatory increase in the biodiesel blend (DOE, 2024a).

In contrast, the bioethanol supply will likely remain dependent on ethanol imports due to limited domestic production capacity and feedstock. The PEP 2023–2050 estimates that the country will need about 760.7 million litres per year of additional bioethanol production capacity under CES1 and CES2 if all bioethanol supply requirements are assumed to be provided by local producers, and 242.8 million litres per year even if 60% of the bioethanol supply were produced domestically (DOE, 2023b).

In February 2025, the government announced a policy change to encourage the expansion of bioethanol production capacity. The SRA issued an amendment, Sugar Order No. 3, to lift the moratorium on applications for molasses-based bioethanol plants.[17] Under this policy amendment, new applications to construct or expand ethanol facilities using molasses as feedstock are allowed if the maximum rated capacity of the plant does not exceed the volume of molasses produced (USDA, 2025d). This measure is expected to help increase the domestic ethanol production capacity.

3. Requirements for Development of the Supply Chain (to fill the supply–demand gap)

3.1. Addressing technical barriers

Challenges related to bioenergy feedstock

Biofuel refineries have faced difficulties in securing biomass feedstock, as the materials used for biofuels also serve competing purposes and are not adequately supplied.[18] As mentioned above, domestic feedstock for bioethanol production is insufficient to meet mandated blending levels. In the Philippines, sugarcane production has decreased in recent years, and average yields are relatively low. Accordingly, the availability of molasses in proportion to sugarcane production is not stable for bioethanol production. The *quedan* system may also indirectly restrict the distribution of molasses, as this enforced sharing agreement can discourage operational efficiency (Briones, 2020).

The coconut industry also suffers from low productivity, primarily due to the senility of coconut trees (about 20% of coconut trees), pest and disease infestations, low adoption of technology at the farm level, and adverse weather conditions (PCA, n.d.; Lu, 2023). This low productivity reduces the availability of coconut oil for biodiesel production.

The seasonal availability of feedstock is another common challenge for bioenergy operations. In the Philippines, sugarcane and rice are harvested twice a year, whilst coconut is harvested four times yearly (Ang et al., 2017). Feedstock prices fluctuate with harvest seasons, and uncertainties in supply can affect the efficiency of bioenergy systems. Although proper storage facilities could help ensure steady feedstock availability, the Philippines still lacks adequate post-harvest facilities to store the necessary feedstock and prevent losses from natural deterioration and insect damage.

Inefficiency in the bioenergy supply chain

Improving efficiency across the bioenergy supply chain is essential in the Philippines. The involvement of many actors in each bioenergy resource, particularly withing the rice, sugarcane, and coconut industries, has hindered a unified and consistent approach to

[17] Sugar Order No. 3, Series 2015 - 2016, suspended the approval of additions of molasses-based ethanol capacity until local molasses production exceeded the estimated requirements of the country's existing ethanol plants.

[18] According to the questionnaire survey conducted for this study.

enhancing efficiency throughout the supply chain.

First, farmers involved in bioenergy resources are engaged in small-scale production with limited resources. Under the Comprehensive Agrarian Reform Law of 1988 (Republic Act No. 6657), landowners are not allowed to retain more than five ha of agricultural land. Economies of scale could be realised for productivity if smallholders collaborated more effectively. Organised farmer groups would have greater access to modern farming technologies, mechanical equipment, and financial assistance programmes. In the coconut industry, for instance, farmer organisations remain weak and often lack the capacity to operate collectively in business (PCA, n.d.).

Inefficiencies are also evident at the processing stage. Agricultural residues are generally collected and handled manually, requiring substantial manpower and time. Better agricultural machinery and equipment could help reduce this labour-intensive work. Processing residues into more manageable forms, such as pelletised rice husk, would make transport more efficient, contributing to savings in transportation costs and GHG emission reductions.

In transportation, appropriate road development is also fundamental for improved efficiency. In the Philippines, many farm-to-market roads remain unpaved and disconnected (Navarro and Latigar, 2022).

Finally, inefficiencies persist in the production phase. Biofuel refineries are not fully utilised due to feedstock shortages. Conversely, in biomass power generation, rice husk utilisation remains limited to large mills and a few biomass power plants, despite its abundance.

Severe climate risk

The agriculture sector, a key provider of bioenergy feedstock, is highly vulnerable to climate change, underscoring the need to strengthen its resilience. Natural disasters such as cyclones, floods, and landslides impact agricultural productivity. The Philippines is regarded as one of the most disaster-prone countries in the world. The *WorldRiskReport 2024* (Bündnis Entwicklung Hilft and Institute for International Law of Peace and Armed Conflict, 2024) ranked the Philippines first out of 193 countries in terms of disaster risk.[19] As climate change intensifies, these risks are expected to worsen. In particular, the Philippines is highly exposed to tropical cyclones; approximately 7–9 make landfall annually, with an average of 19–20 entering its area of responsibility (World Bank Group and Asian Development Bank, 2021). Coconut trees are particularly vulnerable due to their tall and thin structure, making them susceptible to cyclone damage.

[19] The World Risk Index assesses disaster risk for 193 countries by evaluating countries' exposure to natural hazards and vulnerability, which includes the susceptibility of populations and the coping and adaptive capacities of societies.

3.1.1.Addressing policy and regulatory barriers

The increasing penetration of electric vehicles (EVs) in the Philippine vehicle market will influence future biofuel demand. In the PEP 2023-2050, bioethanol demand under the CES is estimated to decline by 9.7% in 2028 and 22.5% in 2050 compared with the REF, due to greater EV utilisation (DOE, 2023b).

The Philippines supports transport sector electrification to advance decarbonisation and reduce dependence on petroleum product imports. The Electric Vehicle Industry Development Act of 2022 (Republic Act No. 11697) mandates that at least 5% of vehicle fleets operated by industrial and commercial companies, public transport operators, national and local governments, and the government-owned corporations must consist of EVs.[20] To facilitate this transition, in 2023, the government issued Executive Order No. 12, under which EVs and their components are temporarily exempted from import duties for 5 years, until 2028.[21]

Furthermore, the Philippine Comprehensive Roadmap for the Electric Vehicle Industry (CREVI) 2023–2040 presents action plans for EVs and EV charging stations (EVCS), manufacturing, human resource development, and research and development to accelerate EV development and utilisation (DOE, 2023a). Furthermore, the CREVI 2023–2040 specifies penetration rate targets for two scenarios aligned with PEP 2023-2050: 10% by 2040 under the REF and 50% by 2040 under the CES (Table 5.4).

Table 5.4. Electric Vehicle and Electric Vehicle Charging Station Targets Under CREVI 2023–2040

	Short Term (2023–2028)	Medium Term (2029–2034)	Long Term (2035–2040)
Reference Scenario	EV: 311,700 EVCS: 7,400	EV: 580,500 EVCS: 14,000	EV: 852,100 EVCS: 20,300
Clean Energy Scenario	EV: 2,454,200 EVCS: 65,000	EV: 1,851,500 EVCS: 42,000	EV: 2,001,600 EVCS: 40,000

EV = electric vehicle, EVCS = electric vehicle charging station.
Source: Compiled by the IEEJ based on DOE (2023a).

The government's supportive measures for EVs have appeared to take effect. EV sales have gradually increased in recent years. The automotive manufacturing industry expects EV sales to grow by 7% in 2025, with an annual purchase volume of 20,000 units (4% of the estimated 500,000 vehicle purchases) (Monzon, 2025). However, the slow development of EVCSs may hinder EV adoption if consumers remain concerned about

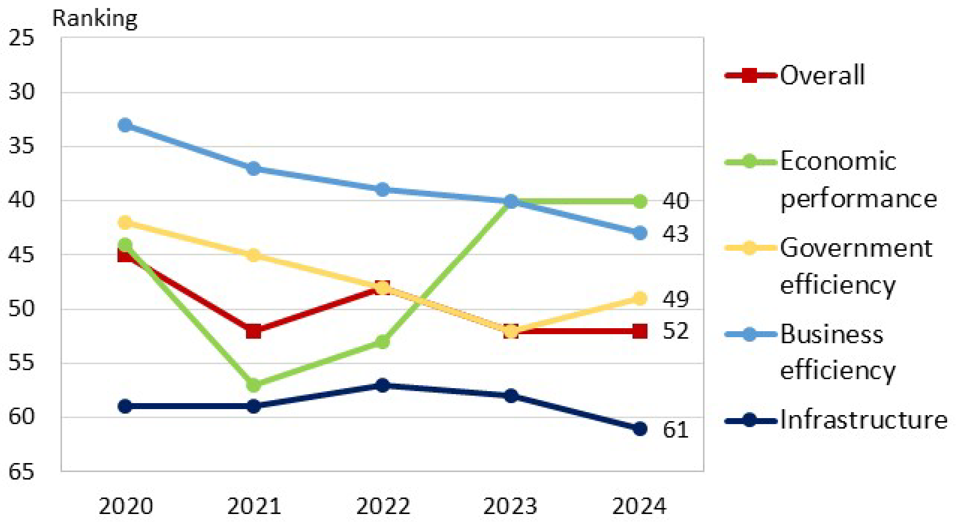
[20] The industrial and commercial companies include cargo logistics companies, food delivery companies, tour agencies, hotels, power utilities, and water utilities.
[21] Hybrid-electric vehicles were not covered by Executive Order No. 12 but were later included to be free from import duties for 5 years under Executive Order No. 62 issued in 2024.

finding charging stations when needed. As of 31 March 2025, 912 publicly accessible charging stations are operational nationwide, predominantly concentrated in the National Capital Region (DOE, 2025c). This figure is far below the target of 7,400 charging stations by 2028. Unless the charging network expands significantly, EV purchases are likely to be discouraged. This uncertainty in EV deployment also complicates forecasts for bioethanol demand.

3.1.2. Addressing market and investment barriers

Insufficient infrastructure development has deterred investment in the Philippines. According to the International Institute for Management Development (IMD) World Competitiveness Center (2024), the country ranked 52nd amongst 67 economies in overall competitiveness.[22] Its poor performance in infrastructure, ranked 61st, was a key factor bringing down its overall score (Figure 5.15). Notably, the Philippines has suffered from inadequate and poor-quality road and rail transport infrastructure (Navarro and Latigar, 2022). The lack of access to reliable public transport has led to a rise in the number of private vehicles, exacerbating traffic congestion, a pressing issue in the country.[23] Adequate infrastructure development will be critical for strengthening the country's competitiveness and attracting investment in bioenergy projects.

Figure 5.15. The Philippines' Competitiveness Ranking



Note: Competitive rankings are expressed as 1 for the most competitive and 67 for the least competitive.
Source: Compiled by the IEEJ based on data from IMD World Competitive Center (2024), pp. 68–69.

[22] IMD World Competitive Center (2024) assessed the competitiveness of 67 economies globally, considering four factors, i.e. economic performance, government efficiency, business efficiency, and infrastructure.
[23] It was reported that three cities – Davao, Metro Manila, and Caloocan – were listed as the top areas with the worst traffic congestion amongst 500 cities in 62 countries (Valmonte, 2025).

Acknowledging that the country lags behind its neighbours in infrastructure development, the previous Duterte administration attempted to address this issue. As a central measure, it initiated the 'Build, Build, Build' programme to boost public spending on infrastructure development. Most government projects under this programme were allocated to the transport and mobility sector, followed by urban development (Senate of the Philippines, 2022).

This infrastructure development programmes continues under the current Marcos administration. President Marcos, a former agriculture secretary, has prioritised building farm-to-market roads for easier transportation, which would increase local trade, enhance productivity, and lower transportation costs. He has also emphasised that agricultural infrastructure projects should be resilient to the negative impacts of climate change (Patinio, 2022).

Furthermore, to improve the legal environment for foreign investors, former President Duterte signed amended laws, namely the Public Service Act (Republic Act No. 11659) and the Foreign Investment Act (Republic Act No. 11647). Effective from April 2023, the Public Service Act permits 100% foreign ownership in public services sector previously capped at 40%, including railways, airports, expressways, and telecommunications (Medina, 2023). Similarly, the Foreign Investment Act opens all small- and medium-sized enterprises to 100% foreign ownership (Cervantes, 2022).

3.2. Recommendations for the development of the bioenergy supply chain

3.2.1. Exploring unutilised agricultural residues as a supplemental feedstock

Given the limited availability of biomass resources for biofuels, the Philippines has been looking for ways to address feedstock shortages. Agricultural residues and wastes should be explored as potential biomass resources because they are abundant, already available, do not compete with food production, and require no additional land development.[24] Utilising agricultural residues will also contribute to sustainable waste-to-energy. Specifically, rice straw and non-standard coconuts have been identified as underutilised resources with potential for bioenergy applications.

Rice straw

Rice straw can be utilised in multiple applications, such as feedstock for bioenergy, soil incorporation, composting, mushroom production, and papermaking (Nath et al., 2025). Table 5.5. shows the theoretical energy potential of crop residues in the Philippines. Theoretically, rice straw has the highest energy potential due to its large volume generated in rice production. However, the feasibility of using rice straw for bioenergy

[24] Quejada et al. (2021) estimated that raising the bioethanol blending target would require more sugarcane-dedicated land, which would decrease forest cover areas.

depends on the availability of an enabling technology to process it as an energy resource, the logistics throughout the supply chain, and the financial viability.

Table 5.5. Theoretical Energy Potential of Crop Residues in the Philippines

Crop	Residue	Residue-to-Crop Ratio	Lower Heating Value (MJ/kg)	Moisture Content %	Annual Crop Production (2023) (tonnes)	Annual Production of Residues (tonnes)	Energy Potential of Residues (TJ/year)
Rice	Rice straw	1	13	15	20,059,562	20,059,562	260,774
Rice	Rice husk	0.225	16.5	14	20,059,562	4,513,401	74,471
Coconut	Coconut shell	0.15	25.32	10	14,892,628	2,233,894	56,562
Coconut	Coconut husk	0.35	21.75	10	14,892,628	5,212,420	113,370
Sugarcane	Bagasse	0.29	16.56	18	21,650,938	6,278,772	103,976
Corn	Corn cob	0.27	12.6	15	8,405,445	2,269,470	28,595

MJ = megajoule, TJ = terajoule.
Source: Compiled and estimated by the IEEJ based on Ang et al. (2017), Table 25, p.191.

Rice straw has the potential to be utilised for second-generation bioethanol production. In the Philippines, the limited supply of sugarcane and molasses restricts domestic bioethanol production. Given concerns regarding food security and sustainability, first-generation bioethanol is not an appropriate option for future production. Therefore, feedstock for second-generation bioethanol must be carefully assessed, with close attention to the technologies currently under development. With continued technological progress, lignocellulosic biomass could help the country expand feedstock availability for bioethanol production over the long term. Amongst the various types of lignocellulosic biomass, rice straw is a promising supplemental feedstock.

Rice straw has been studied for its energy applications, and obstacles its conversion into bioenergy have been identified. The composition of rice straw, primarily cellulose (30%–47%), hemicellulose (10%–32%), and lignin (7%–26%), show promise for bioethanol but pose challenges for its adoption in bioenergy (Nath et al., 2025). Technological and economic challenges exist in the pretreatment process, which is essential for making rice straw fermentable for ethanol production. Physical, chemical, and biological pretreatments are conducted for bioethanol production from lignocellulosic biomass before the stages of saccharification, fermentation, distillation, and dehydration.[25] This pretreatment step adds high production costs and necessitates technological

[25] Physical pretreatment breaks the lignocellulose structure to increase the surface area of the biomass by physical and mechanical means, such as grinding and milling. Chemical pretreatment uses chemicals to delignify the biomass and make it more susceptible to enzymatic hydrolysis. Biological pretreatment uses ligninolytic microorganisms to modify the chemical composition and/or structure of lignocellulosic biomass and make it more suitable for enzyme digestion (Gatdula et al., 2021; Broda et al., 2022).

advancements to improve efficiency and productivity.[26] Additionally, rice straw has a high silica content, which may cause erosion problems in processing machines and boilers (Hung et al., 2020).

Managing rice straw also presents challenges. Burning rice straw in fields is a common practice, primarily due to the labour-intensive and unprofitable nature of manual collection, coupled with the low bulk density of rice straw in its loose form. If mechanical collection with balers were employed instead of manual labour, the bulk density of rice straw would increase. Enhancing its bulk density will be crucial for reducing storage and transportation costs.

Despite the existing challenges, technology for producing bioethanol from rice straw is on the horizon. For instance, in August 2022, Indian Oil began operating a second-generation ethanol biorefinery capable of processing 200,000 tonnes of rice straw annually to produce 30 million litres of ethanol (Praj, 2022). However, if rice straw becomes both technically and economically viable as a feedstock for bioethanol production, existing biorefineries will need to be retrofitted to accommodate the new material effectively.

Biogas derived from rice straw can also be harnessed as a fuel for heat and power generation. Anaerobic digestion is one viable method for converting rice straw into bioenergy (Grisolia et al., 2022).[27] Biomethane produced from rice straw is a sustainable fuel for biogas production and is effective for waste management. This technology is suitable for small-scale power plants and off-grid energy systems, thereby contributing to electrification in rural areas.

An additional benefit of utilising rice straw is its role in a circular economy as a sustainable and environmentally friendly resource. For instance, in Japan, a demonstration project aimed at developing a regional resource circulation system using locally collected rice straw has been, and will be, conducted in a rice-growing region from 2022 to 2029 (Kubota, 2024). This ongoing project intends to produce biofuels (biogas, green hydrogen, and green liquefied petroleum gas) and fertiliser from rice straw. From a long-term perspective, a system in which bioenergy is produced and consumed locally would particularly benefit remote areas, supporting universal energy access in the Philippines.

Non-standard coconuts for SAF production

As the leading coconut-producing nation, the Philippines is well positioned to use non-standard coconuts as a viable feedstock for SAF production. In March 2024, the International Civil Aviation Organization (ICAO) approved non-standard coconuts as a SAF

[26] The bioethanol production cost from rice straw is calculated to be about 1.8 times higher than that from sugarcane (Gatdula et al., 2021).

[27] Thermal conversion (combustion, pyrolysis, and gasification) or biochemical conversion (anaerobic digestion or co-digestion, fermentation, and transesterification) are used to produce bioenergy from crop residues (Grisolia et al., 2022).

raw material under the ICAO Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) framework (ICAO, 2024b). Non-standard coconuts are defined as inedible coconuts that are too small, spouted, cracked, or rotten. IRENA (2024b) reports that the Philippines has significant potential for SAF production from non-standard coconuts, estimating that SAF production could increase by 600,000 tonnes annually. Based on the general assumption that 30% of coconuts produced are non-standard, approximately 4.5 million tonnes of non-standard coconuts could be available in the country, considering a total coconut production of 14.9 million tonnes in 2023.

Innovative technologies for producing SAF from non-standard coconuts are paving the way for commercialisation. In June 2024, Green Power Development Corporation of Japan successfully produced 100% biomass-derived SAF, referred to as 'neat SAF', from non-standard coconut oil. The company is currently developing a supply chain in collaboration with Indonesia under the AZEC framework, aiming for commercialisation by 2030 (Green Power Development Corporation of Japan, n.d.). This newly developed technology can be applied to SAF production from non-standard coconuts in the Philippines. Leveraging international initiatives such as AZEC will enhance the possibility of utilising agricultural residues for bioenergy in the country.

The Philippines aims to lead the production of SAF from agricultural residues to meet demand and foster exports. The DOE has begun collaborating with academic institutions to explore potential feedstocks for SAF. One project aims to identify potential CORSIA-compliant feedstocks for SAF, whilst another focuses on demonstrating the production of CORSIA-eligible SAF derived from used cooking oil through the hydroprocessed esters and fatty acids process.[28] In addition, a feasibility study was conducted in Luzon to evaluate a biorefinery capable of producing commercial volumes of SAF from municipal waste, with operations expected to begin by 2025 (WasteFuel, 2021).

3.2.2. Improving productivity and logistics of feedstocks

Whilst pursuing the use of additional agricultural residues for bioenergy, measures to improve the productivity and logistics of crops currently used for energy should be explored simultaneously. Enhancing productivity will increase the availability of raw materials for bioenergy and likely provide greater income for farmers and environmental benefits for local communities.

Effective farming practices are essential for enhancing productivity. One viable and practical approach is further developing irrigation systems to positively impact productivity. In 2023, irrigated rice production accounted for 76.2% of total output in the Philippines, leaving 23.8% for rainfed rice (PSA, 2024a). The average rice yield for irrigated systems was 4.51 tonnes per hectare per year, compared with 3.34 tonnes per hectare

[28] Comments from the DOE at the expert meeting for this project held virtually on 16 April 2025.

for rainfed systems.

In contrast, sugarcane and coconut production are not as widely irrigated as rice. The government has already taken steps to tackle this issue. A total of 192 sets of irrigation facilities were delivered to sugarcane farms between 2016 and 2023 (SRA, 2024). This support was provided under the Block Farm Programme, which consolidates small sugarcane farms within a 2-km radius into a larger farm, with landowners retaining ownership of their small farms. However, the area covered by this programme represents only 2.5% of the total sugarcane harvested areas. For coconut, it has been less than a decade since the PCA began planning and supporting production through the establishment of irrigation systems (PCA, 2024a).[29] One of the obstacles for the coconut industry is the limited infrastructure supporting irrigation systems and farm-to-market roads (PCA, n.d.). In addition to the assistance already provided, the government needs to maintain consistent support and expand the implementation of irrigation systems so that sugarcane and coconut production can be strengthened and productivity enhanced.

Another suggestion for enhancing productivity is to replace the labour-intensive collection of agricultural residues with agricultural machinery. Mechanical collection and balers would be beneficial in field operations, aiding farmers in handling and transporting rice straw efficiently. Logistical strategies will also be necessary for effective operations. For example, collection points for raw materials can be centralised in designated areas, and farm-to-market roads should be adequately developed or upgraded to improve market access and reduce transportation costs.

3.2.3. Enhancing certainty in policy implementation and support measures for bioenergy development

The Philippines established its policy framework for biofuels in 2006; however, the biofuel blending targets were not implemented as planned. In general, uncertainty in policy implementation raises concerns amongst investors, as it impacts capital investment plans and corporate strategies. The landscape surrounding transport fuels has evolved since the enactment of the Biofuels Act. EVs have gradually gained market presence, and alternative fuels such as synthetic fuels have emerged. Meanwhile, current domestic biofuel feedstocks have proven inadequate to produce sufficient biofuels to meet the blending mandates. In light of advanced technologies and the availability of domestic raw materials for biofuel production, reasonable policy targets and the government's commitment to implementation will signal to the market the anticipated demand for biofuels. This predictability in policy implementation will assist biofuel producers in planning to secure the necessary feedstock and expand their biofuel production facilities accordingly.

Furthermore, the government is expected to provide technical assistance to strengthen

[29] The government started to plan the irrigation systems for coconut production in 2018 (Teves, 2018).

the bioenergy supply chain. The government's collaboration with academia and industry in research and development will enhance the productivity of biofuel feedstocks through breed improvement, suitable water treatment, and sustainable land management. Improving access to finance is also critical, particularly for biorefineries seeking to expand or upgrade their facilities or establish feedstock processing plants. Additionally, it is essential to enhance capacity building in bioenergy for local governments and communities. A bioenergy supply chain aimed at contributing to rural development and electrification will be a rational objective for local stakeholders.

Chapter 6
Conclusion and Recommendations

Country-specific conclusions and recommendations

1. Indonesia

Indonesia, as the largest bioenergy producer and consumer in ASEAN, has made notable strides in biodiesel development, largely driven by its abundant palm oil resources and a robust incentive framework centred on the crude palm oil (CPO) export levy. Whilst the biodiesel programme has nearly met its 2025 target ahead of schedule, other non-power bioenergy sectors, including bioethanol, biogas, and sustainable aviation fuel (SAF), lag behind due to structural, financial, and regulatory challenges. The CPO levy, managed by the Plantation Fund Management Board (BPDP), has proven instrumental in narrowing the cost gap between fossil fuels and biodiesel. However, no similar support exists for bioethanol, biogas, or SAF, resulting in slow development despite considerable resource potential from used cooking oil (UCO), palm oil mill effluent (POME), and agricultural residues.

Key policy targets, such as achieving a 5% SAF blend by 2025 and 50% by 2060, or implementing E10 for gasoline by 2029, remain ambitious given the existing infrastructure, feedstock, and cost constraints. The government has recognised that high costs, feedstock shortages, and underdeveloped infrastructure, particularly for biogas transmission, are the major barriers. Additionally, environmental and social concerns related to palm oil cultivation, such as deforestation and biodiversity loss, remain a critical obstacle for international credibility and market access.

To address these multifaceted issues, expanding the scope of the CPO levy is recommended to support not only biodiesel but also biogasoline, especially when derived from palm oil-related wastes like empty fruit bunches (EFB) and biogas, potentially improving cost-competitiveness. Reforming biomethane price regulations to reflect actual production costs is also essential to improve market feasibility.

Additional recommendations include incentivising UCO collection, scaling up domestic feedstock production – especially sugarcane for ethanol, as outlined in the 2022 Sugarcane Bioethanol Programme – and accelerating R&D on second-generation bioenergy technologies such as cellulosic ethanol, green diesel (hydrotreated vegetable oil), and CPO-based biogasoline. These advanced biofuels offer technological and environmental advantages, including compatibility with existing engines and lower life-cycle emissions, and should be prioritised for policy support and pilot deployment.

Furthermore, carbon pricing is suggested as a supplementary financial mechanism to stabilise and diversify funding sources beyond the volatile palm oil market. Timely implementation of carbon taxes or the expansion of the emissions trading scheme to the transport and industrial sectors could create a predictable demand signal for low-carbon fuels.

From an environmental perspective, reinforcing sustainability governance is vital. This includes stricter enforcement of deforestation moratoria and wider adoption of certification schemes such as the ISPO and RSPO standards. Continued monitoring and stakeholder engagement will be critical to ensuring that bioenergy development aligns with Indonesia's climate commitments and socio-environmental objectives.

Ultimately, an integrated policy approach – combining fiscal incentives, regulatory reform, technical innovation, and sustainability safeguards – is envisioned to unlock Indonesia's vast bioenergy potential beyond the power sector. Such an approach would reduce fossil fuel dependence, enhance energy security, and contribute to decarbonisation.

2. Malaysia

Malaysia's bioenergy supply chain has evolved substantially over the past two decades, driven by abundant oil palm biomass and supported by a progressive suite of energy policies aimed at sustainability, diversification, and industrial development. Despite having abundant biomass resources, estimated at over 160 million tonnes annually, mainly from oil palm residues such as EFB, PKS, mesocarp fibres, and POME, the actual contribution of bioenergy to Malaysia's primary energy mix remains low, at around 1.17% in 2021.

Key enabling policies such as the Renewable Energy Act (REA), the feed-in tariff (FIT) scheme, the National Biofuel Policy (NBP), and, more recently, the Malaysia Renewable Energy Roadmap (MyRER), the National Biomass Action Plan (NBAP), and the National Energy Transition Roadmap (NETR), have laid a strong regulatory foundation for biomass power and biodiesel deployment. Although small- and medium-scale biomass and biogas power plants emerged between 2011 and 2017 under the FIT scheme, biomass power development has since slowed due to limited FIT quotas, high capital and operational costs, capped project sizes, and tougher competition from lower-cost renewables such as solar PV.

In the biofuel sector, Malaysia's focus on palm-based biodiesel (PBBD) has led to the achievement of a B10 national blending mandate, though plans for B20 and B30 have faced infrastructure, economic, and policy delays. Whilst domestic biodiesel consumption continues to be supported through government subsidies financed by a palm oil levy, Malaysia's exports to the EU have declined due to the RED II restrictions on palm oil sustainability with indirect land-use change concerns. Biomass is also increasingly used for heating fuel and pellet exports, with Malaysia emerging as a significant global supplier of wood and palm-based pellets, primarily to Japan and Korea.

Nonetheless, Malaysia's biomass energy potential remains underutilised due to technical, policy, and market challenges. These include dispersed feedstock locations, high logistics costs, heavy reliance on imported technologies, misaligned policies, limited sustainability compliance capacity amongst smallholders, and a lack of investor confidence in the sector

To overcome these barriers, the following measures are recommended: (1) enhancing biomass system efficiency through targeted R&D, mechanised feedstock collection, and advanced conversion to bioenergy; (2) leveraging international finance and technology partnerships, such as Japan's Joint Crediting Mechanism; (3) improving governance through the creation of a dedicated Bioenergy Development Committee to coordinate stakeholders and oversee national strategies like the NBAP; (4) strengthening sustainability standards and traceability for both domestic use and export, especially by expanding MSPO and RSPO certification coverage; (5) stabilising market conditions with long-term instruments such as feed-in premiums, contracts-for-difference, biomass mandates, and green tax incentives; and (6) supporting biomass end-use through rural electrification, industrial boiler switching, public awareness campaigns, and workforce development via technical training.

The potential of biomass co-firing in coal power plants and the development of second-generation biofuels, such as SAF and biohydrogen, are also noteworthy. In the long term, Malaysia aims to bridge the gap between its vast theoretical biomass potential and actual utilisation by building robust supply chains, ensuring sustainability, and integrating bioenergy into its broader energy and industrial transformation. With coordinated policy measures, stronger market mechanisms, and international collaboration, Malaysia is well positioned to establish itself as a regional and global leader in sustainable bioenergy, contributing significantly to its renewable energy targets, economic resilience, and climate objectives.

3. The Philippines

The Philippines, with abundant agricultural residues such as rice husk, bagasse, molasses, and coconut oil, has strong potential to develop a robust bioenergy supply chain that can significantly support its energy security, rural development, and climate mitigation goals. The government has enacted supportive legislation, including the Biofuels Act of 2006 and the Renewable Energy Act of 2008, mandating biofuel blending and offering fiscal and non-fiscal incentives for renewable energy investments.

However, despite these policy ambitions and growing demand, the share of bioenergy in total energy supply and the power generation remains modest due to the persistent challenges in feedstock supply, processing, logistics, and the investment climate. Domestic production of bioethanol, primarily from molasses, has grown but remains insufficient, with bioethanol production covering only about 63% of the mandated 10% blend in gasoline as of 2025, necessitating substantial imports. Biodiesel capacity has expanded to meet higher blending mandates, but high feedstock costs for coconut oil hinder its competitiveness, leading to the suspension of higher blend implementation due to concerns over fuel prices and inflation.

The feedstock supply is constrained by low crop yields, senile coconut trees, climate vulnerability, smallholder fragmentation, and underdeveloped post-harvest infrastructure. For example, sugarcane yields are lower than those of regional peers, and coconut productivity is hampered by ageing trees and pest infestations. Seasonal availability, high transport costs, and inefficient residue management further limit supply reliability. Policy uncertainty, evident in the delayed implementation of blending targets and the growing focus on EVs, which may reduce liquid fuel demand in the future, poses additional barriers to long-term bioenergy planning. The Philippine Energy Plan (PEP) 2023–2050 outlines two development pathways – the Reference and Clean Energy Scenarios (CES) – with CES proposing increased biofuel blending (B5 by 2026) and higher renewable shares. Nevertheless, projections suggest that whilst biodiesel capacity may meet CES demand by 2030, bioethanol will still heavily rely on imports unless domestic production capacity expands significantly.

To address these challenges, recent policy changes have lifted a moratorium on applications for molasses-based ethanol facilities. Additionally, tapping underutilised biomass such as rice straw and non-standard coconuts is recommended to diversify feedstock sources. Rice straw, though challenging due to its high silica content and collection costs, holds significant potential for second-generation bioethanol and biogas production.

Meanwhile, non-standard coconuts were recently approved by the ICAO as an SAF feedstock under the CORSIA scheme, presenting new commercial opportunities. Enhanced productivity through irrigation, mechanisation, and coordinated farmer organisations is essential, as is investment in logistics infrastructure like farm-to-market roads. Strengthening R&D collaboration and supporting biorefineries with technical assistance are also vital. Additionally, ensuring policy consistency and foreseeability will help build investor confidence and encourage long-term planning. With these measures, bioenergy can play a transformative role in achieving national targets for energy diversification, climate resilience, and inclusive rural development.

In conclusion, whilst structural, technical, and regulatory barriers remain, with sustained policy support and strategic investment, particularly in expanding local feedstock supply, diversifying biomass inputs, and improving supply chain logistics, the Philippines could substantially scale up its bioenergy utilisation.

Cross-country common issues and recommendations

The discussions and analyses in this report have so far been presented on a country-by-country basis. The key findings and recommendations for Indonesia's non-power sectors, Malaysia, and the Philippines vary substantially, reflecting each country's specific circumstances regarding energy systems and biomass resources. However, a number of key elements are common across the countries. This final section considers the cross-country common issues derived from the country-specific analyses, including not only for those countries included in this Phase II report but also those discussed in the Phase I report (Ninomiya et al. 2025), specifically, Indonesia's power sector, Thailand, and Viet Nam.

Across Southeast Asia, the development of sustainable bioenergy supply chains in Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam faces a common set of key issues and challenges, as shown in Table 6.1 which are compiled from the results presented in the previous chapters. Whilst all five countries possess abundant biomass resources, from palm oil residues and sugarcane bagasse to rice husks, coconut shells, and wood waste, the utilisation of these resources remains uneven due to technical, economic, and institutional barriers.

Table 6.1. Summary of Key Issues and Recommendations for Bioenergy Supply Chain Development Across the Five Countries Considered in the Study Series

Country	Key Issues	Key Recommendations
Indonesia	- Heavy reliance on CPO for biodiesel; limited diversification into other biofuels such as bioethanol, biogasoline, biogas, and SAF - High production costs without subsidies - Fragmented supply chain for non-biodiesel bioenergy - Feedstock shortages for bioethanol such as molasses and corn - Limited rural infrastructure	- Expand use of the CPO levy to support biogasoline and other emerging biofuels - Improve rural infrastructure and logistics for feedstock collection - Incentivise second-generation biofuels from EFB and rice straw - Strengthen R&D and local SAF pilots
Malaysia	- Abundant palm oil residues but largely underutilised for domestic bioenergy - Focus on exports of pellets and palm biomass over domestic	- Develop local bioenergy demand through policy incentives - Promote industrial heat applications using palm

	energy use - Weak market demand and policy support for biomass in industrial heat - Slow technology transfer and commercialisation	biomass - Support technology adoption, such as pelletisation and gasification - Enhance sustainability certification for global markets
Philippines	- High biomass resource potential, such as coconut husks and rice straw, but lower utilisation - Poor rural logistics and lack of biomass collection systems - Regulatory and investment uncertainty - Weak coordination across government agencies	- Focus on community-based bioenergy projects, such as off-grid systems - Empower local governments in biomass programme execution - Improve collection and aggregation systems for agricultural residues - Provide financial guarantees for small bioenergy projects
Thailand	- Ambitious bioenergy targets like the Alternative Energy Development Plan 2037 but large supply-demand gaps - Regulatory complexity and market fragmentation - Overlap of feedstock use between power generation and industrial heat - Inadequate coordination amongst stakeholders	- Strengthen supply chain coordination and market platforms - Streamline and clarify the regulatory framework for bioenergy - Tailor quality standards to local conditions - Promote cross-sector planning for feedstock allocation
Viet Nam	- Strong biomass potential, for example rice straw, bagasse, and wood waste, but underdeveloped supply chains - Limited financial support and high risk perception amongst investors - Weak policy enforcement and institutional capacity at the local level	- Enhance policy predictability and implementation - Attract international capital for bioenergy development - Develop localised biomass supply chains for CHP - Support provincial-level engagement in bioenergy deployment

Source: Compiled by authors.

One of the primary issues is feedstock accessibility. Although Indonesia and Malaysia are global leaders in palm oil production, seasonal variability, scattered production sites, and logistical inefficiencies hinder consistent and scalable biomass collection. In Viet Nam and the Philippines, significant amounts of agricultural waste remain uncollected due to the lack of adequate aggregation and transport infrastructure. Furthermore, feedstock competition with the food, chemical and export industries, particularly for molasses and cassava, has constrained the availability of raw materials for bioethanol and biogas production. These supply challenges are compounded by weak and fragmented supply chain infrastructure.

Across all countries, collection, storage, and transport systems remain underdeveloped. In Indonesia and the Philippines in particular, the cost of moving bulky and low-energy-density biomass from rural areas to processing hubs often renders projects commercially unviable. Though Thailand and Viet Nam have made better progress in pelletising and exporting biomass, they still face domestic supply–demand imbalances, notably in provinces with high energy demand but limited local biomass supply.

The lack of economic competitiveness of bioenergy relative to fossil energy also remains a substantial barrier observed consistently across the region. Bioenergy production, particularly for second-generation biofuels, often exceeds the market price of fossil fuels. Indonesia's success with biodiesel was made possible through the CPO export levy, which subsidises the price differential between biodiesel and conventional diesel. However, similar support mechanisms are largely absent for other bioenergy types such as bioethanol, biogas, and SAF. In many cases, even with government price controls, as seen with biogas and biomethane in Indonesia, actual production costs far exceed the regulated tariffs, discouraging private investment. The situation is similar in the Philippines and Viet Nam, where high capital costs, limited economies of scale, and uncertain returns limit commercial viability. Whilst Thailand has adopted FITs and set ambitious targets under its Alternative Energy Development Plan, implementation lags due to regulatory and financial complexity.

Across the region, unclear or inconsistent policy frameworks further restrict progress. Although national energy strategies and plans typically include renewable energy targets, the integration of bioenergy within these energy strategies and plans often lacks coherence and enforcement. For instance, Indonesia's bioenergy goals for sectors beyond biodiesel remain vague, despite strong policy rhetoric. In Malaysia and the Philippines, inter-agency coordination challenges and frequent policy shifts have created uncertainty for investors and developers. Even where supportive policies are in place, such as Indonesia's mandate for co-firing biomass in coal plants or Thailand's industrial bioenergy targets, local implementation tends to be hindered by inadequate regulatory alignment, weak institutional capacity, and inadequate funding for monitoring.

Market conditions also present challenges. In all five countries, investors face elevated risks due to fluctuating fossil fuel prices, limited access to long-term PPAs, and nascent or underdeveloped carbon credit markets. The absence of reliable market signals and financial guarantees discourages innovation and prevents the scale-up of new technologies such as gasification, cellulosic ethanol, and drop-in low-carbon fuels.

Moreover, the lack of sustainability certification and traceability systems in many domestic markets limits export potential, especially for biodiesel and wood pellets, which are subject to increasing environmental scrutiny from international buyers. Indonesia's palm oil-based biofuels, for instance, have faced criticism over land-use change, deforestation, and high life-cycle emissions, which affect their acceptability in global SAF markets. These environmental concerns, unless otherwise addressed through stronger standards and transparent enforcement, could significantly constrain the role of bioenergy in the region's decarbonisation pathway.

Based upon the discussion above, several recommendations are presented as common solutions across the countries considered in this study.

First, developing integrated and decentralised supply chain infrastructure is critical. Establishing biomass collection hubs and pelletisation facilities near production zones can drastically reduce transport costs and minimise feedstock degradation. Improving rural infrastructure, including roads and mini-grid connectivity, would enable better access to bioenergy markets for smallholders and cooperatives.

Second, governments need to expand and diversify financial incentives. Building on the CPO levy model in Indonesia, targeted subsidies or fiscal instruments such as carbon pricing and green bonds should be introduced to support underdeveloped bioenergy segments, particularly biogas, second-generation ethanol, and SAF. Policy predictability is crucial, as long-term commitments with clear timelines and performance-based rewards can unlock private capital and reduce investor risk.

Third, countries should adopt more inclusive and technology-neutral policy frameworks. Rather than focusing on a narrow set of technologies, policy design should support a diverse portfolio of solutions, such as pelletisation, gasification, anaerobic digestion, hydrothermal liquefaction, that is tailored to local feedstocks and end-use requirements to maximise the use of locally available bioenergy. This includes integrating bioenergy into broader national energy plans, industrial decarbonisation strategies, and rural development programmes.

Fourth, enhancing sustainability standards and certification is vital for both domestic trust and international credibility. Governments should work with private actors to establish robust, transparent, and harmonised standards aligned with international benchmarks. Technical assistance and funding should be provided to help small-scale producers and processors meet these standards.

Fifth, countries should invest in research and development to accelerate the commercialisation of second-generation and advanced biofuels. Regional collaboration, particularly through platforms like AZEC, can foster shared knowledge, standardisation, and joint ventures that pool risk and scale solutions.

Sixth, promoting local participation through community-based bioenergy initiatives can increase social acceptance and distribute economic benefits. Decentralised projects, such as village-level biogas systems or municipal waste-to-energy plants, should be supported through concessional financing, capacity building, and public–private partnerships led by government.

Finally, country-specific measures could leverage each country's advantages in bioenergy production. Indonesia could continue to scale biodiesel whilst expanding support to biogas and SAF through fiscal reform and R&D. Malaysia could capitalise on palm oil infrastructure to diversify into pellet and ethanol production. The Philippines could focus on mobilising underused feedstocks such as coconut husks and rice straw for rural bioenergy and off-grid systems. Thailand could streamline regulation, improve inter-agency coordination, and match ambitious targets with execution. Viet Nam could strengthen policy coherence, expand local government involvement, and attract international investment for biomass power and biofuel production.

Bioenergy could offer a critical opportunity for Southeast Asian countries to reduce GHG emissions, enhance energy security, and generate rural employment. However, without significant improvements in feedstock logistics, economic incentives, policy clarity, investment frameworks, and environmental governance, bioenergy will remain a largely untapped resource in the region. By adopting an integrated, inclusive, and regionally coordinated approach, these countries can unlock the full potential of bioenergy as part of a sustainable energy transition.

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