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Development of the Bioenergy Supply Chain in AZEC Partner Countries

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List of Abbreviations and Acronyms

ADB	Asian Development Bank
AEDP	Alternative Energy Development Plan (Thailand)
ASEAN	Association of Southeast Asian Nations
AZEC	Asia Zero Emission Community
B	Thai baht
BOI	Thailand Board of Investment
BPP	Electricity generation basic cost (Biaya Pokok Penyediaan Pembangkitan, Indonesia)
CFB	Circulating fluidised bed (boiler)
CFPP	Coal-fired power plant
CHP	Combined heat and power (system)
D	Vietnamese dong
DEA	Danish Energy Agency
DEDE	Department of Alternative Energy Development and Efficiency (Thailand)
DEN	National Energy Council (Indonesia)
EFB	Empty fruit bunches
EGAT	Electricity Generating Authority of Thailand
EMR	Ministry of Energy and Mineral Resources (Indonesia)
ENCON	Energy Conservation Promotion Fund (Thailand)
EPEC	Energy Policy Executive Committee (Thailand)
ERC	Energy Regulatory Committee (Thailand)
EREA	Electricity and Renewable Energy Authority (Viet Nam)
EV	Electric vehicle
EVN	Vietnam Electricity
FAO	Food and Agriculture Organization of the United Nations
FIT	Feed-in tariff

FITF	Fixed-based Tariff (Thailand)
FITV	Variable-based Tariff (Thailand)
FSC	Forest Stewardship Council
GDP	Gross domestic product
GHG	Greenhouse gas
GW	Gigawatt
GWh	Gigawatt hour
GWh_{th}	Gigawatt hour of thermal
ha	Hectare
HBA	Reference Coal Price (Harga Batubara Acuan, Indonesia)
HTI	Industrial Plantation Forest (Indonesia)
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
IRENA	International Renewable Energy Agency
JCM	Joint Crediting Mechanism
JETP	Just Energy Transition Partnership
kcal	Kilocalorie
ktoe	Kilotonnes of oil equivalent
kW	Kilowatt
kWh	Kilowatt hour
MWh	Megawatt hour
LASUCO	Lam Son Sugar Cane Joint Stock Corporation
LCOE	Levelised cost of electricity
LULUCF	Land use, land use change, and forestry
m^3	Cubic metre
MJ	Megajoule
MEMR	Ministry of Energy and Mineral Resources (Indonesia)
MT	Million tonnes
Mtoe	Million tonnes of oil equivalent

MOIT	Ministry of Industry and Trade (Viet Nam)
MW	Megawatt
MWe	Megawatt electricity
MWh	Megawatt hour
MWh_{th}	Megawatt hour of thermal
NCV	Net calorific value
NEP	National Energy Policy (Indonesia)
NDC	National determined contribution
NHCO	National Health Commission Office (Thailand)
O&M	Operation and maintenance
PC	Pulverised coal-fired (boiler)
PDP	Power Development Plan
PEFC	Program for Endorsement of Forest Certification (Viet Nam)
PKS	Palm kernel shell
PLN	Perusahaan Listrik Negara (state-owned electricity company in Indonesia)
PLN EPI	PT PLN Energi Primer Indonesia
PPA	Power Purchase Agreement
R&D	Research and development
Rp	Indonesian rupiah
RUEN	General Plan for National Energy (Indonesia)
RUPTL	Electricity Supply Business Plan (Rencana Usaha Penyediaan Tenaga Listrik, Indonesia)
SLVK	Timber Legality Assurance System (Sistem Verifikasi Legalitas Kelestrian, Indonesia)
Solar PV	Solar photovoltaic
SPP	Small Power Producer
t	Tonne
t-CO_2	Tonne of CO_2 equivalent
TJ	Terajoule

UNFCCC	United Nations Framework Convention on Climate Change
US$	US dollar
VFCS	Vietnam Forest Certification System
VSPP	Very Small Power Producer

Executive Summary

Amid the global movement toward decarbonising economies, major multinational corporations are intensifying efforts to decarbonise their supply chains. As a result, demand for locally produced renewable energy and carbon-free fuels is rising steadily amongst manufacturing enterprises operating in Southeast Asia. To assess both the current landscape and future potential of bioenergy in the region, it is essential to collect and analyse comprehensive, bioenergy-related data.

This report has two primary objectives. The first is to collect and analyse information and data on bioenergy resources in Southeast Asia, develop a comprehensive mapping of bioenergy supply and demand in the region – focusing on Indonesia, Thailand, and Viet Nam – and identify priority areas for further promotion of bioenergy use. The second objective, based on the findings of the first, is to propose feasible approaches for developing the bioenergy supply chain and to present specific recommendations for effective bioenergy utilisation in each country.

In **Indonesia**, the analysis shows that, in most provinces, biomass resource availability is projected to exceed the biomass demand required for co-firing in on-grid coal-fired plants by 2030. However, in provinces with high electricity demand, sawdust supply is insufficient to meet co-firing needs. Moreover, the bulky nature of biomass feedstock poses storage and transportation challenges. While the supply of palm kernel shells is currently sufficient to meet export demands, it is unlikely to accommodate a significant increase.

To address these issues, the report recommends the pelletisation of biomass feedstock near production areas as a practical solution to storage and transport constraints. Two business models for co-firing in coal-fired plants are proposed for Indonesia, both of which require streamlined and traceable systems for biomass collection and distribution.

In **Thailand**, the biomass potential is similarly high, estimated at approximately 69.92 million tonnes of oil equivalent annually. Bioenergy use in the country revolves around three main pillars: biomass power plants, industrial heat applications, and biofuels. However, each is at a different stage of development. Although Thailand has made commendable progress in biomass utilisation, a significant gap remains between the current status and the ambitious targets set for 2037, suggesting a major supply–demand imbalance in the 2030s.

The development of a robust bioenergy supply chain in Thailand faces numerous challenges across technical, regulatory, and market dimensions. The report offers several recommendations, including strengthening supply chain management linked to sustainable biomass cultivation, streamlining regulatory frameworks, enhancing market coordination via a common platform, and expanding quality standards to better suit local conditions.

In **Viet Nam**, the country possesses abundant biomass resources, particularly from agricultural and woody residues, though current utilisation remains limited. While supply chains for bagasse-fired combined heat and power (CHP) systems and wood pellet exports are well established, supply chains for rice husk, rice straw, and woody biomass remain underdeveloped, despite their considerable potential for energy use.

The collection, transportation, and efficient storage of widely scattered biomass residues remain significant challenges. In addition, current government support is insufficient to stimulate large-scale investment in bioenergy for power, heat, and transport fuel applications. Uncertainty in policy implementation contributes to perceived investment risks, and most bioenergy projects struggle to attain commercial viability without state support.

To address these barriers, the report recommends the implementation of sound policies and regulatory frameworks that provide predictability for investors. Attracting long-term international capital will be crucial for scaling bioenergy development. Furthermore, active participation by local governments and communities in bioenergy supply chain development should be encouraged to ensure that such projects yield tangible local economic benefits.

Finally, the report identifies common cross-country challenges based on the country-specific findings and presents overarching recommendations. These aim to address a fundamental question: What policies, regulations, markets, technologies, and business models are most suitable for developing effective and sustainable bioenergy supply chains in Southeast Asia?

Chapter 1
Introduction

In the global trend towards decarbonisation of the economy, major multinational corporations are making strong efforts to decarbonise their supply chains. As a result, demand for locally produced renewable energy and carbon-free fuels is increasingly rising for manufacturing enterprises operating in Southeast Asia. However, Southeast Asian countries are generally behind in deploying wind and solar photovoltaic (solar PV) generation, which have been leading renewable energy resources in other regions.

Under these circumstances, it is crucially important to consider the effective utilisation of potentially abundant bioenergy resources in Southeast Asia. Bioenergy is inherently a non-intermittent energy source that could play a critical role in providing the flexibility required by power grids in accommodating increased shares of variable renewable energy, namely wind and solar PV.

On the other hand, bioenergy resources are substantially diverse, thus requiring different approaches for their effective utilisation. There are various barriers, such as securing land for cultivation and appropriate cooperation and collaboration amongst stakeholders, and in some cases, huge investments are required. Therefore, it is essential to collect and analyse bioenergy-related information to evaluate the actual situation and potential of bioenergy use in Southeast Asia.

A simple question here arises: Why not use bioenergy? This is immediately followed by the subsequent: Why not develop a bioenergy supply chain? With the aim of ultimately answering these questions, the objectives of this report are as follows. First is to collect and analyse information and data related to bioenergy resources in Southeast Asia, create an overall mapping of bioenergy supply and demand in the countries concerned in the region, namely Indonesia, Thailand, and Viet Nam, and identify focus areas for the further promotion of bioenergy use. Second, following the outcome of the first objective, is to consider a feasible approach for developing the bioenergy supply chain for the effective utilisation of bioenergy in the region and present specific recommendations for the countries concerned.

The structure of this report is as follows. After this introduction, Chapter 2 describes the research scope and methodologies employed in the report. The following Chapters 3, 4, and 5 are the central parts of this report, offering country-specific findings for Indonesia, Thailand, and Viet Nam, respectively. They are further divided into several sections. The first section is 'an overall mapping of bioenergy supply and demand at present', including policy and regulatory framework, resource availability, current commercial production, existing supply chain, cost, advantages of bioenergy in comparison to other available energy resources, and the selection of bioenergy focused on in the subsequent sections. This section serves as a prologue, providing readers with the current bioenergy situations of these countries and the reasons why bioenergy matters. The second section is concerned with the 'expected supply and demand of the focused bioenergy in 2030', identifying the expected gaps between the supply and demand of bioenergy in 2030.[1] This part may also include a cost estimation of bioenergy to highlight the issue of the economic competitiveness of bioenergy as well as the supply-demand gap.

Understanding the expected supply-demand gap in 2030, the third section presents the requirements for the development of the supply chain in order to fill the supply-demand gap for each country. This subsection is a prominent part of this report, indicating how to develop the supply chain of bioenergy in the countries by addressing three main barriers: technical barriers, policy/regulatory barriers, and market/investment barriers.

These barriers vary significantly depending upon the countries' specific circumstances. Nonetheless, it can be generally said that the technical barriers relate to availability, maturity, compatibility with the existing system, the workforce, and the cost of the range of technologies at each stage of the bioenergy supply chain, such as collection, transportation, storing, conversion, and end-use. The policy and regulatory barriers can be driven by a lack of robust policies with clear quantitative targets underpinned by policy incentives to promote bioenergy under proper regulatory and legal frameworks within an integrated energy system. Accordingly, the existing policy and regulatory frameworks themselves might be an obstacle to the development of bioenergy, calling for regulatory reform. Issues related to sustainable/quality standards certification could also be considered here. Finally, market/investment barriers could be highly related to the existing market structure and associated financial uncertainties of the existing business model for bioenergy.

Chapter 6 ends the report by presenting recommendations in two parts. Firstly, it briefly summarises the country-specific recommendations, and secondly, it provides cross-country recommendations derived from the discussions in the previous chapters.

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[1] For Thailand, 2037 is adopted in place of 2030 since the governmental targeted year is defined to be 2037 rather than 2030.

Chapter 2
Scope and Methodology

The scope of this report is formally the development of the bioenergy supply chain in Asia Zero Emission Community (AZEC) partner countries, specifically Australia, Brunei Darussalam, Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Philippines, Singapore, Thailand, and Viet Nam. However, due to limited resource availability in FY2023, the scope is narrowed to Indonesia, Thailand, and Viet Nam in the first year of the research. This implies that upon completion of the research in FY2023, the scope could be extended to other countries in the AZEC in the subsequent year.

Throughout this report, bioenergy is defined as 'energy content in solid, liquid, and gaseous products derived from biomass feedstocks, including solid bioenergy, liquid biofuels, and biogases, but excluding hydrogen produced from bioenergy, as well as synthetic fuels made with carbon dioxide (CO_2) feedstock from a biomass source' (IEA, 2023b). For Indonesia, the scope is limited to the co-firing of bioenergy in coal power plants, given the substantially large potential of bioenergy in Indonesia. Other bioenergy, such as biogas and biofuel, could be included in the scope of the research in the subsequent year.

The methodology employed in this report is mainly a literature review involving an extensive study of published reports, official documents, books, statistics, and any other documents related to bioenergy. To understand the actual circumstances of bioenergy supply and demand in the countries concerned, site visits were conducted as needed. Furthermore, to strengthen and support the literature review, questionnaire surveys were conducted in certain cases by sending questionnaires directly to bioenergy stakeholders via email. In parallel, a series of interviews with a range of stakeholders was conducted to reflect their views in this report. The stakeholders included bioenergy producers, bioenergy traders, and biomass power plant developers and operators.

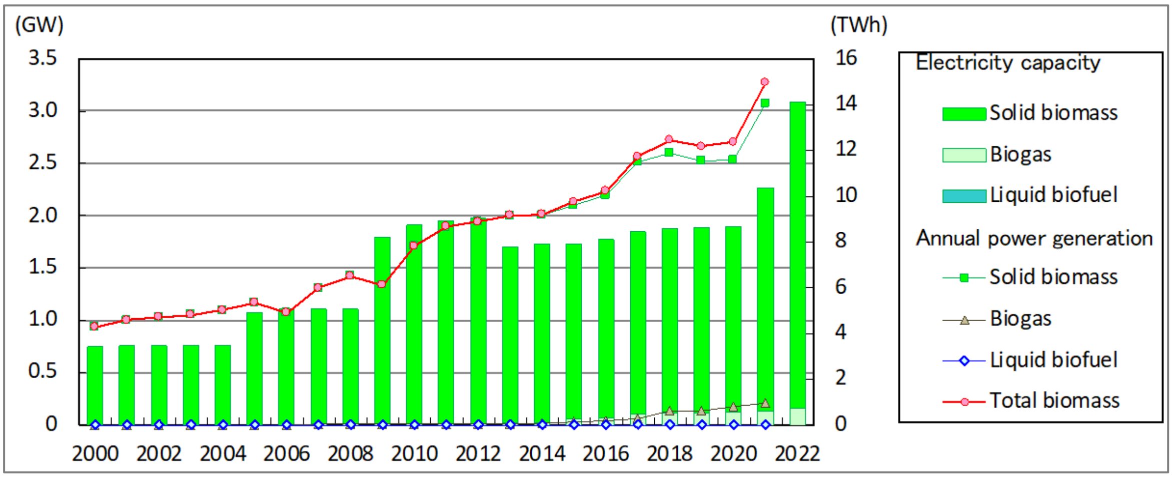
An expert group consisting of a number of bioenergy experts from Indonesia, Thailand, and Viet Nam was established to ask them to review and comment on the output from the research on a regular basis, ensuring that the research outcomes adequately reflect the various perspectives of the countries and avoid any biased views from a single standpoint.

Chapter 3
Findings: Indonesia

Indonesia marked an annual GDP growth rate of 5.3% in 2022, recovering from negative growth (-2.1% in 2020) during the COVID-19 pandemic (World Bank, n.d.-a) despite declines in the prices of Indonesia's main export commodities, such as coal and crude palm oil (ESDM Directorate of Minerals and Coal, n.d.).

Biomass is an important renewable energy source in Indonesia. Whilst traditional biomass use for heat has constantly decreased since 2008 (ESDM, 2023), Indonesia has promoted biomass use in the transport and power generation sectors. With 3.1 gigawatts (GW) in installed capacity, biomass accounted for 5.6% of the power generation mix, exceeding the share of geothermal power (5.15%) in 2022 (IEA, 2023a). (Figure 3.1)

Figure 3.1. Biomass Power Trends in Indonesia



GW = gigawatt, TWh = terawatt hour.
Source: IRENA (2023) and IEA (2023a).

From 2010 to 2021, Indonesia increased its share of coal-fired power generation by 1.5 times against a 1.8-time increase in total power generation. With coal accounting for 61.5% of its power mix, Indonesia needs to decarbonise its coal-fired power fleet to achieve carbon neutrality in 2060. The government is currently implementing a plan to co-fire biomass in its coal-fired power plants, which will require a great amount of biomass feedstock. This chapter will focus on the supply-demand balance of biomass in the context of co-firing biomass with coal in line with the roadmap outlined by

Perusahaan Listrik Negara (PLN), the state electric power company.

3.1. Overall Mapping of bioenergy supply and demand at present

3.1.1. Policy and regulatory framework

Indonesia's climate targets

On 23 September 2022, Indonesia submitted its Enhanced Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC), a revision to its Updated NDC submitted in 2021. This revision increased its unconditional emission reduction target from 29% to 32% below the business-as-usual (BAU) scenario, and its conditional target from 41% to 43% below BAU, including emissions from land use, land use change, and forestry (LULUCF). The Enhanced NDC is the transition towards Indonesia's Second NDC, which will be aligned with the Long-Term Low Carbon and Climate Resilience Strategy (LTS-LCCR) 2050, which has a vision to achieve net-zero emissions by 2060 or sooner.

Biomass-related targets

Under Government Regulation Number 79 of 2014 on the National Energy Policy (NEP14), Indonesia aimed to increase the share of renewable energy in its primary energy mix to 23% by 2025 and 31% by 2050, with around 10% from bioenergy.

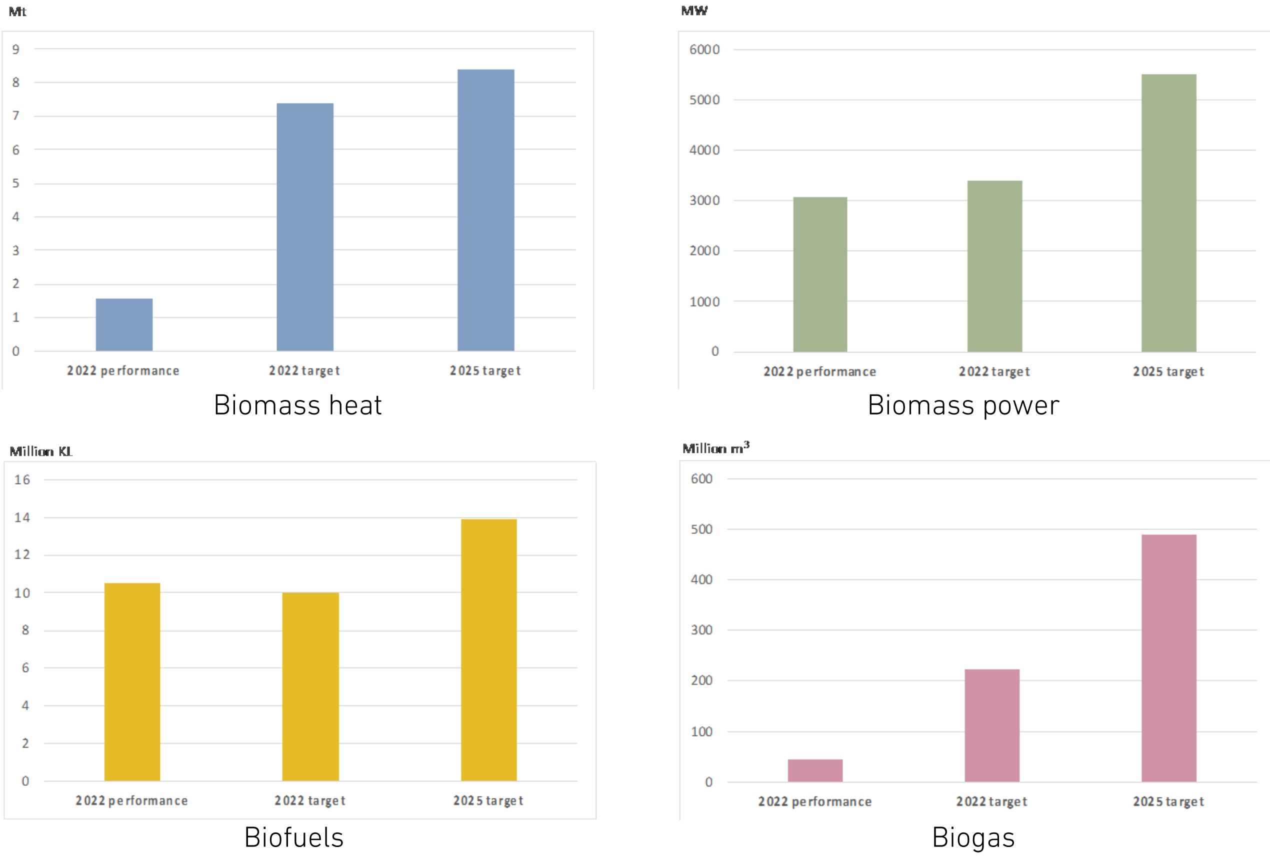
In 2017, Indonesia introduced its General Plan for National Energy (RUEN), which estimated that the capacity of Indonesia's new and renewable energy power plants would increase from 8.6 GW in 2015 to 45.2 GW in 2025 and to 69.7 GW in 2030. Given that 23% of the primary energy mix would be renewable energy in 2025 under NEP14, renewable energy was projected to amount to 92.2 million tonnes of oil equivalent (Mtoe), of which 69.2 Mtoe would be used to generate electricity. Bioenergy would account for 5.5 GW (12.2%). In the non-electricity sector, the biofuel supply was projected to be 13.9 million kilolitres (kL), and biomass for other use and biogas were estimated at 8.4 million tonnes and 489.8 million cubic metres, respectively.

However, having continuously failed to reach its annual renewable energy deployment target, Indonesia has decided to abandon the aforementioned target. The National Energy Council (DEN) plans to revise the target of the new renewable energy mix for 2025 to 17%–19% by renewing the National Energy Policy. Specific targets for bioenergy are yet to be revealed (Antara News, 2024).

Indonesia has promoted biomass use to decarbonise power generation, industrial heat, and mobility as an alternative to conventional gas. The RUEN outlines annual targets for each use; however, all targets except for that for biofuels were underachieved in 2022 (DJ-EBKTE, 2022), as with the overall renewable energy target.

It is becoming increasingly critical for Indonesia to find effective ways to fully and sustainably harness its biomass resources (Figure 3.2).

Figure 3.2. Current Gaps with Former Near-term Targets



Note: The 2025 target is based on Government Regulation PP 79/2014.
Source: Compiled by the Institute of Energy Economics, Japan (IEEJ) based on DJ-EBKTE (2022).

Policies to promote biomass power

Based on the RUEN, PT PLN developed the 2021–2030 Electricity Supply Business Plan (Rencana Usaha Penyediaan Tenaga Listrik, RUPTL), which was approved by the Minister of Energy and Mineral Resources and issued in 2021. Also called the 'Green RUPTL', RUPTL 2021–2030 features lower demand growth projections (at an average growth rate of 4.9% per year across the next 10 years compared to 6.4% in the previous RUPTL 2019–2028 and an increased share of renewable energy in new power generation capacity (40,575 MW). It also aims to replace diesel plants with renewable power plants in accordance with the local renewable energy potential (Table 3.1).

Table 3.1. Projections of New Installed Renewable Capacity Based on a 23% Target

(MW)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Geothermal	136	108	190	141	870	290	123	450	240		3,355
Hydropower	400	53	132	87	2,478	327	456	1,611	1,778		9,272
Mini/micro hydro	144	154	277	289	189	43	-	2	13	6	1,118
Solar PV	60	287	1,308	624	1,631	127	148	165	172	157	4,680
Wind	-	2	33	337	155	70	-	-	-	-	597
Biomass/ waste	12	43	88	191	221	20	-	15	-	-	590
EBT base power	-	-	-	-	-	100	265	215	280	150	1,010
Renewable peaker plants	-	-	-	-	-	-	-	-	-	300	300
Total	752	648	2,028	1,670	5,544	978	991	2,458	2,484	3,370	20,923

Source: Compiled by the IEEJ based on the RUPTL 2021–2030.

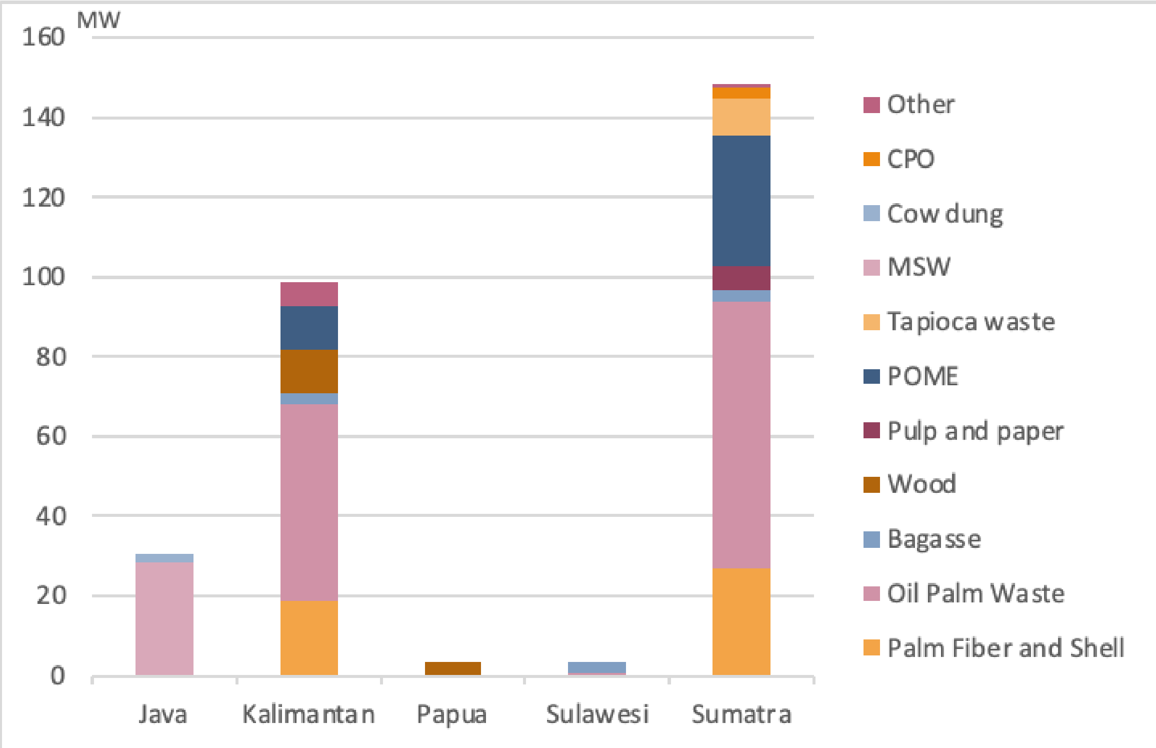
The most recent legislation to promote renewable energy deployment is Presidential Regulation No. 112 of 2022 on the Acceleration of Renewable Energy Development for Electric Power Monitoring (PR 112/2022), enacted in September 2022. PR 112/2022 (1) bans the development of new coal power plants and mandates the Ministry of Energy and Mineral Resources (MEMR) to prepare a roadmap that will accelerate the termination of coal-fired power plants operated by PLN and/or independent power producers (IPPs); (2) introduces a ceiling price for the renewable energy tariff that varies according to the type of energy source; (3) implements a direct appointment and direct selection (tender) process to streamline the purchasing process of renewable energy; and (4) enables the government to grant incentives for the development of renewable energy power plants.

Status of biomass power generation

As of 2022, Indonesia had 3,086 MW of biomass power plants, with 233 MW on-grid and 2,853 MW off-grid. Off-grid biomass power plants account for most of the biomass power generation in Indonesia. These include on-site power generation for industrial use, such as in the pulp and paper and sugar and palm oil industries.

On-grid biomass power plants cover less than 8% of total biomass power. Various types of biomass feedstock are utilised according to local availability. Oil palm residue (116 MW) and palm oil mill effluent (44 MW) in Kalimantan and Sumatra accounted for more than half of the on-grid biomass power plants. In Java, municipal solid waste accounted for 28 MW out of a total of 30 MW on the island (Figure 3.3).

Figure 3.3. On-grid Biomass Power Plants in Operation, 2022



CPO = crude palm oil, MSW = municipal solid waste, POME = palm oil mill effluent.
Source: Compiled by the IEEJ based on DJ-EBKTE (2022).

Biomass co-firing mandate

Minister of Energy and Mineral Resources (MEMR) Regulation No. 12 of 2023 on Biomass Co-firing in Existing Coal-fired Power Plants (CFPPs) regulates the use of biomass and encourages community economic development through the provision of biomass as a blending fuel in existing coal-fired power plants. RUPTL 2021-2030 contains a plan to co-fire biomass in coal-fired power plants. The plan identifies 18,895 MW of installed capacity of coal-fired power plants located in 52 locations to implement biomass co-firing. PLN is committed to co-firing 10%, 30%, and 70% of the biomass in coal-fired power plants using pulverised coal (PC), circulating fluidised beds (CFB), and stoker technologies, respectively. This will require up to 10.2 million tonnes of biomass fuel per annum, according to PLN's calculations (Figure 3.4 and Table 3.2).

Figure 3.4. PLN's Biomass Co-firing Plan

Source: PLN EPI (2024).

Table 3.2. List of Coal-fired Power Plants Under Co-firing Programmes

	Name of CFPP	Boiler Type	Biomass Feedstock Utilised	Planned Co-firing Rate (2030)
1	Paiton 1-2	PC	Pellet, sawdust	10%
2	Pacitan	PC	Sawdust	10%
3	Jeranjang	CFB	Solid recovered fuel	30%
4	Suralaya 1-4	PC	Rice husk, sawdust	10%
5	Ketapang	CFB	PKS	30%
6	Sanggau	Stoker	PKS	70%
7	Rembang	PC	Wood pellet	10%
8	Anggrek	CFB	Woodchip lamtoro	30%
9	Suralaya 5-7	PC	Sawdust	10%
10	Labuan	PC	Sawdust	10%
11	Lontar + Lontar extension	PC	Refuse derived fuel, water hyacinth	10%
12	Adipala	PC	Wood pellet	10%
13	Pelabuhan Ratu	PC	Sawdust	10%
14	Ropa	Stoker	Wood pellet	70%
15	Bolok	CFB	Woodchip	30%
16	Paiton 9	PC	Sawdust	10%
17	Barru	CFB	Sawdust	30%
18	Tembilahan	Stoker	Woodchip	70%
19	Indramayu	PC	Wood pellet	10%
20	Nagan Raya	CFB	PKS	30%

	Name of CFPP	Boiler Type	Biomass Feedstock Utilised	Planned Co-firing Rate (2030)
21	Tarahan	CFB	Woodchip	30%
22	Sintang	Stoker	PKS	70%
23	Belitung	CFB	PKS	30%
24	TL.Balik Papan	CFB	PKS	30%
25	Tenayan	CFB	PKS	30%
26	Kaltengsel	CFB	N.A.	30%
27	Pulang Pissau	CFB	Woodchip and sawdust	30%
28	Kendari (Nii Tanasa)	Stoker	PKS	70%
29	Bengkayang	CFB	PKS	30%
30	Bukit Asam	PC	Sawdust	10%
31	Tarahan Baru	CFB	Woodchip	30%
32	Tidore	Stoker	Coconut shell	70%
33	Asam asam	PC	Sawdust	105
34	Berau	Stoker	Woodchip kaliandra	70%
35	Talaud	Stoker	RDF	70%
36	Bangka Baru	CFB	PKS	30%
37	Tj. Jati 1-2	PC	N.A.	10%
38	Tj. Jati 3-4	PC	N.A.	10%
39	Holtekam (Jayapura)	Stoker	N.A.	70%
40	Bangka	CFB	Woodchip	30%
41	Tg. Awar-awar	PC	Sawdust	10%
42	Amurang	CFB	Woodchip	30%
43	Ombilin	PC	N.A.	10%
44	Labuhan Angin	CFB	N.A.	30%
45	Punagaya (Takalar)	CFB	N.A.	30%
46	Sofifi	Stoker	N.A.	70%
47	Malinau	Stoker	N.A.	70%
48	Ampana	Stoker	Woodchip	70%
49	Suralaya 8	PC	Sawdust	10%
50	Teluk Sirih	CFB	N.A.	30%
51	Tg Balai Karimun	Stoker	N.A.	70%
52	Pangkalan Susu	PC	Rice husk	10%

CFB = circulating fluidised bed, N.A. = not available, PC = pulverised coal, PKS = palm kernel shell.

Source: Pen Consulting (2021).

Electric power pricing

MEMR Regulation No. 50 of 2017 Regarding the Utilisation of Renewable Energy for Power Supply (MEMR Reg. 50/2017) and PR 112/2022 mandate PLN to purchase electricity generated at renewable power plants. MEMR Reg. 50/2017 provides a mechanism to determine the tariffs for renewable power purchased by PLN from IPPs by benchmarking against the applicable Electricity Generation Basic Cost (Biaya Pokok Penyediaan Pembangkitan; BPP) in the area where the power is generated or through negotiations between PLN and the IPP. PR 112/2022 provides two pricing models for purchasing electricity: (1) maximum benchmark prices (subject to annual re-evaluation) replacing PLN's BPP, which is based on non-renewable energy and (2) an agreed price based on direct negotiation with PLN followed by approval from the Minister of Energy and Mineral Resources.

PR 112/2022 lists the benchmark prices for electricity purchases for solar, hydro, geothermal, wind, biomass, and biomass power generation. The maximum benchmark price for biomass is provided in Appendix 1 of PR 112/2022, shown in Table 3.3. The actual purchase price is determined through individual negotiations with PLN or by tender, with the benchmark price as the upper limit.

The benchmark price is set depending on the type, size, and location of the renewable energy power plants, as well as on the terms of the relevant power purchase agreement (PPA). The base tariff is multiplied by a location factor ('F' factor) during the first 10 years to incentivise renewable power generation. The factor ranges from 1.0 to 1.50, with areas outside of Java, Madura, and Bali given location factors above 1.0.

Table 3.3. Maximum Benchmark Price for Biomass

(US cents/kWh)

	1 MW	1–3 MW	3–5 MW	5–10 MW
Years 1–10	11.55×F	10.73×F	10.20×F	9.86×F
Years 11–25	9.24	8.59	8.16	7.89

Note: F represents the location factor provided in Appendix 2 of PR112/2022 and is as follows:

No.	Region	Factor
1	Java, Madura, Bali	1.00
	- Small islands	1.10
2	Sumatra	1.10
	- Riau Island	1.20
	- Mentawai	1.20
	- Bangka Belitung	1.10
	- Small Islands	1.15
3	Kalimantan	1.10
	- Small Islands	1.15
4	Sulawesi	1.10
	- Small Islands	1.15
5	Nusa Tenggara	1.20
	- Small Islands	1.25
6	North Maluku	1.25
	- Small Islands	1.30
7	Maluku	1.25
	- Small Islands	1.30
8	West Papua	1.50
9	Papua	1.50

Source: Presidential Regulation No. 112 of 2022 (PR 112/2022).

As Purwanto (2022) points out for solar and onshore wind power, considering the average levelised cost of energy (LCOE), the maximum purchase prices may not effectively attract private investment in renewable power. For biomass power generation, assuming that the LCOE for a 1 MW power plant using agricultural residue can be as high as 16.04 US cents/kWh[2], investing in biomass power would not be attractive even in areas with the highest location factor. Therefore, PR 112/2022 may not contribute to accelerating the deployment of biomass power plants.

Financial support policy

PR 112/2022 provides that the government may grant incentives to business entities developing renewable power plants. These can be offered in the form of corporate tax facilities, import tariff facilities, land and building tax facilities, geothermal development support, financial support and/or guarantees through state-owned enterprises, and non-fiscal measures.

3.1.2. Resource availability

Indonesia is home to a wealth of bioenergy resources. Agriculture, forestry, and fishery accounted for 12.4% of Indonesia's GDP in 2022 (World Bank, n.d.-b). Residues from the agriculture and forestry sectors are promising sources of biomass resources. IRENA (2022a) found that Indonesia had the largest biomass resource potential of the five Southeast Asian countries studied.[3] Almost 65% of the total of 304.9 million tonnes of potentially available biomass resources in 2050 comprised agricultural residues, including oil palm, rice, and sugarcane residues.

Agricultural residues: Oil palm

As discussed earlier in Figure 3.2, Indonesia is a major exporter of palm oil, and biomass residues from palm oil mills are available in the highest abundance and are already utilised across the country, both on-grid and off-grid.

Oil palm production has increased 1.7 times over the past decade, from 29 million tonnes in 2013 to 47 million tonnes in 2023, whilst plantation area has increased 1.5 times from 10 million hectares to 15 million hectares during the same period (Figure 3.5). Studies, including Gaveau et al. (2021), have associated forest degradation in Indonesia with the expansion of oil palm plantations. The Indonesian government seeks to have 200,000 hectares of oil palm plantations found in areas designated as forests returned to the state to be converted back into forests (Reuters, 2023). This

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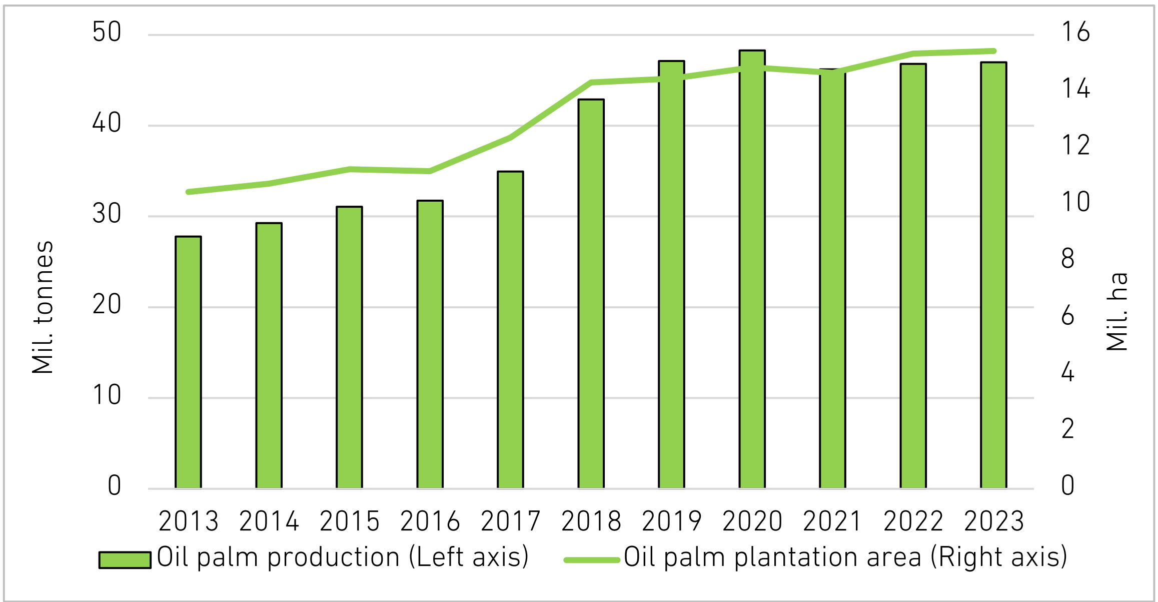
[2] The Institute for Essential Services Reform (IESR) (2022) provides an LCOE range of 3.29–16.04 US cents/kWh for agriculture residue biomass power plants of 50 MW to 1 MW.

[3] The countries studied are Indonesia, Thailand, Viet Nam, Myanmar, and Malaysia.

should be taken note of when considering the future potential of oil palm residues to be used as biomass resources.

Figure 3.5. Oil Palm Production and Plantation Area, 2013–2023



Source: Compiled by the IEEJ based on BPS-Statistics Indonesia.

Palm oil mill residues are in the form of solid residues, such as fibre, shells, and empty fruit bunches (EFB), as well as in liquid form, as with palm oil mill effluent. Existing internal use, such as fertiliser use, also needs to be considered when assuming the potential availability for energy use, as discussed in Section 3.2.2.

Table 3.4 presents the residue-to-fresh fruit bunch (FFB) ratio along with the availability after internal use. EFB accounts for a large portion of FFB and is seemingly available in abundance. However, according to interviews with palm oil producers, EFB is used as fertiliser on-site at their plantations, sometimes at rates of 100%. This will be discussed in Subsection 3.3.2.

Table 3.4. Availability of Oil Palm Residues as Biomass Feedstock

	Residue to Fresh Fruit Bunch Ratio	Ratio of Internal Use	Availability for Other Use
Fibre	11%–13%	90%	10%
Palm kernel shell	5%–7%	70%	30%
Empty fruit bunches	20%–22%	0%	100%

Source: Adapted by the IEEJ based on Pen Consulting (2021).

Agricultural residues: other crops

The residues of many crops can be used as feedstock. Figure 3.6 shows the production trend of selected crops whose residues can theoretically be used as feedstock.

Figure 3.6. Production of Selected Crops in Indonesia, 2013–2022

Source: Compiled by the IEEJ based on data from FAOSTAT (2023).

Rice has the highest production level of the crops studied and promises to be an abundant source of agricultural residue after palm oil residues. Rice husk amounts to around 25% of rice production (Table 3.5) and is usually collected at rice mills. Rice straw constitutes a substantially larger amount of residue, with almost the same volume as the paddy. However, it is not considered herein, as rice straw is normally left in the field and requires a new collection scheme. Agricultural residues that can be collected as agri-industrial waste can be more efficiently used as biomass feedstock.

Table 3.5. Residue-to-crop Ratio of Selected Crops in Indonesia

Crop	Residue	Average Residue-to-crop Ratio
Rice	Husk	0.25
	Straw	1.33
Sugarcane	Tops/leaves	0.20
	Bagasse	0.26
Maize	Cob	0.33
	Husk	0.22
	Stover	1.96
Coconut	Fronds	0.47
	Shell	0.39
	Husk	0.49
Cassava	Stalk	0.13
Coffee	Husk	1.32

Source: Compiled based on FAO (2014).

As Rhofita et al. (2022) point out, the open burning of rice husks and rice straw results in greenhouse gas (GHG) emissions; therefore, the utilisation of these residues as biomass feedstock can also contribute to avoiding emissions.

Seasonal variations may affect the availability of agricultural residue-based biomass feedstock. Geographical gaps and competition with other uses (e.g. risk husk used in the cement industry or as fertiliser) will also need to be considered. There will be a need to determine the priority uses for each biomass feedstock that has no alternatives in the energy transition.

Woody biomass resources

Indonesia has 98 million hectares (ha) of forest land (covering around 50% of the country's total land area), with the largest forest areas in Kalimantan and Papua (Table 3.6). Indonesia has been challenged with serious deforestation during the past two decades, having lost 6 million ha from 2000 to 2012 (Alisjahbana et al., 2014). Laws and regulations have been implemented by the government to promote sustainable forestry and thus stop deforestation.

Table 3.6. Forest Area by Island in Indonesia

(ha)

	Conservation Forests	Protected Forests	Production Forest	Total Forest
Sumatra	5,363,550	5,604,106	11,935,724	17,539,829
Java	4,413,458	734,940	1,812,626	2,547,565
Bali	4,118,630	95,766	8,626	104,392
Nusa Tenggara	3,438,221	1,115,057	973,855	2,088,912
Kalimantan	2,808,378	7,031,608	24,515,931	31,547,539
Sulawesi	2,356,539	4,320,490	4,744,894	9,065,384
Maluku	1,730,212	1,211,314	4,575,486	5,786,800
Papua	1,293,541	9,446,872	20,258,222	29,705,094
Total	**25,522,529**	**29,560,153**	**68,825,364**	**98,385,515**

Note: Under Indonesian law, 'Forest Area' is under the jurisdiction of the Ministry of Environment and Forestry but includes areas both forested and not forested and designated for both conservation and forestry uses. Under Government Regulation No 23 of 2021, Article 1, a 'Conservation Forest' is a Forest Area with the main function of preserving ecological diversity. A 'Protection Forest' is a Forest Area with the main function of protecting the natural system. A 'Production Forest' is a Forest Area with the main function of producing forest products.
Source: Compiled by the IEEJ based on BPS-Statistics Indonesia.

Woody biomass feedstock should ideally be derived from by-products of industrial wood processing or residues of sustainable forest stewardship practices – e.g. sawdust and pellets made from residues.

The industrial wood value chain offers industrial wood residues, which include both logging residue[4] and wood-processing residue (mill waste). In Indonesia, around two times the logs utilised are left in the forest, with around 10% recovered for other uses. Wood-processing residues have a higher recovery rate as they can be collected at industrial establishments, such as sawmills and plywood mills. The recovery rate of residues from sawmilling industries is around 54% on average. For plywood, the recovery rate ranged from 40% to 55% in Java, Sumatra, and Kalimantan (Asia-Pacific Forestry Commission, 2001).[5]

[4] Logging residue includes treetops, trunks, standing trees damaged during logging, and logs of commercially unacceptable quality.
[5] Recovery rates vary depending on factors including the wood type and technologies used. The data were compiled in 2000 and include conventional manufacturing methods; therefore, the recovery rate today may be improved.

The wood pellet industry is relatively new in Indonesia, with production rapidly increasing since 2015. Figure 3.7 indicates that most of the domestically produced wood pellets are exported, with the main destinations being the Republic of Korea (henceforth, Korea), Japan, China, and Germany. Interviews with power plants and biomass producers in Indonesia also revealed that there is limited domestic use in power plants due to the high cost of pellets.

Figure 3.7. Wood Pellet Trends, 2013–2022

Source: Compiled by the IEEJ based on data from FAOSTAT (2023).

As shown in Table 3.7, Indonesia's log production increased by around 24% from 2019 to 2023. The increase in log production in Indonesia, which is not a large wood importer, has been driven by increased demand for pulp and wood chips, with pulp increasing by 14% and woodchips by 27%, whilst little change was seen in the production of Indonesia's leading wood products, such as plywood and veneer laminate and sawn timber.

Table 3.7. Production Trends of Major Forest Products in Indonesia

(1,000 m^3)

	2019	2020	2021	2022	2023
Woodchips	31,351	38,043	39,755	42,205	39,752
Wood pellets	109	107	140	220	172
Logs	48,242	52,679	54,947	56,674	59,737
Sawn wood	2,710	2,730	2,661	2,075	2,302
Moulding	-	0	1	4	4
Veneer	1,547	1,553	1,807	1,427	1,738
Plywood and veneer laminate	4,214	3,907	4,641	3,385	4,211
Block board	152	203	228	282	304
Particle board	4	3	11	200	142
Pallet	-	13	14	26	14
Pulp	7,807	8,592	8,598	9,789	8,871

Source: Forestry Agency (2024).

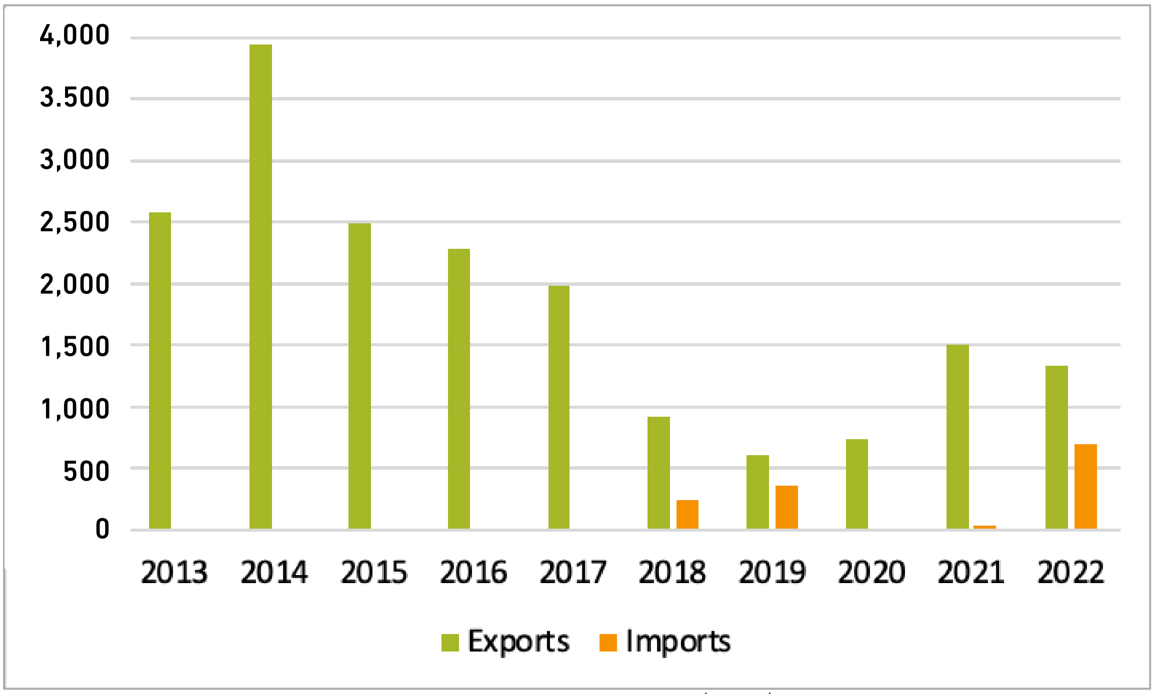
Wood chip exports followed a decreasing trend before starting to gradually increase in 2019 (Figure 3.8). Whilst domestic wood chip consumption data are not available,[6] a gradual rise in imports has also been driven by increased domestic consumption for power generation[7] and the pulp and paper industry (ABC News 2023).

[6] Production data in FAOSTAT (2023) are constant across 2013 and 2022 at a level exceeding exports and are not relevant for analysis.

[7] Interviews with local stakeholders revealed a preference for wood chips to wood pellets for their lower costs.

Figure 3.8. Wood Chip Export and Import Trends, 2013–2022

(1,000 m^3)



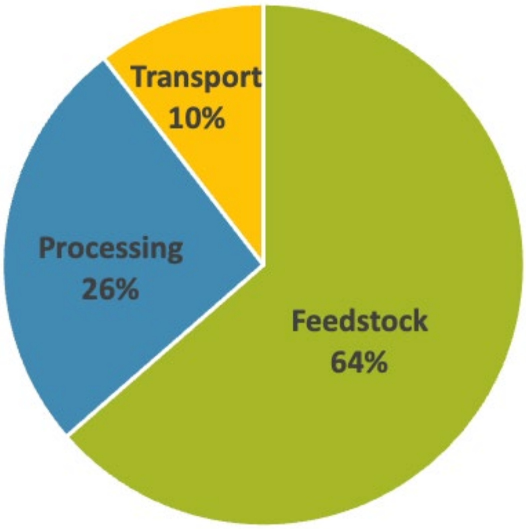
Source: Compiled by the IEEJ based on data from FAOSTAT (2023).

There is insufficient data on whether the increased production of woodchips, which should be logging residue, is a result of pursuing higher efficiency in logging practices or whether more logs are being directly processed into woodchips. Woody biomass feedstock procurement should not contribute to forest degradation. The forest area certificated under international schemes, namely the Forest Stewardship Council (FSC) and Program for Endorsement of Forest Certification (PEFC), is 3.2 million ha (as of March 2024) and 4.6 million ha (as of December 2023), respectively. This amounts to only around 8% of the total forest area in Indonesia. Further efforts to ensure the sustainability of woody biomass feedstock are called for.

3.1.3. Cost

The biomass feedstock procurement cost is largely comprised of the biomass feedstock price, production cost (processing, labour, and capital costs), and transport cost. IESR (2022) provides the cost structure for procuring woodchips on Java Island. The feedstock price accounts for more than 60% of the total cost and is, thus, the most significant factor (Figure 3.9). The total cost is estimated to be US$40 per tonne without considering the maintenance costs.

Figure 3.9. Example of Biomass Procurement Cost Components



Note: The transport cost presented is for transporting woodchips 50 km on Java Island.
Source: IESR (2022).

The current procurement costs of biomass feedstock have been investigated by various studies, as provided in Table 3.8.

Table 3.8. Characteristics of Biomass Feedstock

	Calorific Value (kcal/kg)	Price	Conflicting Uses
Rice husk	3,000–3,400	Rp290/kg	Tile, brick and cement production, fertiliser, poultry feed
Sawdust	3,000–3,500	Rp350–600/kg (±2,450 kcal/kg net calorific value (NCV))	Chicken bedding, insect repellent
Woodchip	3,000–3,500	Rp829–922/kg	Paper and pulp
Wood pellet	3,940–4,400	Rp1,300+/kg (>4,100 kcal/kg NCV)	Exports
Palm kernel shell	3,500–4,200	Rp825–960/kg (>3,500 kcal/kg NCV)	Exports
Empty fruit bunch	-	Rp45–68/kg	Internal use, fertiliser, paper and pulp

	Calorific Value (kcal/kg)	Price	Conflicting Uses
Empty fruit bunch pellet	3,600–4,000	N.A.	Internal use, fertiliser, paper and pulp

Sources: Compiled by the IEEJ based on Adhiguna (2021), Pen Consulting (2021), PLN EPI (2024) and interviews.

Transport

The transport cost of biomass feedstock can have a significant impact on the delivery price. Pen Consulting (2021) estimates transport costs for woodchips and EFB to be Rp85/kg and Rp38-48/kg, respectively, for each 50 km travelled. IESR (2022) estimates the transportation cost for woodchips on Java Island to be US$4.2/t for every 50 km travelled and points out that to meet the economic equivalent of coal, the feedstock distance needs to be limited. The transport costs vary according to region and tend to be higher outside Java.[8]

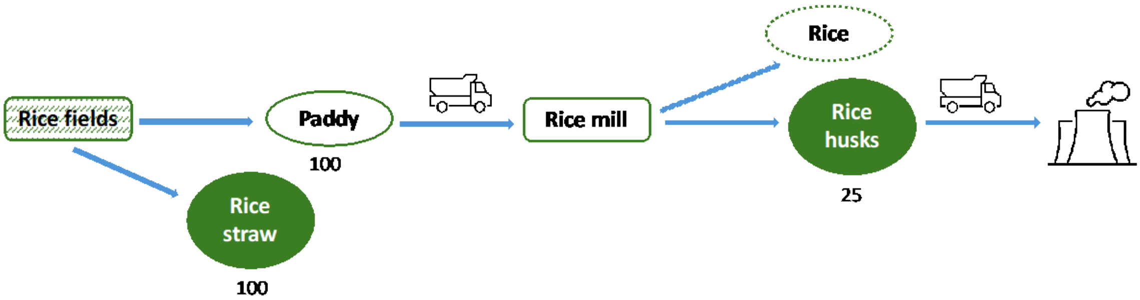
3.1.4. Existing supply chains

Biomass residues that are by-products of commercial supply chains can be more efficiently collected at processing plants along existing supply chains compared to residues left on-site in the fields or the forest. For example, even when rice is produced on small scales, harvested paddy is taken to a rice mill to be processed into rice, thus facilitating the collection of rice husks, which comprise 25% of the paddy. On the other hand, rice stalks, which amount to the same volume as paddy, are often left in piles in the fields and need to be collected individually to be utilised.

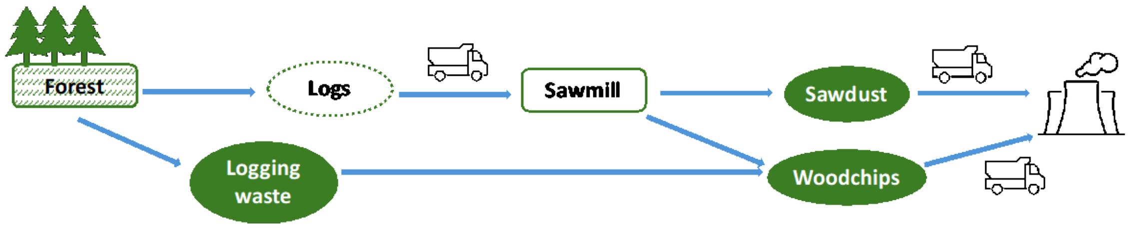
[8] The cost-efficient distance is 360 km for Java, 300 km for Sumatra, Kalimantan, and Sulawesi, and 187 km for Maluku and Papua. (IESR, 2022)

Figure 3.10. Simplified Biomass Feedstock Supply Chains

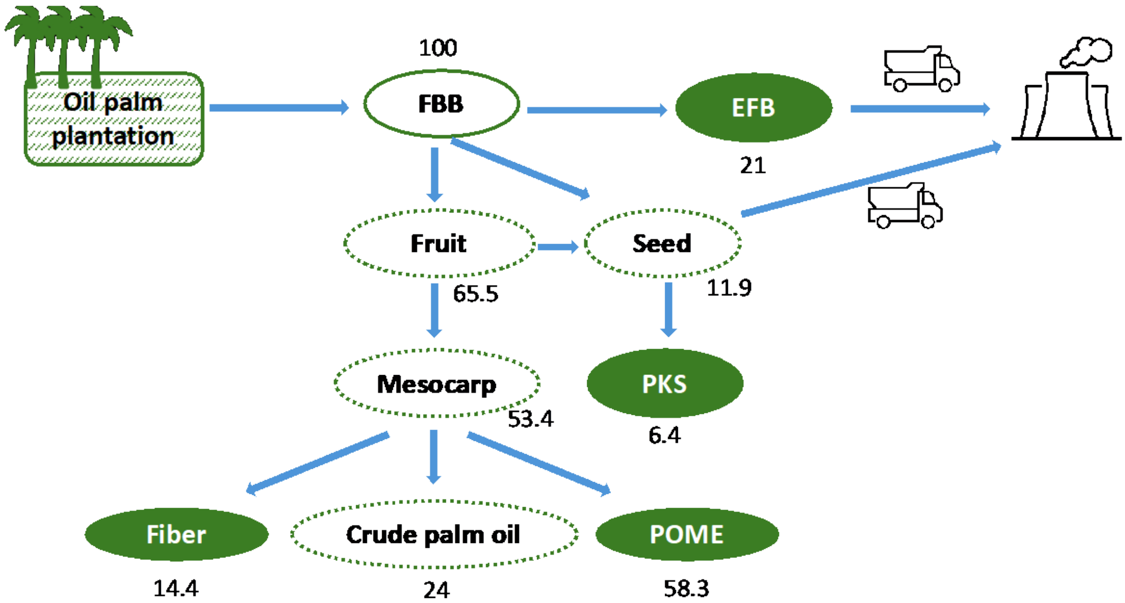
a. Rice husks and rice straw



b. Woody biomass residues



c. Oil palm residues



Notes:
1) Numbers indicate the ratio to crop.
2) Other by-products can be generated; however, these have been omitted for simplicity.
Source: Compiled by the IEEJ based on various sources, including Pen Consulting (2021) and IRENA (2022a).

3.2. Expected Supply and Demand of Focused Bioenergy in 2030

3.2.1. Identifying the gaps between supply and demand

Given the scale of the feedstock demand for co-firing biomass in 52 coal-fired thermal power plants, evaluating the supply-demand balance for biomass feedstock required for co-firing is of utmost importance as it will have a significant impact on the bioenergy supply. For this exercise, the theoretical potential of biomass resources was compared with the co-firing biomass demand in 2030.

Whilst the ideal location of biomass supply is within a 50 km radius of a power plant, it is difficult to accurately identify potential within a given area. Therefore, the potential biomass supply in each province defined by PEN Consulting (2021) was used to analyse the local supply-demand balance. Biomass demand was estimated based on the total amount of electricity output to be produced using biomass at each coal-fired power plant implementing commercial co-firing in 2022, assuming 10% co-firing in PC boilers, 30% co-firing in CFB boilers, 70% co-firing in stoker boilers, in accordance with the roadmap developed by PLN.

Status of co-firing

As of 2022, commercial co-firing was conducted at rates of 1%–4% at 37 power plants out of the 52 designated by PLN in its roadmap. Various types of biomass feedstocks are being used depending on the boiler type and location, as indicated in Figure 3.11.

Figure 3.11. Status of Co-firing by Boiler Type and Feedstock, 2022
(number of power plants)

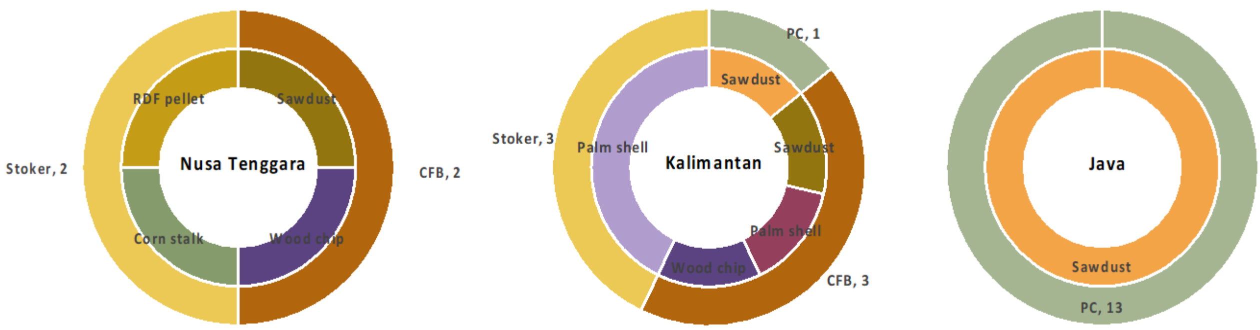
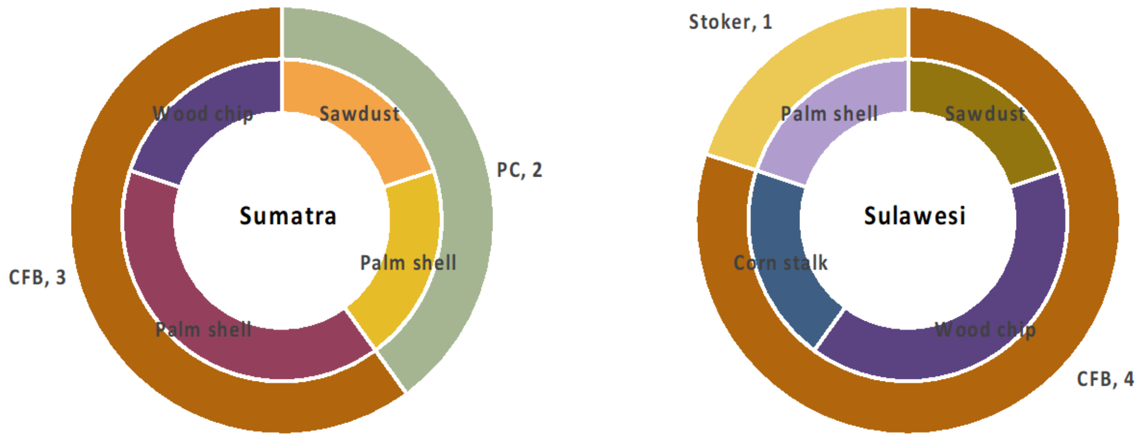


Figure 3.11. *Continued*

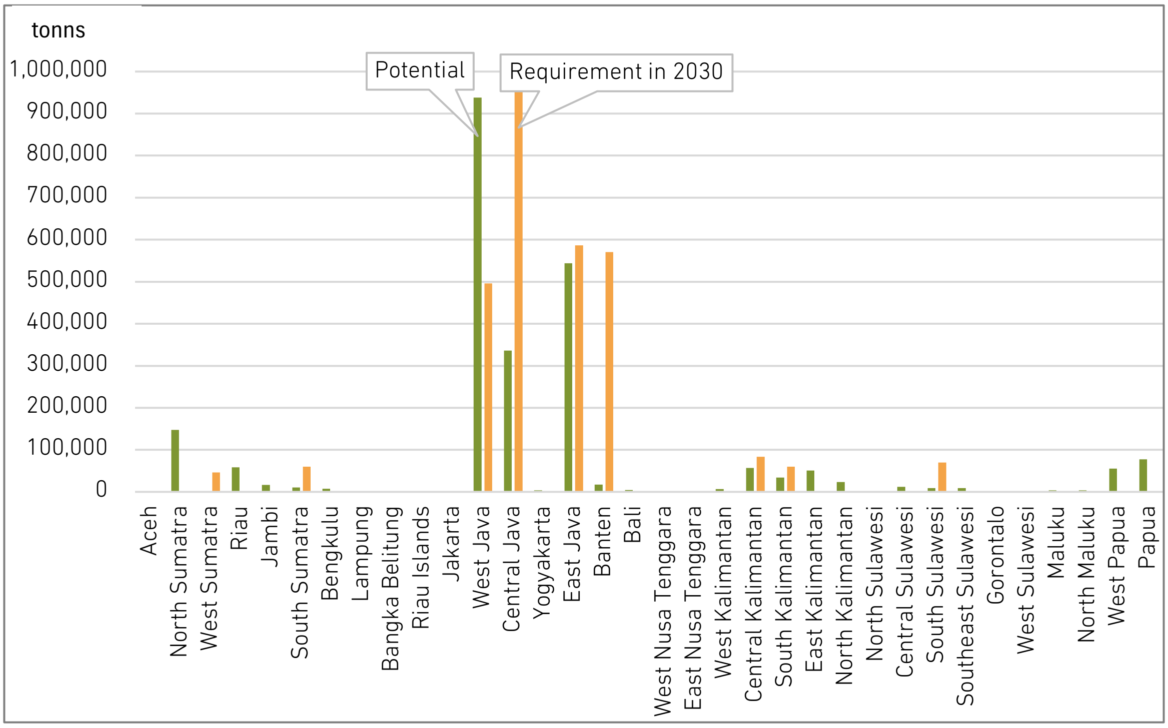


Source: Compiled by the IEEJ based on DJ-EBKTE.

As distribution gaps will increase costs, there is a need to analyse the specific needs (feedstock type and amounts) for co-firing according to boiler type for other existing and planned CFPPs.

CFPPs under the co-firing plan comprise a total of 12,650 MW of PC boilers, compared to 1,621 MW of CFB and 118 MW of stoker boilers. PC boilers are concentrated in electric power demand centres and mostly utilise sawdust for co-firing. This is because the fineness of sawdust particles is similar to that of pulverised coal. Given that the demand for sawdust is expected to be significant, the supply-demand balance of sawdust was first evaluated, assuming that sawdust would be utilised in all PC boiler power plants as well as those of other boiler types that co-fire sawdust today (Figure 3.12).

Figure 3.12. Sawdust Supply-demand Balance for Co-firing in 2030

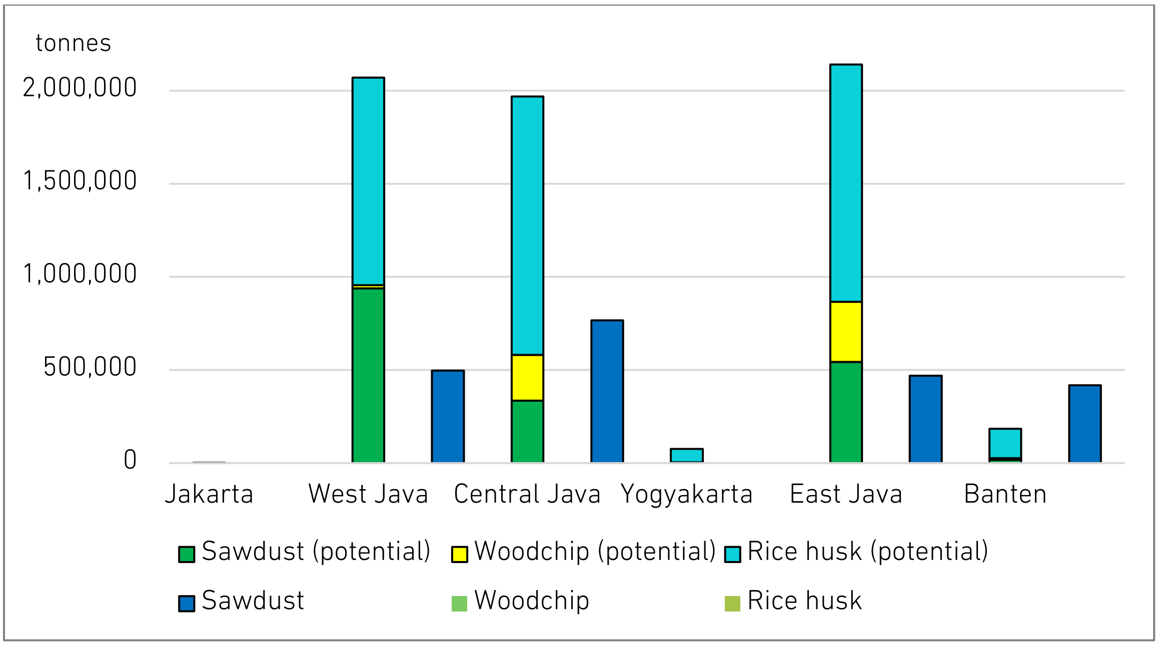


Source: Compiled by the IEEJ based on PEN Consulting (2021) and PLN EPI.

In most provinces, potential sawdust resources are in surplus of the sawdust supply required for co-firing at on-grid coal-fired plants in 2030. However, in Banten, East Java, and Central Java, the potential sawdust supply is not sufficient to cover co-firing needs. Therefore, rice husks and woodchips were also considered, as shown in Figure 3.13. Rice husk has competing demand in the cement and brick/tile sectors, as well as in conventional use for poultry; therefore, assuming that current demand levels[9] will be unchanged in 2030, current demand is deducted from the total resource potential. It should also be noted that the utilisation of rice husks involves challenges with silica content, which is more compatible with cement production.

[9] For a given year, rice husk production was 10.9 million tonnes in Indonesia. There is existing demand for around half of the amount, with 3.7 million tonnes used on poultry farms, 0.6 tonnes supplied to the brick and tile industry, and 0.6 tonnes supplied to the cement industry.

Figure 3.13. Biomass Supply-demand Balance for Co-firing in 2030: Java Island



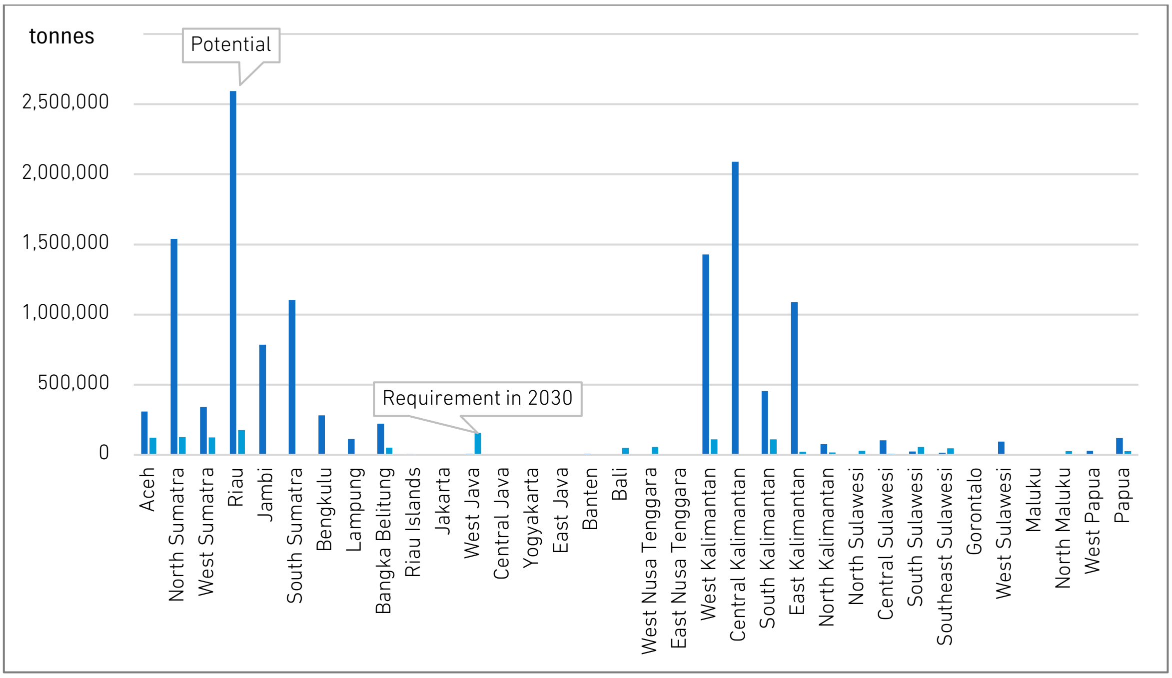
Source: Compiled by the IEEJ based on PEN Consulting (2021) and PLN EPI.

When rice husks and woodchips are included in the potential supply, Central Java will have enough biomass to meet co-firing needs. However, Banten will still be in short supply. Rubber may also be utilised in Banten.

For stoker and CFB boiler-type power plants, whilst cornstalks and sawdust are used in some areas, PKS is mostly utilised as biomass feedstock for co-firing. The theoretical potential of PKS supply can meet the co-firing demand in 2030, as indicated in Figure 3.14.

However, it should be noted that the self-consumption of palm oil mill residue at oil palm plantations has not been considered and may lead to supply shortages in the market as more operators are becoming reluctant to sell their oil palm residue. The potential PKS supply is sufficient to cover current exports but will not be able to cover the significant increases expected in the international market.

Figure 3.14. PKS Supply-demand Balance for Co-firing in 2030



Source: Compiled by the IEEJ based on PEN Consulting (2021) and PLN EPI.

3.3. Requirements for Supply Chain Development (to Fill the Supply-Demand Gap)

3.3.1. Addressing technical barriers

Transportation

An interview with an anonymous Indonesian steel company sourcing its electric power from on-site biomass power generation revealed that transportation costs have risen by 1.2–1.5 times from 2022 to 2023 and could sometimes be equivalent to the feedstock price of EFB.

Whilst sawdust and rice husks are convenient for utilisation in PC boilers, their bulkiness (approximately four times the volume of pellets) poses a challenge in terms of both transportation and storage. A co-firing rate of 10% at a PC boiler-type coal-fired power plant will involve a hundred 7-tonne trucks delivering biomass feedstock every day for one unit and will lead not only to road congestion but also a significant increase in GHG emissions from transport, thus watering down the overall decarbonisation achieved by co-firing biomass.

Large areas of roofed storage facilities will be needed on-site to accommodate the biomass and for mixing the feedstock before feeding it to the bunker. Buffer storage may also be a solution, but it will also require reduced volume.

Pelletising biomass feedstock near supply areas can solve transport and storage issues. It will also allow for the shipping of biomass feedstock. Interprovincial trade of biomass could be a solution, especially for large-scale PC boilers located in demand centres.

Co-firing technologies

As provided in Table 3.9, CFB boilers can accommodate a wide range of biomass feedstock, whereas PC boilers ideally use wood pellets, which can be delivered with a stable level of quality in terms of moisture content and calorific value. Wood pellets can be crushed back to the original sawdust size distribution.

Table 3.9. Features of PC and CFB Boilers in the Context of Biomass Co-firing

	Pulverised Coal	Circulating Fluidised Beds
Output	25–1,000 MW	Up to 75 MW
Biomass feedstock	Wood pellets	Wood pellets, woodchips, palm kernel shell, tree fellings, woody construction debris
Features	Large scale, high efficiency Uses pulverised feedstock	Fuel flexibility Long residence time leads to high combustion
Co-firing rate	0%–100%	100% (single firing)

Source: Compiled by the IEEJ based on an interview with an anonymous boiler manufacturer.

When co-firing biomass in PC boilers, design considerations need to be made regarding the bunkers, mills, burners, and environmental equipment, in addition to safety measures. When the biomass feedstock is pulverised together with coal, the quality of the mill can be heavily degraded by co-firing ratios exceeding 5% on a calorific value basis.

The maximum co-combustion ratio is determined by the existing milling capacity. For biomass co-firing rates of up to 70% on a calorific value basis, the feedstock feeding system should be dedicated to biomass.

Given the high percentage of pulverised coal-fired boilers in terms of capacity, it is critical to increase both the co-firing rate and efficiency in these power plants to increase the decarbonisation rate. This points to the importance of using pellets in these boilers.

Storage needs

Moisture content has a large impact on the quality of biomass feedstock and, thus, on the performance of boilers. Large areas of roofed storage facilities will be needed on-site to accommodate the biomass and for mixing the feedstock before feeding it to the bunker. Buffer storage may also be a solution but will require reduced volume, which can be achieved by proper pre-treatment[10] and by pelletising the feedstock.

3.3.2. Addressing cost barriers

Biomass feedstock pricing

Ministerial of EMR Reg 12/2023 provides that biomass feedstock prices must be less than 1.2 times the free-on-board price of the reference coal price (HBA). The June HBA for 6,322 kcal/kg GAR coal[11] was set at US$123/tonne for June 2024.

Based on Ministerial of EMR Number 139 /2021, the domestic sales price of coal to generate electricity for the public is set at the HBA of US$70/tonne, which is a threshold difficult to compete with. The sawdust price in Banten was around Rp600,000/t, much cheaper than the coal procurement price.

Competition with fertiliser demand

Surging fertiliser prices driven by rising ammonia prices are affecting the EFB market. Plantation owners are more reluctant to sell their EFB as they can be directly used as fertiliser on their plantation, thus saving costs. Table 3.10 indicates that around Rp537,000 can be saved by replacing mineral fertiliser with EFB. Given that raw EFB is sold at around Rp45,000–68,000 per tonne, the savings can be far more attractive than the income brought from selling the EFB to off-takers.

[10] Studies such as Thiffault et al. (2018) point out that proper pre-treatment of biomass material at an early stage in the supply chain can considerably increase its energy density.

[11] High-grade coal with high calorific value and the properties of total moisture 12.26%, sulphur 0.66%, and ash 7.94%. GAR stands for 'Gross as Received'.

Table 3.10. Cost Savings Achieved by Replacing Mineral Fertiliser with EFB

Elements	EFB % weight	Nutrient content in 1 tonne EFB (kg)	Mineral fertiliser % weight	1 tonne EFB equivalent per kg of mineral fertiliser	Mineral fertiliser cost (Rp/kg)	Cost savings for 1 tonne EFB (Rp/t)
Nitrogen	2.20%	22.00	46%	47.8	5,600	267,826
Phosphorus	1.28%	12.80	46%–54%	25.6	1,800	46,080
Kalium	2.79%	27.90	60%	46.5	4,800	223,200

Source: Anonymous oil palm plantation owner.

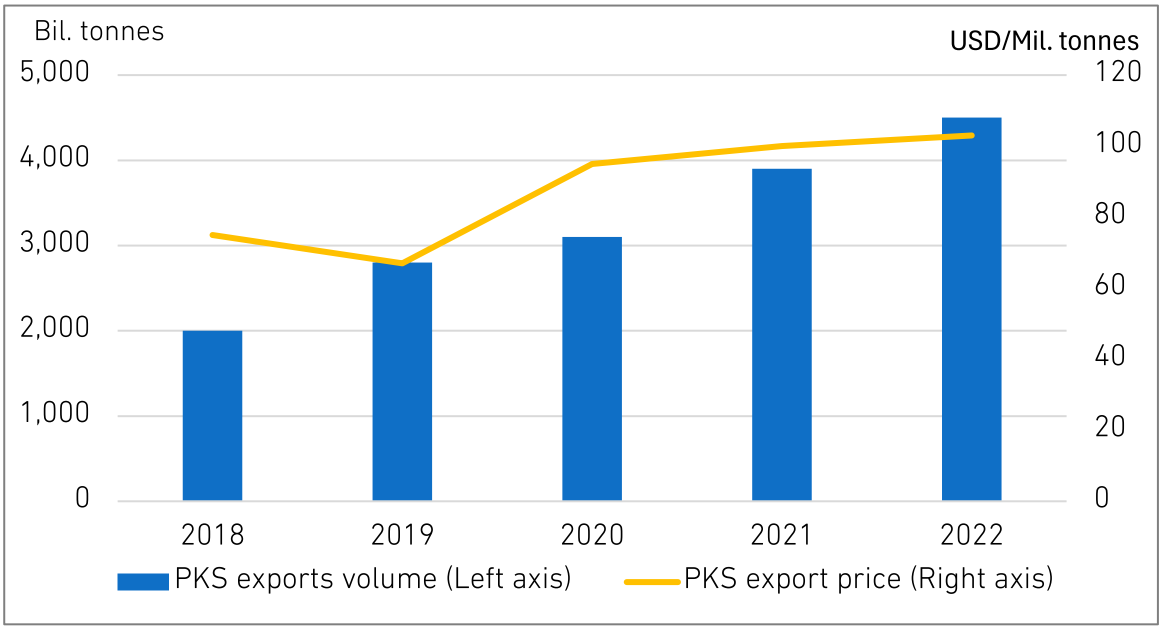
Furthermore, interviews with Indonesian stakeholders engaged in biomass power generation revealed that biomass procurement contracts are often based on total volumes of supply and, thus, usually only cover annual supplies. It has become increasingly difficult to secure long-term contracts for a fixed price, given rising prices.

Competition with export demand

On the other hand, based on interviews with several Japanese companies, Japanese exporters have been able to sign long-term contracts with biomass feedstock suppliers because they offer a higher price. Biomass feedstock is currently subject to dual pricing – low domestic prices and high export prices, which can range from US$100–US$240 per tonne.[12] For instance, the export price of PKS in 2022 is estimated to be around US$100, as presented in Figure 3.15. The ceiling price for biomass procurement, which is set the same as the calorific value of coal as guided by the internal rules of PLN, is disincentivising suppliers from providing biomass feedstock to the local market.

[12] The lower value is derived from Figure 3.15 and the higher value is derived from IESR (2022).

Figure 3.15. PKS Export Volume and Price Trends



Source: Anonymous PKS exporter.

3.3.3. Addressing social barriers

Lack of public awareness is another factor that hinders the development of commercial biomass feedstock. Many local people are reluctant to collect what they consider valueless waste. Awareness-raising is called for to foster a shared understanding of the value and potential of agricultural residue.

An interview with a palm oil mill revealed that they were not familiar with climate change issues and the call for decarbonisation. Such plants utilise palm residue for power generation and fertiliser only because of the cost benefit and have no notion of their contribution to decarbonisation.

Impacts on health and agricultural yield caused by coal-fired power plants[13] may serve as an incentive for local communities to engage in building a biomass supply chain, including the collection of agricultural residues.

3.4. Recommendations for the Development of the Bioenergy Supply Chain

3.4.1. Pelletising biomass feedstock

Advantages of pelletisation

Currently, biomass feedstock is mixed with coal outside the mill and bunker and fed

[13] Some villages around coal-fired power plants in Banten Province are experiencing impacts on health and crops. For example, Della Syahni (2021) and Kelly et al. (2023).

into the mill together. Pelletising raw material can reduce the volume of biomass feedstock by as much as one-fourth and thus limit transportation costs, as well as storage requirements.[14] The use of pellets will improve the quality of biomass feedstock and, therefore, contribute to the improvement of co-firing rates. This will enable the use of more biomass to replace coal in coal-fired power plants.

Pelletising biomass feedstock near supply areas can solve transport and storage issues, further allowing for the interprovincial shipping of biomass feedstock, which is effective for coal-fired power plants with receiving ports.

Furthermore, as mentioned, improvements in bulk density will reduce carbon dioxide emissions from transport. Higher co-firing rates will also contribute to reduced emissions; therefore, a combination of pelletisation and retrofitted mills and bunkers to accommodate higher co-firing rates can help achieve further decarbonisation of coal-fired power plants.

Figure 3.16. Comparison of Direct Use of Biomass and Pelletisation

Source: Compiled by the IEEJ based on interviews.

Biomass pellet production costs

The raw feedstock price of rice husks can be almost four times that of raw EFB, but other cost factors, including the feedstock-to-pellet conversion ratio (1.15 and 2.57 for rice husk and EFB, respectively) and bulk density, which has a direct impact on transportation costs, make the production cost of EFB pellets higher than that of rice husk pellets.

Pen Consulting (2021) provides a comparison of the production and transportation costs of rice husk and EFB pellets, as well as woodchips, based on a project net

[14] Pelletisation can improve the bulk density fourfold for EFB and twofold for rice husk.

present value analysis, as shown in Table 3.11. The total cost for sawdust remains the most attractive amongst the four types of feedstocks compared; however, longer transportation distances[15] will bring costs comparable to other feedstock types. Whilst the production cost of woodchips is higher than EFB pellets, the transportation cost for pellets is cheaper due to the reduced bulk and effectively brings the total cost down.

Table 3.10. Comparison of Biomass Supply Costs

(Rp/tonne)

	Sawdust	Rice Husk Pellet	Woodchips	EFB Pellet
Production	417,000	592,000	658,946	696,000
Transportation (50 km)	100,000	65,000	85,000	65,000
Total (50 km)	**517,000**	**647,000**	**743,946**	**761,000**
(200 km)	**817,000**	**852,000**	**998,946**	**956,000**

Note: The exchange rate assumed is Rp14,500/US$.
Source: PEN Consulting (2021: 68).

This shows that assuming an exchange rate of Rp14,500/US$, even EFB pellets can theoretically be procured for less than US$70 per tonne, the HBA of coal used in coal-fired power plants.

Investment costs

Pen Consulting (2021) also revealed the investment costs of pelletisation, which provided the basis for the above calculations. The process involved in making rice husk pellets includes pelleting, cooling, and packaging; therefore, the equipment required is pelletisation machinery, a pellet cooler, and packaging equipment. The process for making EFB pellets mainly consists of five processes: grinding, drying, pelleting, cooling, and packaging (Table 3.10).

Assuming the pelletisation equipment cost is the only variable factor, capital expenditures for EFB pelletisation are 33% higher than those for producing rice husk pellets. Depending on the cost of rice straw collection and additional processes, including chopping, drying, and hammering, pelletising rice straw could be competitive against EFB, which has other competitive uses.

[15] A questionnaire survey with PLN EPI revealed that the distance between the biomass supply point to power plants ranges from 50 km to 200 km.

Table 3.10. Investment Costs for the Pelletisation of Rice Husk and EFB

(US$)

	Rice Husks	EFB
Pelletisation equipment	639,420	852,560
Electrical costs	101,088	101,088
Construction costs	560,160	560,160
Skid loader	44,640	44,640
Project management and consultancy fees	85,206	85,206
Total investment	**1,430,514**	**1,643,654**

Source: Compiled by the IEEJ based on PEN Consulting (2021).

3.4.2. New business models

Two business models can be suggested to solve the supply chain issues identified: pellet manufacturing by PLN EPI or by exporters.

Pellet manufacturing by PLN EPI

PLN EPI could take the initiative in manufacturing pellets from local agricultural residue or industrial wood waste. Part of the products can be sold to exporters, thus using the margin to subsidise domestic biomass procurement and retrofit mills for the implementation of higher co-firing rates. Whilst rice husk pellets are the most competitive, utilising rice straw residue will increase the number of pellets produced, thus allowing more sales to exporters.

According to Pen Consulting (2021), the cost to collect and carry straw waste from the fields to the roadside is Rp237 per kg, cheaper than the price of rice husks collected from local mills. Corn residue, such as corn stalks, leaves, and cobs, may also be utilised where available.

Since pellet plants should ideally be built close to the raw feedstock supply, the entire supply chain scheme of raw feedstock collection to pelletisation can be developed as a local business through the enhancement of public awareness for community engagement. This will also help create local employment.

Pellet manufacturing by exporters

Exporting businesses could manufacture pellets from local agricultural residue or industrial wood waste collected by local farmers and businesses and sell part of the products to local power plants for a discounted price. In this case, exporters would bear the investment costs for the pellet plants, which can be challenging for PLN EPI to shoulder. PLN EPI could be responsible for providing the raw biomass feedstock, harnessing its local networks.

This could be advantageous for exporters, thus creating a win-win relationship between exporters and PLN EPI. If PLN EPI can receive a consultation fee for the collection of raw biomass feedstock, this will bring the final off-taking cost down.

Moreover, some Japanese companies are exploring technologies to manufacture pellets from a mixture of biomass with different calorific values and moisture content to achieve the optimal configuration. EPI PLN would benefit from improved biomass feedstock quality.

Furthermore, the use of biomass feedstock to decarbonise local power generation fleets could be the target of a Joint Crediting Mechanism (JCM) scheme. PLN EPI could be the joint owner of such a project with the pelletisation technology provider.

Certification of sustainability

Both of the abovementioned schemes involve exporting pellets to countries, including Japan. Many export destinations require third-party certification to demonstrate their traceability and sustainability. Whilst Japan does not have its own certification programme, Japan's FIT scheme acknowledges certification by the Roundtable on Sustainable Palm Oil, Green Gold Label, International Sustainability and Carbon Certification, and Sustainable Biomass Program.

As of April 2024, PKS and palm trunks for use in biomass power plants in Japan require third-party certification; palm residue-derived pellets are subject to the same third-party certification. For PKS, the percentage of traders or importers with certification has reached 95%. On the other hand, as of July 2023, only 30% of palm oil mills had acquired certification; the ratio has remained stagnant since January 2023 (Agency of Natural Resources and Energy, 2023).

There are several factors contributing to the slow progress made in certification acquisition. One significant factor is that agricultural residues comprise only a small portion of the main product. Furthermore, there are other domestic uses that do not require certification. Therefore, producers are reluctant to take the additional measures required for certification and assume the costs entailed. These additional measures include production information disclosure and hiring dedicated personnel for safety measures. The lack of awareness amongst producers regarding the importance of sustainability certification requirements for exporting pellets also hinders the promotion of certification.

Cooperation between local producers and exporters could alleviate the burden felt by producers in acquiring certification. Increasing the number of certified export-ready producers that also provide feedstock to domestic users will contribute to enhancing the sustainability of the domestic supply chain.

The Indonesian government should also take measures to ensure the sustainability of the domestic biomass supply chain. Regulations are key to implementing sustainability standards.

It should also be noted that woody biomass-derived pellets are subject to the Timber Legality Assurance System (Sistem Verifikasi Legalitas Kelestrian; SVLK), the implementation standards and guidelines for which are stipulated in Decree Number SK. 9895/MenLHK- PHL/BPPHH/HPL-3/12/2022 pertaining to 'Standards and Guidelines for SVLK.' This decree was issued by the Ministry of Environment and Forestry on 14 December 2022.[16]

3.4.3. Promoting biomass use in other industries

Industrial use of coal for heat and off-grid electricity amounted to 85 million tonnes in 2022. In terms of electricity, 85 million tonnes of coal is equivalent to what is needed to operate roughly 17,755 MW of coal-fired power plants (assuming coal with an average calorific value of 4,500 kcal/kg and a plant efficiency of 35%).

Table 3.11. Coal Consumption by Industry, 2021

Industry	Coal Consumption (tonnes)
Textile	10,050,373
Non-metallic mining	8,414,203
Food	6,606,530
Metal	6,349,807
Wood products	4,017,241
Chemical	3,915,672
Leather	1,234,243
Garment	1,068,602
Paper	894.631
Electrical equipment	177,679

Source: MEBI based on BPS-Statistics Indonesia (2023).

Converting this amount of coal use to biomass or co-firing with biomass will have a significantly larger impact than implementing co-firing in all on-grid CFPPs; therefore,

[16] Overall forest management in Indonesia is governed under Indonesian Government Regulation No. 23 of 2021 pertaining to Forestry Management, which covers all types of forests, including state-owned and private forests, customary forests, conservation forests, convertible production forests, and nature reserve forests. This regulation covers the utilisation of these forests, timber and non-timber forest products sourced from them, as well as granting business permits and licenses related to these products.

working with competent ministries overseeing these industries to obligate the use of biomass in their coal-fired facilities will largely contribute to reducing CO_2 emissions. This will, however, require significant amounts of biomass feedstock, often in competition with on-grid power plants already subject to mandatory co-firing requirements. Java Island, where Indonesia's manufacturing sector is centred (Halim, n.d.), is also the area where a shortage of biomass feedstock for co-firing in CFPPs is most likely to occur.

3.4.4. Industrial Plantation Forests

An Industrial Plantation Forest (HTI) is a plantation forest in a production forest that is managed by entities to enhance quality and productivity using silvicultural systems. The Production Forest Development Roadmap published by the Association of Indonesia Forest Concession Holders suggests planting fast-growing energy plants, such as acacia, across 675,000 ha of HTI in 2045. The Roadmap also allocates areas for producing rubber and timber, the residues from which could be collected and used as biomass feedstocks (APHI, 2019).

According to the Ministry of Environment and Forestry (2022), around 1.8 million hectares of unused land remain inside existing forest concession areas. Some other parts of these concession areas have been allocated for seasonal crops and community plantations. These areas may be utilised as forest plantations to sustainably produce industrial wood and, thus, reduce the dependency on natural forests, and the wood residues can potentially be used as biomass feedstocks.

Hence, there are various options to be explored and harnessed in Industrial Plantation Forests. Species to be planted will need to be carefully chosen with consideration of the potential impacts on local ecosystems. Given that there are many illegal forest management practices and plantation operations yet to be dealt with,[17] HTI operations can often cause conflict with local communities over land ownership. The proper implementation of HTI in combination with the SLVK can improve forest governance and, at the same time, promote the sustainable supply of biomass feedstock. Community engagement will be key to the promotion of HTI.

3.4.5. Community engagement

Raising awareness and engaging local communities is a critical factor in biomass procurement. As aforementioned, there is a lack of understanding amongst many local

[17] For example, oil palm plantations have been found in areas designated to be forests, and the government seeks to have these lands returned to the state for conversion to forest (Reuters, 2023).

people and businesses regarding climate issues and the need for decarbonisation. Therefore, the potential economic value of agricultural and wood residues is not fully acknowledged. If local economies could benefit from the collection, processing, and sales of these residues, then that could serve as an incentive for developing sustainable local biomass supply chains.

PLN EPI promotes collaboration with local communities to plant multipurpose plants and implement distributed biomass processing as a part of a 'Green and Circular Village Project' (PLN EPI, 2024). Such initiatives lead to local empowerment, which is critical in building a sustainable biomass procurement system.

Chapter 4
Findings: Thailand

4.1. Overall Mapping of Bioenergy Supply and Demand

4.1.1. Bioenergy development policy framework

Thanks to the continuous support of the government, bioenergy has increased to 7.7% of total final energy consumption and 6.4% of total power installed capacity in Thailand in 2022, according to the Department of Alternative Energy Development and Efficiency (DEDE). According to the IEA's World Energy Statistics and Balances (IEA, 2024), bioenergy accounted for over 17.6% of the total primary energy supply and over 10.3% of total power generation in Thailand in 2022, positioning Thailand at the top level amongst ASEAN countries. Power generation, heat usage in manufacturing, and biofuels are the three pillars of biomass usage in Thailand, and the country has implemented a series of policies to support these usages. These policies are part of the country's commitment to increase the share of renewable energy in its energy mix, reduce reliance on fossil fuels, and transition towards low carbonisation. Key policies include the following.

The Renewable and Alternative Energy Development Plan

The Renewable and Alternative Energy Development Plan 2018–2037 (AEDP 2018) (DEDE, 2020) represents the most recent important policy in Thailand's efforts towards sustainable energy use. Approved by key national councils and the Cabinet in 2020, this comprehensive plan sets forth an ambitious agenda to enhance Thailand's energy security, reduce reliance on imported fuels, and address climate change concerns through the increased use of renewable and alternative energy sources.

The AEDP 2018, implemented by DEDE, seeks to elevate renewable energy's share to 30% of Thailand's total final energy consumption by 2037. This initiative encompasses a broad spectrum of energy forms, including biomass-based electricity, heat, and biofuels, leveraging the country's abundant natural resources and technological advancements.

The AEDP 2018 notably elevates the ambitions for biomass utilisation compared to its predecessor, the AEDP 2015. Specifically, the AEDP 2018 sets a more robust target for biomass-based electricity generation capacity, aiming for a substantial increase to 5,790 MW. Additionally, it envisions a significant rise in heat production from biomass, setting a goal of 23,000 kilotonnes of oil equivalent (ktoe). The plan also enhances its focus on biofuels, with an updated target of 4,085 ktoe, reflecting a strategic commitment to fully harness the potential of bioenergy in driving Thailand's energy transformation towards sustainability and self-reliance.

Small Power Producer and Very Small Power Producer programmes

Thailand's renewable energy landscape is significantly shaped by the Small Power Producer (SPP) and the Very Small Power Producer (VSPP) schemes, which have evolved to support the nation's shift towards more sustainable energy sources. These initiatives, established to promote the generation of power using alternative fuels and waste, including cogeneration, are pivotal in efficiently utilising domestic alternative resources and by-product energy.

The SPP scheme, initiated in 1992, was a strategic move by Thailand's cabinet to enhance power generation from alternative fuels and waste. This initiative aimed to leverage domestic resources effectively, reducing the government's investment in power infrastructure. The National Energy Committee's endorsement on 26 December 2006 for the Electricity Generating Authority of Thailand (EGAT) to procure electricity from diverse fuel sources marked a significant expansion. The subsequent announcement in 2007 categorised purchasing existing capacities ranging from 10 MW to 90 MW (Phoumin et al., 2019).

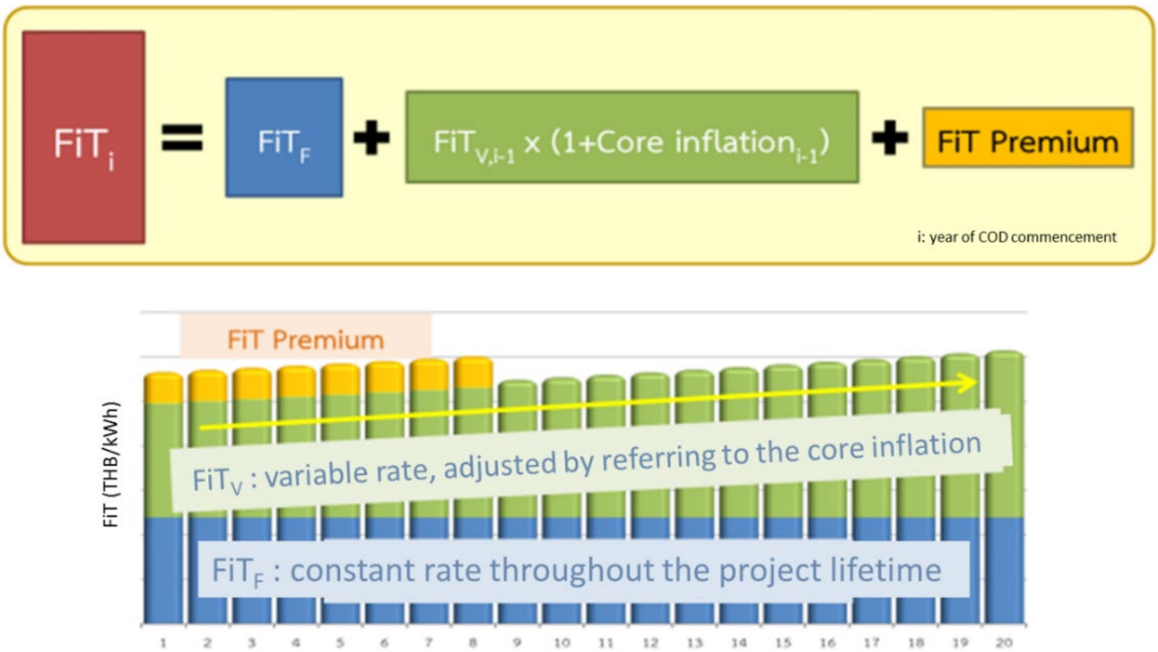
The VSPP scheme began in 2006 to promote domestic resource usage, enhance national transmission stability, reduce government expenditure on new power plants, and support conventional power plants during peak periods. Initially catering to power plants with capacities under 1 MW, the scheme expanded in 2007 to include capacities up to 10 MW. An 'adder' or feed-in premium programme was introduced, offering a special rate atop the normal purchasing price to encourage diverse renewable energy sources. For biomass and biogas, the adder rate was set as B0.30/kWh for 7 years. To further incentivise power generation in specific southern provinces and districts, an additional B1/kWh was added to the ordinary adder rate for biomass, biogas, municipal waste, and small/micro hydropower, whilst solar and wind received an extra B1.50/kWh.

Feed-in tariffs

The feed-in tariff (FIT) scheme, which emerged in 2012 as a strategic replacement for the adder mechanism, represents a pivotal shift in Thailand's approach to incentivising renewable energy projects. Originally tailored for rooftop and ground-mounted solar PV projects, the Ministry of Energy broadened the FIT scheme to encompass non-solar renewables for VSPPs with an installed capacity of less than 10 MW in 2014. This expansion included a wide range of power sources, including biomass and biogas, showcasing a comprehensive effort to diversify Thailand's renewable energy portfolio (Phoumin et al., 2019).

The formulation of the FITs for this diverse group of renewable energy sources, as detailed in Figure 4.1, addresses the inherent challenges posed by uncertain resource availability and fluctuating fuel prices. To accommodate these variables, the FIT scheme is structured around three main components. They are the fixed-based tariff (FITF), which is a component of capital and operations and maintenance (O&M) costs, the variable-based tariff (FITV), which is a component of fuel costs, and the additional premium, which is a component of an extra financial boost for the first 8 years of operation. Furthermore, FIT premium is also available in some southern provinces and districts to better promote biomass development in specific areas.

Figure 4.1. FIT Formulation



Source: Based on information provided by DEDE.

Programme of community-based renewable power plants for local economic development

A community power plant is a small-scale electricity generation facility producing no more than 3 MW (for biomass) and 6 MW (for biogas generated from fast-growing crops). It can sell electricity to the government. The programme involves two main groups: project proponents (private or private sector in collaboration with government agencies) and the local community enterprise. At a project's outset, the project proponents will hold approximately 90% of the community power plant's shares, whilst the community enterprise will have around 10%. However, these proportions can be adjusted in the future, with the community having the opportunity to increase their shareholding to a maximum of 40% (GSB, 2020).

Box 4.1. Programme of Community-based Renewable Power Plants for Local Economic Development

The 'Community-based Renewable Power Plants for Local Economic Development' programme was inaugurated in 2019 under the leadership of Energy Minister Sontirat Sontijirawong. Its primary goals include fostering community the involvement, awareness, and approval of renewable energy power plant initiatives. Communities are encouraged to become active partners in these projects, collaborating in the generation and distribution of electricity alongside the private sector and/or governmental entities through community enterprises.

Thailand's Energy Regulatory Committee (ERC) has established criteria for procuring power from community-based power plants. These criteria permit the utilisation of two types of renewable energy sources: biomass and biogas derived from energy crops.

Type of Renewable Source	Maximum Contract Capacity	Target
Biomass	Maximum 6 MW	75 MW
Biogas from energy crops (wastewater or sewage can be mixed at a maximum ratio of 25%)	Maximum 3 MW	75 MW
	Total	150 MW

The community power plant deploys a non-firm contract FIT to encourage investment and increase community engagement. Moreover, projects situated in the three southern border provinces will receive an additional FIT premium rate.

Fuel Type/Installed Capacity (MW)	FIT (B/kWh)			Subsidy Period	FIT Premium (B/kWh)*
	FITF	FITV	FIT		
1) Biomass					
Capacity less than 3 MW	2.61	2.2382	4.8482	20 years	0.50
Capacity higher than 3 MW	2.39	1.8736	4.2636	20 years	0.50
2) Biogas (energy crop)					

(max. 25% wastewater and sewage mix)	2.79	1.9369	4.7269	20 years	0.50

*Premium FIT for the project in three southern border provinces.

The implementation of the programme has yielded promising results, indicating that 150 MW of community-based power plants can significantly reduce GHG emissions by an estimated 486,574 t-CO_2 per year. Over a span of 20 years, farmers and local communities stand to earn more than B47 billion. Additionally, the programme has the potential to create approximately 19,000 job opportunities, further fostering economic growth and sustainability.

Source: Based on information provided by DEDE.

Biofuel mandate policies

Thailand has a biofuel mandate that requires a certain percentage of transportation fuel to come from biofuels, primarily bioethanol and biodiesel. The policy supports the production of biofuels from biomass sources such as sugarcane, cassava, and palm oil. The key supportive policy is the State Oil Fund, which was established in 1991 in response to the fluctuations in global oil prices and the need to stabilise domestic fuel prices. The fund has been used for various purposes, including subsidising fuel prices, supporting alternative energy development (including biofuels), and funding other energy-related initiatives.

Investment Promotion Guide

The Investment Promotion Guide, enacted by the Thailand Board of Investment (BOI), offers the nation's support for green energy and sustainable industrial practices, including the promotion of biomass as a key component of its renewable energy strategy.

The investment promotion strategies for biomass focus on incentivising the development of biomass power plants, the production of biofuels, and the utilisation of biomass for heat in industrial processes. The BOI offers a range of incentives to attract investment in these areas, including tax exemptions, import duty exemptions on machinery and raw materials, and non-tax incentives, such as permission for foreign nationals to work in promoted biomass projects and land ownership rights for foreign investors.

The guide details specific criteria and conditions under which biomass projects can qualify for BOI incentives. For example, projects that contribute to the reduction of GHG emissions, utilisation of agricultural waste, or incorporation of innovative technologies for biomass conversion into energy are particularly encouraged. The BOI also supports the establishment of biomass research and development centres to foster innovation in biomass technology.

Moreover, the guide mentions area-based incentives, indicating a strategic approach to distribute the economic benefits of biomass projects across different regions, with particular emphasis on rural areas rich in biomass resources. This not only promotes regional development but also aligns with Thailand's broader goals of sustainable development and energy security.

Research and development support

To develop and improve biomass technology and applications, the Thai government provides funding for research in renewable energy technologies, including biomass, and collaboration with universities and the private sector. For example, the government sponsored a research project, 'Study of guidelines to promote the use of biomass for thermal energy production by alternative energy development plan for 15 years', in 2010; some of its results still provide insights for our studies like the challenges in industrial sectors, as outlined in Table 4.1. The Thai government's sponsorship of the research project 14 years ago is a testament to its proactive approach to fostering the technologies of biomass from an early stage.

Table 4.1. Biomass Promotion Challenges in Industrial Sectors

Sector	Challenges
Tapioca	Insufficient biomass quantity, government bureaucracy.
Power plants	Lack of public awareness, high production costs.
Rice mills	Insufficient husk, lack of emissions measurement tools.
Paper	Lack of public understanding.
Sugar	Implementation delays, storage issues.
Palm oil	Implementation delays, lack of knowledge, funding gaps.
Cement	Insufficient husk, costly fuel.
Ranch	Difficulty in sales.
Lumber	Lack of information.
Food	Knowledge transfer, technology, weather challenges.
Other	Insufficient husk, funding gaps.

Source: TEC (2010).

The Energy Conservation Promotion Fund (ENCON Fund)

The ENCON Fund is a part of the country's broader Energy Conservation Program (ENCON). Launched in 1992, this initiative aims to support the introduction and promotion of new and renewable energy technologies. The ENCON Fund was established with capital initially secured through the existing Oil Fund, with additional levies collected from petroleum producers and importers. The ENCON Fund supports various projects and initiatives aimed at increasing energy efficiency and the utilisation of renewable energy, including biomass. Using the ENCON Fund, DEDE launched a biomass promotion measure that partially subsidises biomass pellet boiler replacement.

Box 4.2. 'Promoting Renewable Heat Generation and Utilisation' Programme under ENCON

In alignment with the goals outlined in the AEDP 2018 to promote renewable heat, DEDE launched the 'Promoting Renewable Heat Generation and Utilisation' programme. Selected applicants under this programme will receive government funding from the Energy Conservation Promotion Fund (ENCON Fund). The subsidy schemes have been categorised into two distinct groups: biomass and biogas.

1) Biomass group: For a biomass project, the subsidy schemes will be separated into the following three sub-categories

- Fuel collectors (community enterprise or agro-cooperative)
- Biomass fuel producers (community enterprise or agro-cooperative)
- Biomass fuel users (community enterprise, agro-cooperative, or industry)

The selected project owner is eligible to receive a maximum of 30% of the total investment cost, capped at B3 million per project.

2) Biogas group: For a biogas project, the target groups are the biogas producer, community enterprise, and cooperative. The subsidy schemes will be separated into two sub-groups.

Sub-group 1: Subsidy for compressed bio-methane gas system installation

- Capacity of 3,000–5,999 kg/day: subsidy 30% (maximum B9 million/project)
- Capacity of 6,000–11,999 kg/day: subsidy 25% (maximum B12 million/project)
- Capacity higher than 12,000 kg/day: subsidy 20% (maximum B15 million/project)

Sub-group 2: Subsidy for biogas system improvement for thermal generation (subsidy 30% of project investment, maximum B3 million/project)

In terms of project implementation, the initiative showcases a notable increase of 62 ktoe in renewable energy utilised for heat production. Additionally, this programme plays a pivotal role in advancing the renewable share outlined in the AEDP whilst also mitigating outdoor burning, PM 2.5 pollution, and GHG emissions by preventing methane release from sewage.

Source: Based on information provided by DEDE.

The routine updates made by the Thai government to its policies also play a crucial role. For instance, in March 2023, the Energy Policy Executive Committee of the Ministry of Energy's Energy Policy and Planning Office made additional decisions to further implement the Thailand Power Development Plan 2018–2037, 1st revised edition (PDP2018 Rev.1). These decisions included approving plans to increase clean energy-based electricity production and endorsing the principle of purchasing additional electricity from renewable sources, particularly those not reliant on fuel costs, such as industrial waste (EPEC, 2023). This will be facilitated through the FIT for 2022–2030. This decision serves as evidence of the government's continued alignment with the goals outlined in its plans.

It is worth noting that whilst Thailand has supported the development and utilisation of biomass through the above comprehensive policy framework, two concrete policies, i.e. FIT for power plants with SPP/VSPP programmes and the State Oil Fund for biofuels, have played instrumental roles in this regard.

It is also worth noting that Thailand has supported the development and utilisation of biomass by periodically updating these policies, thus ensuring that its biomass promotion strategies remain relevant and responsive to technological advancements, market dynamics, and environmental considerations. This adaptive approach has facilitated robust growth in the biomass sector, attracting both domestic and international investors and contributing significantly to the country's renewable energy mix and sustainability goals.

4.1.2. Resource availability

The total biomass potential in Thailand is substantial, amounting to 296.34 million tonnes per year, with an energy equivalent of 69.92 million tonnes of oil equivalent (Mtoe)/year. As can be seen in Tables 4.2 and 4.3, which provide detailed information on the biomass, potential biomass sources and production in Thailand focus on various agricultural products and their by-products, as well as fast-growing trees. The following are major biomass sources.

Sugarcane

Sugarcane by-products, including bagasse and sugarcane leaf and trash, are amongst the largest sources of biomass. Bagasse alone contributes 65.53 million tonnes/year, with an energy potential of 11.53 Mtoe/year, whilst sugarcane leaf adds another 45.19 million tonnes/year, with an energy potential of 11.80 Mtoe/year.

Rice

Rice husks and straw are also significant, with rice straw providing 43.06 million tonnes/year (10.87 Mtoe/year in energy potential) and rice husks contributing 8.97 million tonnes/year (3.25 Mtoe/year in energy potential).

Cassava

Cassava by-products, including cassava pulp, rhizome, and trunk, together represent significant biomass potential, with the pulp alone amounting to 20.51 million tonnes/year (720.20 ktoe/year in energy potential).

Oil palm

Oil palm by-products, including empty fruit bunches, fibre, shells, frond, and trunk, are notable contributors, with the trunk alone offering 30.16 million tonnes/year (5,430 ktoe/year in energy potential).

Para wood

Para wood, derived from the rubber tree, is represented in Table 4.2 as sawdust, residual wood, leaf, branch, slab, and root. The combined total for these categories presents a significant portion of the biomass, with residual wood alone amounting to over 12.68 million tonnes/year (4.23 Mtoe/year in energy potential), all of which is available for energy production.

The table distinguishes between the total occurring biomass and the portion available for energy production after accounting for utilisations in agriculture and industry. A significant portion of the biomass, especially from sugarcane leaves and rice straw, is available for energy production, highlighting the vast potential for renewable energy sources in Thailand, as well as the importance of these two biomass sources.

The observation that biomass by-products from industry are almost fully utilised in Thailand underscores an important aspect of biomass management and energy production. This high utilisation rate of industrial biomass by-products, such as bagasse from the sugar industry or rice husks from the rice milling process, indicates a successful integration of biomass utilisation within these sectors for purposes like energy production, material recycling, or as inputs in other industrial processes. The reasons for this high utilisation include the following.

Economic incentives

Industries have economic incentives to utilise by-products efficiently. Using biomass for energy production can reduce waste disposal costs, provide an additional revenue stream, and decrease reliance on external energy sources.

Technological advancements

Many industries have access to technologies that can convert biomass by-products into energy or other valuable materials, making utilisation more feasible and efficient.

Policy support

Policies that encourage the use of renewable energy sources, including biomass, can drive industries to adopt biomass utilisation practices, including biomass power generation.

Sustainability goals

Industries aiming to improve their sustainability profiles may use biomass by-products as part of their strategy to reduce GHG emissions and enhance environmental stewardship.

However, for biomass resources that are not by-products of industries, such as agricultural residues (e.g. rice straw) or naturally occurring biomass (e.g. oil palm trunks), the utilisation rates may be lower due to challenges like collection, transportation, seasonal availability, and the lack of established markets or technologies for their efficient use.

Table 4.2. Biomass Potential (Physical Unit of Tonnes)

Agricultural Product	Biomass	Occurring Biomass	Utilisations		Available Biomass for Energy Production
			Agriculture	Industry (Energy Production)	
		tonnes/year	tonnes/year	tonnes/year	tonnes/year
Rice	Rice husk	8,974,554.14	2,620,273.46	6,354,280.68	0.00
	Rice straw	43,056,371.20	15,371,124.52	0.00	27,685,246.68
Sugarcane	Bagasse	65,526,015.61	0.00	65,526,015.61	0.00
	Sugarcane leaf	45,194,485.00	0.00	0.00	45,194,485.00
Cassava	Cassava pulp	20,512,651.48	0.00	20,512,651.48	0.00
	Cassava rhizome	5,964,933.00	0.00	0.00	5,964,933.00
	Cassava trunk	15,214,725.00	0.00	0.00	15,214,725.00
Oil palm	Empty fruit bunch	298,036.34	101,887.30	187,868.16	8,280.88
	Fibre	196,194.78	77,117.50	112,809.57	6,267.72
	Shell	83,869.52	29,766.47	51,683.79	2,419.27
	Frond	357,741.00	0.00	0.00	357,741.00
	Trunk	30,155,059.13	0.00	0.00	30,155,059.13
Para wood	Sawdust	2,680,184.62	0.00	2,680,184.62	0.00
	Residual wood	12,680,443.38	0.00	12,680,443.38	0.00
	Leaf	2,400,518.56	0.00	0.00	2,400,518.56
	Branch	56,730.66	0.00	0.00	56,730.66
	Slab	5,086,331.40	0.00	5,086,331.40	0.00
	Root	16,414,619.35	0.00	0.00	16,414,619.35
Coconut	Shell	84,308.39	0.00	84,308.39	0.00

Agricultural Product	Biomass	Occurring Biomass	Utilisations		Available Biomass for Energy Production
			Agriculture	Industry (Energy Production)	
		tonnes/year	tonnes/year	tonnes/year	tonnes/year
	Fibre	20,972.24	0.00	20,972.24	0.00
	Leaf	480,476.54	0.00	0.00	480,476.54
	Frond	780,489.19	0.00	0.00	780,489.19
Corn	Cob	2,165,533.90	0.00	2,165,533.90	0.00
	Pulp	2,280,772.50	0.00	2,280,772.50	0.00
	Trunk	14,779,405.40	0.00	0.00	14,779,405.40
Wood	Bark	596,873.98	0.00	596,873.98	0.00
	Leaf and Branch	298,177.15	0.00	0.00	298,177.15
Total		296,340,473.46	18,200,169.25	118,340,729.70	159,799,574.53

Source: DEDE (2020).

Table 4.3. Biomass Potential (Thermal Unit of ktoe)

Agricultural Product	Biomass	Occurring Biomass	Utilisation		Available Biomass for Energy Production
			Agriculture	Industry (Energy Production)	
		ktoe/year	ktoe/year	ktoe/year	ktoe/year
Rice	Rice husk	3,254.25	961.11	2,293.14	0.00
	Rice straw	10,874.90	3,882.34	0.00	6,992.56
Sugarcane	Bagasse	11,534.50	0.00	11,534.50	0.00
	Sugarcane leaf	11,801.94	0.00	0.00	11,801.94
Cassava	Cassava pulp	720.20	0.00	720.20	0.00
	Cassava rhizome	2,362.93	0.00	0.00	2,362.93
	Cassava trunk	1,738.00	0.00	0.00	1,738.00
Oil palm	Empty fruit bunch	51.53	17.62	32.48	1.43
	Fibre	55.29	21.73	31.79	1.77
	Shell	33.85	12.01	20.86	0.98
	Frond	140.64	0.00	0.00	140.64
	Trunk	5,430.61	0.00	0.00	5,430.61
Para wood	Sawdust	893.65	0.00	893.65	0.00
	Residual wood	4,228.02	0.00	4,228.02	0.00
	Leaf	924.24	0.00	0.00	924.24
	Branch	25.99	0.00	0.00	25.99
	Slab	2,330.06	0.00	2,330.06	0.00
	Root	7,100.12	0.00	0.00	7,100.12
Coconut	Shell	36.10	0.00	36.10	0.00
	Fibre	8.12	0.00	8.12	0.00
	Leaf	184.65	0.00	0.00	184.65
	Frond	318.00	0.00	0.00	318.00
Corn	Cob	104.68	0.00	104.68	0.00
	Pulp	95.85	0.00	95.85	0.00
	Trunk	5,581.31	0.00	0.00	5,581.31
Wood	Bark	89.67	0.00	89.67	0.00
	Leaf and Branch	4.35	0.00	0.00	4.35
Total		69,923.45	4,894.81	22,419.12	42,609.52

Source: DEDE (2020).

4.1.3. Commercial production and usage

To better understand the current status of biomass production and its usage in Thailand, biomass balance tables are explored and analysed. A biomass balance table provides a comprehensive overview of the primary supply, transformation, and final consumption of various forms of bioenergy, including solid biomass, biogas, biofuels, and traditional biomass.

Table 4.4. Bioenergy Balance Table, 2013

(ktoe)

	Solid Biomass	Biogas	Biofuels	Traditional Biomass
Primary supply	8,347	670	1,520	13,835
Power plants	3,029	175		
Other transformation				5,759
Manufacturing	5,318	495		1,832
Residential				6,244
Transportation*			1,520	

* The data is moved from the 'transformation' sector in the original balance table.
Source: DEDE (2023b).

Table 4.5. Bioenergy Balance Table, 2022

(ktoe)

	Solid Biomass	Biogas	Biofuels	Traditional Biomass
Primary supply	16,380	1,279	1,924	4,521
Power plants	11,181	591		
Other transformation				1,245
Manufacturing	5,199	688		
Residential				3,276
Transportation*			1,924	

* The data is moved from the 'transformation' sector in the original balance table.
Source: DEDE (2023b).

The two biomass balance tables of Table 4.4 and Table 4.5 offer a snapshot of the evolution of Thailand's bioenergy landscape over the course of nearly a decade, from 2013 to 2022. The data encompass various forms of bioenergy, including solid biomass, biogas, biofuels, and traditional biomass. The tables categorise these energy sources by primary supply and their utilisation across sectors such as power plants, manufacturing, residential, and other transformations.

Primary supply growth

Between 2013 and 2022, there was a significant increase in the primary supply of bioenergy in Thailand. In 2013, the total primary supply was approximately 8,347 ktoe, whilst it more than doubled to reach around 16,380 ktoe in 2022. This growth can be attributed to various factors, including increased efforts to harness renewable energy sources and a greater emphasis on sustainable energy practices.

Power plant utilisation

The utilisation of biomass in power plants has also seen substantial growth. In 2013, biomass supplied 3,029 ktoe to power plants, whereas in 2022, this figure surged to 11,181 ktoe. This indicates the success of the government's comprehensive policy framework to promote renewable energy and demonstrates the government's strong commitment to using bioenergy for electricity generation and reducing reliance on conventional fossil fuels.

Biofuels

Biofuels have witnessed substantial growth, with utilisation increasing from 1,520 ktoe in 2013 to 1,924 ktoe in 2022. This expansion aligns with global efforts to reduce GHG emissions and enhance energy security through biofuel adoption.

Biogas

Biogas utilisation has also shown a positive trend, rising from 670 ktoe in 2013 to 1,279 ktoe in 2022. Biogas plays a vital role in waste management and renewable energy production, contributing to Thailand's sustainability objectives.

Manufacturing

The manufacturing sector plays a pivotal role in Thailand's energy landscape, particularly in terms of heat utilisation. In 2013, manufacturing relied on biomass for heating processes, accounting for 5,318 ktoe of energy supply. This figure slightly decreased to 5,199 ktoe in 2022, indicating the sector's sustained use of biomass as a crucial source of thermal energy. Biomass offers an eco-friendly and cost-effective solution for industrial heating requirements, contributing to the sector's operational efficiency and environmental sustainability. The consistent utilisation of biomass for heat in manufacturing underscores the importance of renewable energy sources in supporting Thailand's industrial activities whilst simultaneously reducing GHG emissions.

Shift from traditional biomass

One notable trend is the reduction in the utilisation of traditional biomass for residential and other transformations. In 2013, traditional biomass accounted for a significant portion of energy use in these sectors, totalling 6,244 ktoe. By 2022, this figure dropped to 3,276 ktoe. This shift reflects a move towards cleaner and more efficient energy sources, contributing to reduced indoor air pollution and improved environmental sustainability.

4.1.4. Existing supply chain and cost

The existing supply chain and cost for bioenergy in Thailand varies depending on the specific usage, such as power plants, heat usage, and biofuels.

For biomass power plants, the supply chain involves sourcing diverse types of biomass feedstock from various regions of Thailand. The cost and challenges are influenced by factors such as the stability of biomass supply, transportation logistics, moisture management, and quality control. Biomass power plants often rely on multiple types of biomass to ensure a reliable fuel supply. The cost of biomass feedstock can range from B900–B1,300/tonne, depending on the type of biomass. Key challenges include competition for biomass resources, regulatory hurdles, and the need for efficient handling and processing of biomass. These issues will be analysed in more detail in Section 4.4.

In the case of biomass heat usage, the supply chain is more complex, particularly for wood pellets. It involves various stakeholders, including raw biomass producers, pellet producers, consumers, and supportive entities. Trading of wood pellets occurs through direct channels between producers and users or via buying agents. The cost of producing wood pellets in Thailand is estimated to be around B2,903/tonne as of 2023, with the selling price to end-users around B4,209/tonne. The limited domestic consumption of wood pellets, preference for exports, and lack of established standards pose challenges for this sector. A more comprehensive analysis will be provided in Section 4.5.

For biomass used in biofuel production, the supply chain is influenced by government mandates and subsidies. Biofuels such as biodiesel and ethanol are produced from feedstocks like palm oil, sugarcane, and cassava. The cost dynamics are affected by factors such as agricultural production, crude palm oil prices, and the operation of the Oil Fuel Fund. The biofuel sector faces uncertainties related to the continuity of subsidies beyond 2026 and the need to align with evolving fuel standards. These aspects will be discussed further in Section 4.6.

4.2. Expected Supply and Demand of Bioenergy in 2037

The expected supply and demand of bioenergy in 2037 is analysed based on the government's official development plan, including policies and targets.

4.2.1. Biomass development target in 2037

The latest biomass-related renewable energy development policy and target in Thailand is the revised AEDP 2018 (DEDE, 2020), which was approved by the government in 2020. The AEDP 2018 is part of the Thailand Integrated Energy Blueprint, which consists of five energy plans, namely (1) the Power Development Plan (PDP), (2) Energy Efficiency Plan, (3) Alternative Energy Development Plan (AEDP), (4) Gas Plan, and (5) Oil Plan.

The AEDP 2018 has set an increased target of achieving a 30% proportion of renewable and alternative energy in the form of electricity, heat, and biofuels by 2037, contributing to domestic final energy consumption, as outlined in Table 4.6.

Table 4.6. Bioenergy Development Targets in Thailand

Power Type	Targets for the Year 2037	
	Unit	Volume
Electricity	**ktoe**	**7,298**
	MW	**29,411**
Biomass (estimated energy demand)	MW (ktoe)	5,790 (17,222)
Biogas	MW	1,565
Heat	**ktoe**	**26,901**
Biomass	ktoe	23,000
Biogas	ktoe	1,283
Biofuels	**ktoe**	**4,085**
Ethanol	million litres/day	7.50
Biodiesel	million litres/day	8.00
Pyrolysis oil	million litres/day	0.53
Use of Renewable Energy	**ktoe**	**38,284**
Final Energy Consumption	**ktoe**	**126,867**
Proportion of Renewables in Final Energy Consumption	**%**	**30**

Source: DEDE (2020).

To assess the total bioenergy consumption across various biomass uses targeted for biomass development in the AEDP 2018, the targeted biomass power capacity (MW) is converted into energy consumption (ktoe) using the same ratio observed between these two indicators in 2022, which is derived from the bioenergy consumption data provided in the balance table. The ratio calculated for MW to ktoe in 2022 is 11,181 MW to 3,759 ktoe, equating to 2.9745 ktoe per MW. Multiplying the projected biomass power capacity of 5,790 MW for 2037 by this ratio yields an estimated energy consumption of 17,222 ktoe.

Thus, the projected bioenergy consumption targets for biomass power plants, heating purposes, and biofuels in 2037 are calculated as 17,222 ktoe, 23,000 ktoe, and 4,085 ktoe, respectively. In total, this amounts to 44,307 ktoe by the year 2037. This figure represents 63.4% of the total anticipated biomass resource, which is estimated to be 69,923 ktoe.

However, it is important to note that readily accessible types of biomass from industrial by-products, such as rice husk and bagasse, are already being utilised to their full capacity. Consequently, further expansion in biomass utilisation will require tapping into more challenging sources scattered across fields, such as rice straw and sugarcane leaves, or enhancing the biomass resource base through new planting initiatives.

4.2.2. Identifying the gaps between supply and demand

Whilst Thailand has made commendable progress in its biomass development efforts, there is a significant gap between the supply and the ambitious targets set for 2037. This gap is illustrated in Table 4.7 and Figure 4.2 to Figure 4.4.

Table 4.7. Bioenergy Development and Targets in 2037

	Unit	2020	2021	2022	Target 2037
Biomass power plant	MW	3,517	3,646	3,759	5,790
Biogas power plant	MW	557	635	652	1,565
Biomass heat usage	ktoe	5,903	4,395	5,419	23,000
Biofuels	million litres/day	9.21	8.29	7.63	15.50

Source: DEDE (2023b).

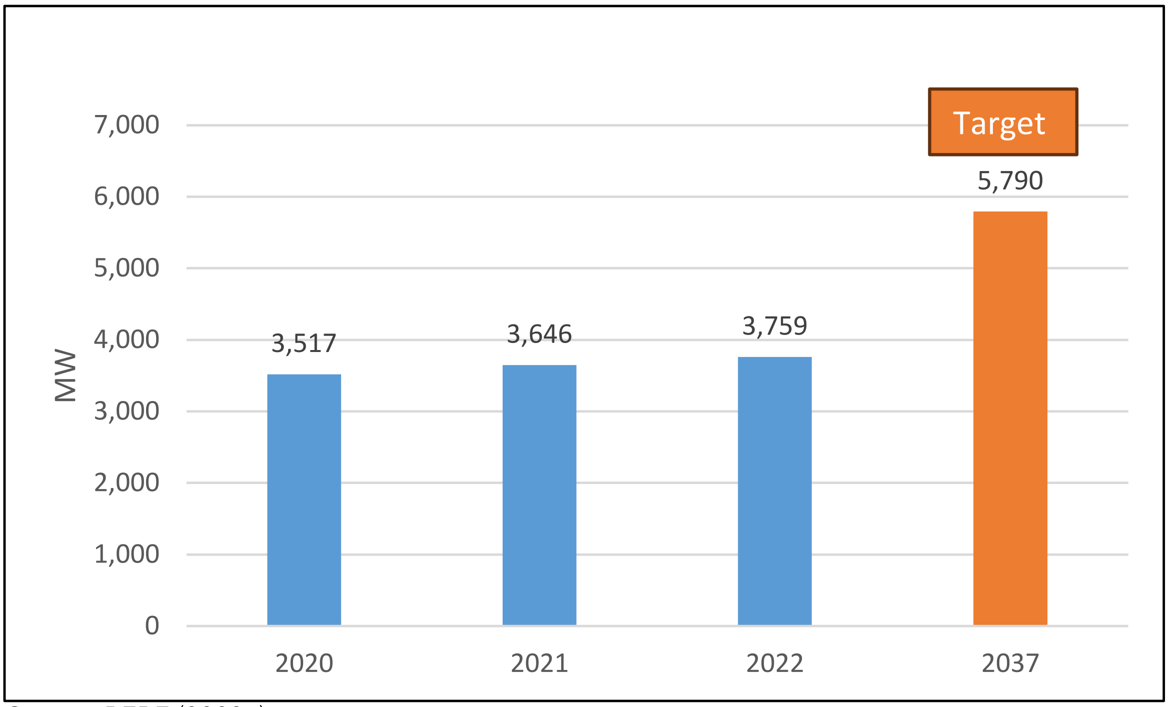
Thailand's biomass power plant capacity has seen incremental growth over the years, reaching 3,759 MW in 2022. However, to meet the ambitious target of 5,790 MW by 2037, further significant capacity expansion will be required. It is crucial to continue investing in biomass power generation infrastructure and incentivising renewable energy projects to bridge the gap.

The biogas sector has also shown steady progress, with an installed capacity of 652 MW in 2022. To reach the target of 1,565 MW by 2037, there is room for growth and investment in biogas production. Biogas, derived from organic waste, can play a vital role in waste management and renewable energy generation, aligning with sustainability goals.

Biomass heat usage has witnessed fluctuations in recent years. Whilst it increased to 5,419 ktoe in 2022, it remains significantly below the ambitious 2037 target of 23,000 ktoe. Achieving this target will require substantial efforts to promote the use of biomass for heating applications, particularly in industrial areas.

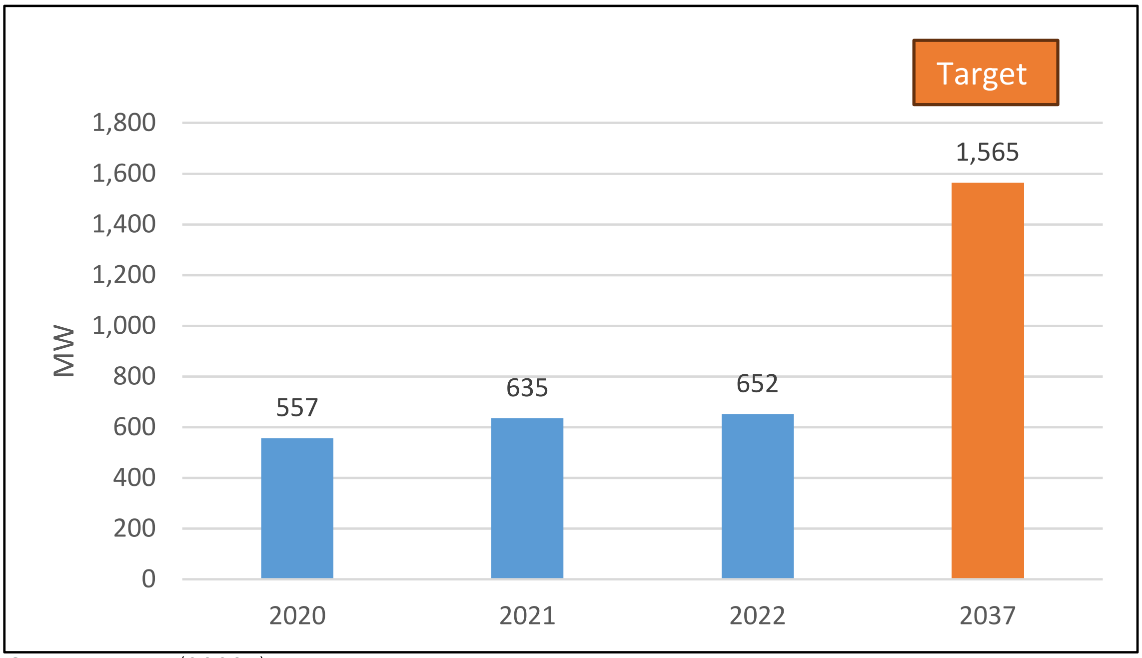
Biofuel production has shown a decreasing trend from 9.21 million litres per day in 2020 to 7.63 million litres per day in 2022. To reach the target of 15.50 million litres per day by 2037, there is a need for strategic investments in biofuel technologies and feedstock availability to revitalise the sector and promote biofuels as a sustainable alternative to fossil fuels.

Figure 4.2. Biomass Power Plant Capacity and Target in 2037



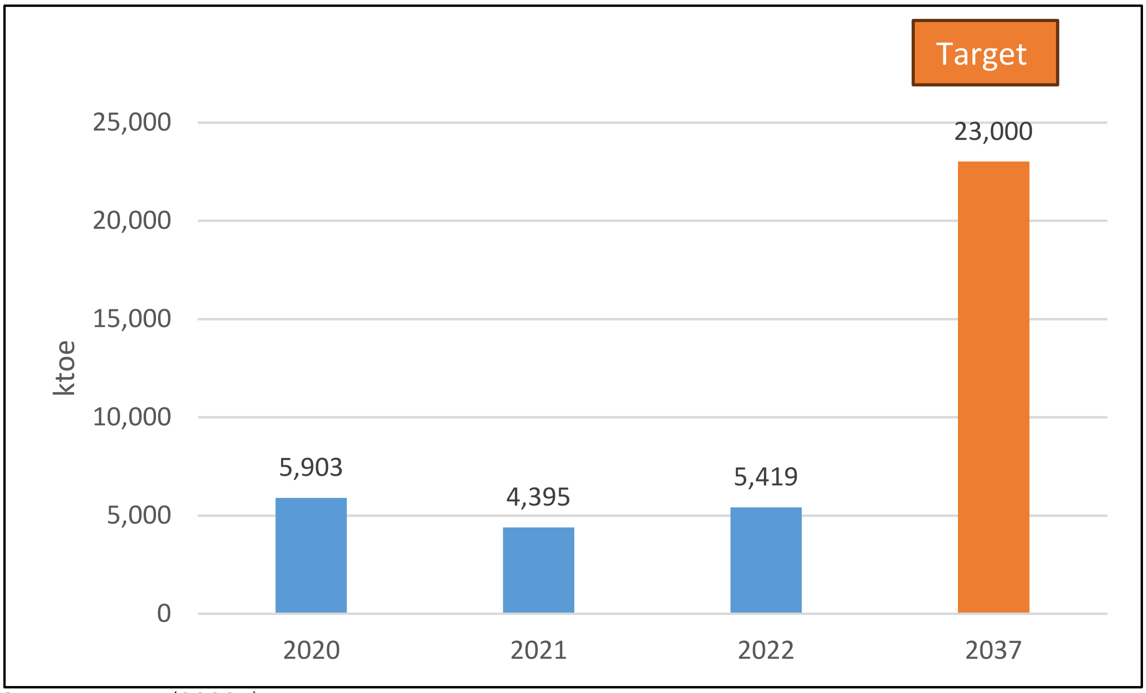
Source: DEDE (2023a).

Figure 4.3. Biogas Power Plant Capacity and Target in 2037



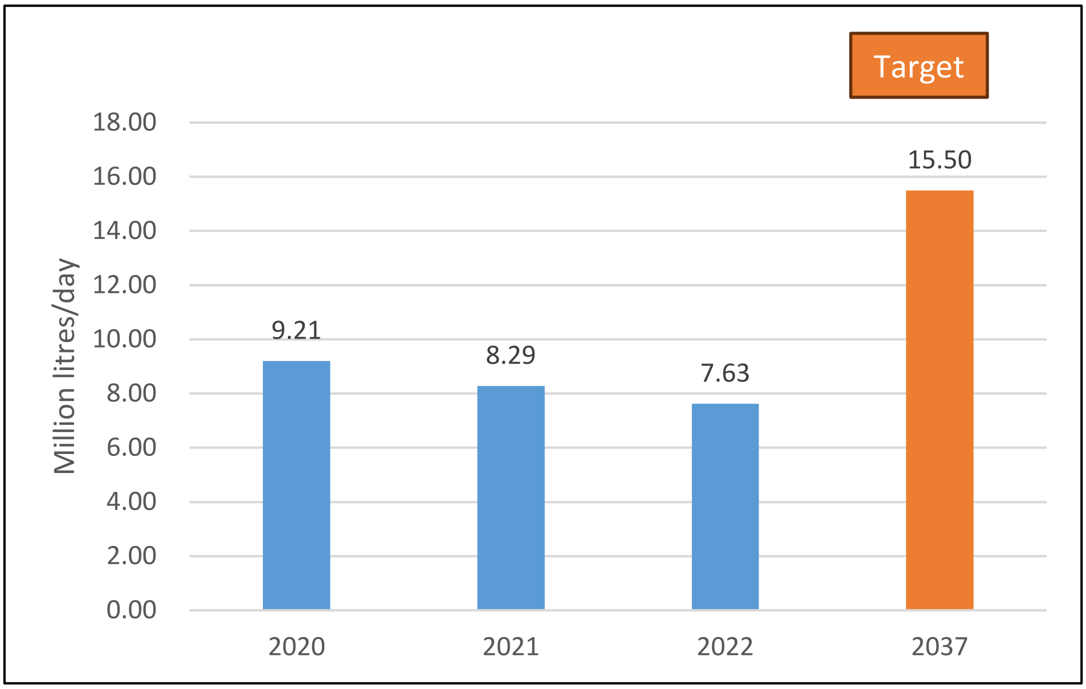
Source: DEDE (2023a).

Figure 4.4. Biomass Heat Usage and Target in 2037



Source: DEDE (2023a).

Figure 4.5. Biofuel Production and Target in 2037



Source: DEDE (2023a).

4.3. Requirements for the Development of the Supply Chain

The development of a robust and sustainable biomass supply chain in Thailand faces various barriers, including technical, policy, and market aspects. These barriers need to be addressed to ensure the efficient utilisation of biomass resources for energy production.

4.3.1. Technical barriers

Technical barriers in the biomass supply chain include challenges related to major stakeholders and companies involved in manufacturing technologies, equipment, transportation, capacity, and human resources in the sector. For biomass power plants, ensuring a stable and diverse supply of biomass feedstock, managing moisture content, and maintaining quality control are key technical hurdles. In the case of biomass heat usage, the limited availability of efficient pelletisation technologies and the lack of broader standardisation in biomass properties pose technical challenges. For biofuel production, technical barriers may include the need for advanced processing technologies and the compatibility of biofuels with existing vehicle engines. Addressing these technical barriers requires collaborative efforts from stakeholders across the supply chain.

4.3.2. Policy barriers

Policy barriers encompass issues related to policy targets, incentives, and regulatory reforms. The inconsistency or uncertainty of government policies and subsidies can hinder the long-term growth of the bioenergy sector. For instance, the expiration of biofuel subsidies beyond 2026 creates uncertainty for investors and producers. For heat usage, heat promotion incentives have not been regularly deployed, and the current voluntary promotion scheme is not attractive enough to ramp up the use of renewable heat. Therefore, streamlining policies, providing clear long-term targets, avoiding inconsistent policies or regulation changes, and implementing supportive regulations are essential to overcoming policy barriers.

4.3.3. Market barriers

Market barriers include aspects such as certification and standards, sustainability criteria, and financial constraints. The absence of widely accepted certification and standards for biomass fuels can limit market confidence and hinder trade. Sustainability concerns, such as the environmental impact of biomass cultivation and competition for food production, can also pose market barriers. Moreover, the high initial investment costs for biomass projects and the lack of financing mechanisms can deter market entry and growth. Addressing market barriers involves establishing clear sustainability guidelines, developing certification schemes, creating innovative financing models to support biomass projects, and establishing long-term contracts between suppliers and consumers. For biofuels, government subsidies can help bridge the gap between biofuels and petroleum, but fiscal sustainability must be pursued in the long run.

4.3.4. Summary of barriers to specific usage

The specific challenges and requirements for developing the biomass supply chain vary depending on the end-use application. Major barriers to the three usages of biomass, analysed in detail in the following sections, are summarised as follows.

For biomass power plants

- Supply chain instability and complexity, including fuel cost competitiveness
- Regulatory hurdles and environmental concerns
- Shift towards other renewables like solar and wind

For biomass heat usage

- Complex supply chain and lack of broader standards
- Limited market demand and unknown consumer willingness
- Uneven distribution of biomass resources across regions
- Financial obstacles, such as limitations in financial accessibility
- Challenge in biomass usage monitoring (especially in the manufacturing industries)

For biomass for biofuel

- Uncertainty around the future of biofuel subsidies beyond 2026
- Need for alignment with Euro 5 fuel quality standards
- Balancing of agricultural interests and environmental goals
- Limited flexibility and diversity in biofuel feedstocks

In the following sections, these barriers are analysed in more detail for biomass power plants (Section 4.4), biomass heat usage (Section 4.5), and biomass for biofuel (Section 4.6). By understanding the unique challenges faced by each sector, targeted strategies can be developed to overcome the technical, policy, and market barriers, fostering sustainable growth of the bioenergy industry in Thailand.

4.4. Biomass power plants

4.4.1. General situation

Biomass contributes significantly to Thailand's power mix, with about two-thirds of the 15% share of renewable electricity (excluding large hydropower) coming from biomass, according to the IEA (2024). The total installed capacity of grid-connected biomass power plants was 2,090 MW in 2022, according to DEDE (2023a). This includes 459 MW in the Northern region, 691 MW in the Northeastern region, 614 MW in the Central region, and 326 MW in the Southern region.

Incentives for renewable energy, like FITs, together with the Small Power Producer (SPP) and Very Small Power Producer (VSPP) schemes under the Power Purchase Agreement (PPA), have been instrumental. However, scaling up biomass usage faces challenges like feedstock transportation costs and regulatory hurdles. Companies often cap production at 9.9 MW to avoid Environmental Impact Assessment requirements, leading to competition for feedstock and inefficiencies.

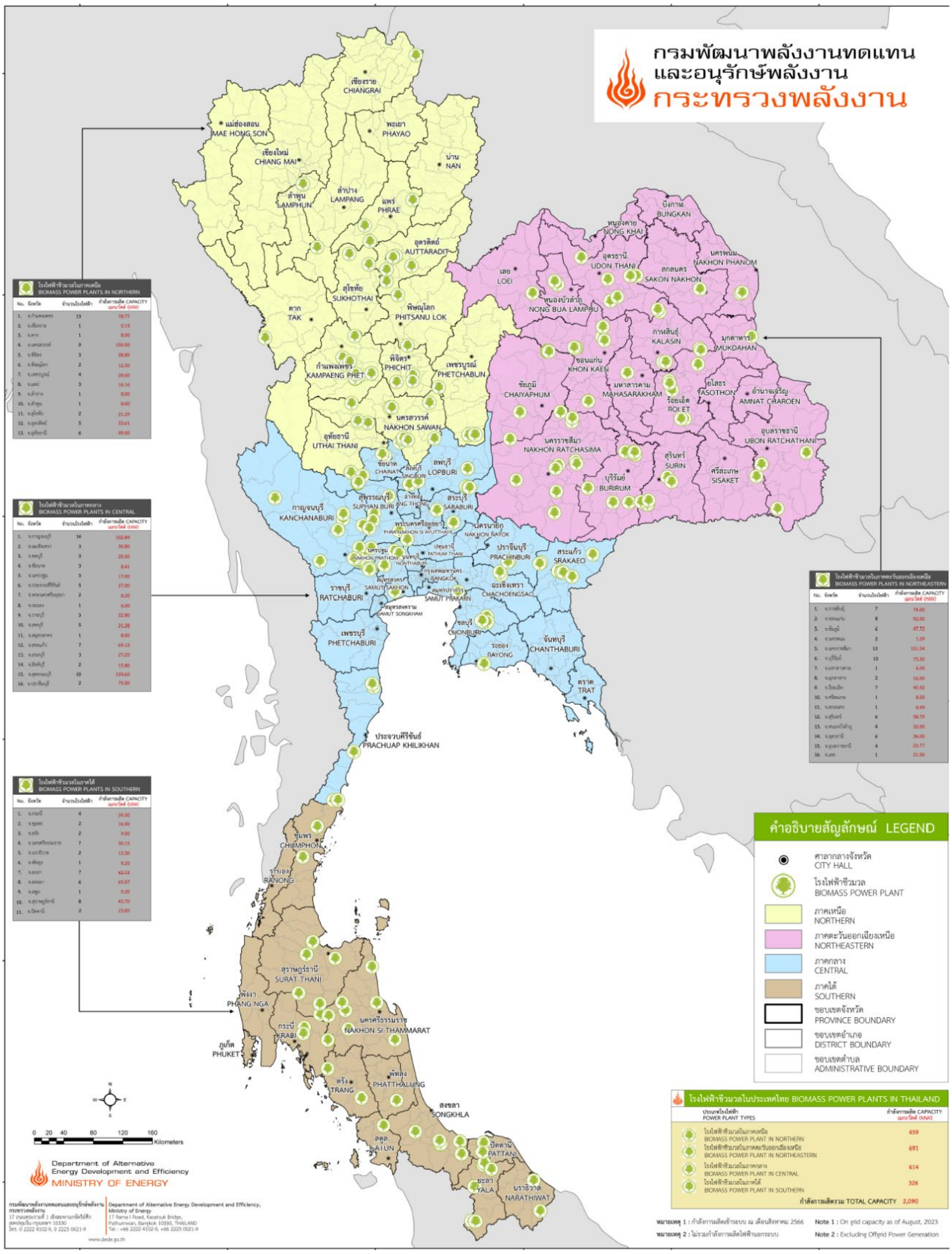
Furthermore, there is a growing shift towards solar and wind energy because solar energy is becoming more affordable, leading to widespread adoption in commercial spaces like shopping malls and factories. Flexible business models of solar energy, like the option to choose direct investment or an energy service company, are also a strong point. The government's new policy to permit energy service companies in government buildings for solar energy in early 2024 will strengthen this trend. These developments are widening the margin for renewable energy, prompting a need for more efficient energy utilisation and reasonable electricity pricing.

The country also faces challenges in balancing the desire for green electricity with the need to keep prices low. Regulatory disagreements and the need for efficient pricing strategies are current issues. All these issues raise the concern that the market for biomass power plants is becoming saturated, and further development will require addressing the issues the market is facing.

4.4.2. Supply chain and challenges

The map of the locations of biomass power plants in Thailand presented in Figure 4.6 clearly shows that the biomass power plants are nearly evenly distributed across the country. This distribution highlights the fact that biomass is a low-energy-intensity resource and that a large surrounding area is crucial for a stable feedstock supply to the biomass power plants.

Figure 4.6. Map of Locations of Biomass Power Plants in Thailand



Source: DEDE (2023a).

Complexity of biomass supply and challenges

To understand the status of biomass power plants, particularly the supply chain, the Energy Research Division's Biomass Group of DEDE has compiled data regarding the procurement of various biomass fuels for Thailand's biomass power plants in 2022. These data cover a total of 79 locations, distributed as follows: 17 in the Northern region, 22 in the Central region, 14 in the Southern region, and 26 in the Northeastern region.

As an overview of the survey, the breakdown of biomass purchases by type includes biomass from 66 different economic crops, such as rice, sugarcane, corn, cassava, coconut, and palm; woody biomass from 45 locations, encompassing rubberwood, eucalyptus wood, mixed deciduous wood, and other wood types; and additionally seven other types of biomass, such as bamboo, bamboo leaves, Napier grass, tree roots, and vinasse.

The survey data were originally in Excel file format in the Thai language. The translated and recompiled English version of the data is in Appendix 1. Detailed analysis is provided below.

Biomass diversity and regional variation

The data indicate the use of a wide variety of biomass types, including rice straw, husk, sugarcane leaves, bagasse, corn stalk, corn leaf, cassava stem/cassava joint, and more. This diversity suggests that Thailand relies on a mix of agricultural and plant-based biomass sources for power generation.

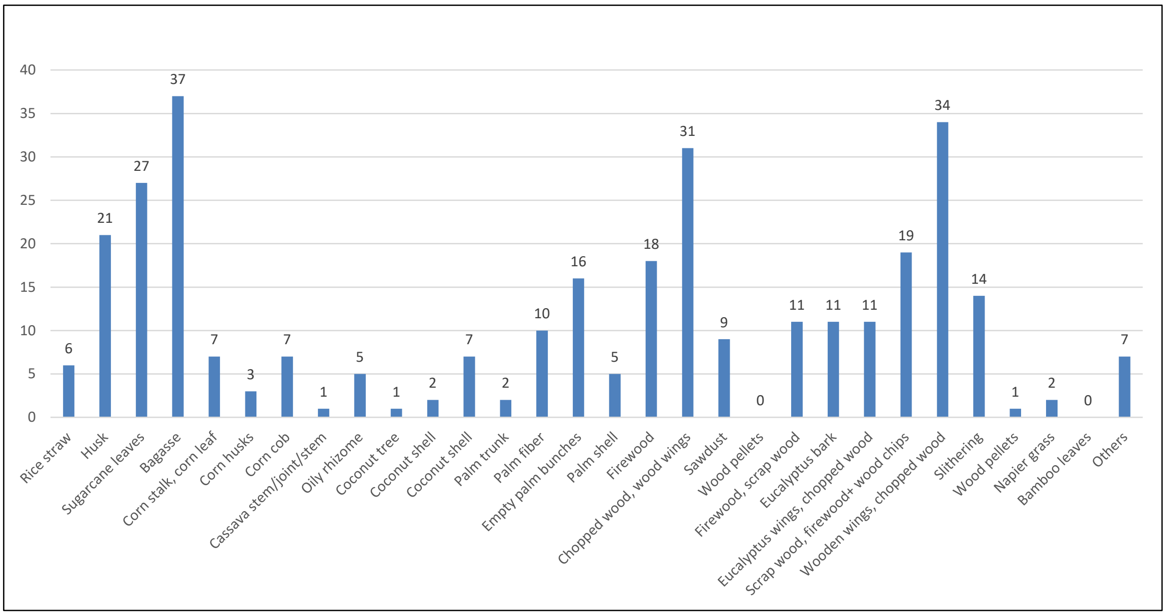
The data are categorised into different regions: the Northern region, Western region, Eastern region, Central region, Northeastern region, and Southern region. These regions have different environmental conditions and biomass availability, which could influence biomass usage patterns.

Regional differences in biomass availability and agricultural practices likely contribute to variations in biomass usage. Regions with abundant rice production may use rice straw and husk more extensively, whilst regions with palm trees may favour palm-related biomass. For example, the Northern region appears to use biomass types like rice straw, husk, and corn stalk more frequently. In contrast, the Southern region relies more on palm trunks and palm fibre.

The number of power plants and their usage of different biomass types also reflects regional economic development and infrastructure. Regions with more power plants may have higher energy demand or greater access to biomass resources.

The data suggest that some biomass types are used more widely than others, as illustrated in Figure 4.7.

Figure 4.7. Number of Power Plants Using Different Types of Biomass, 2022



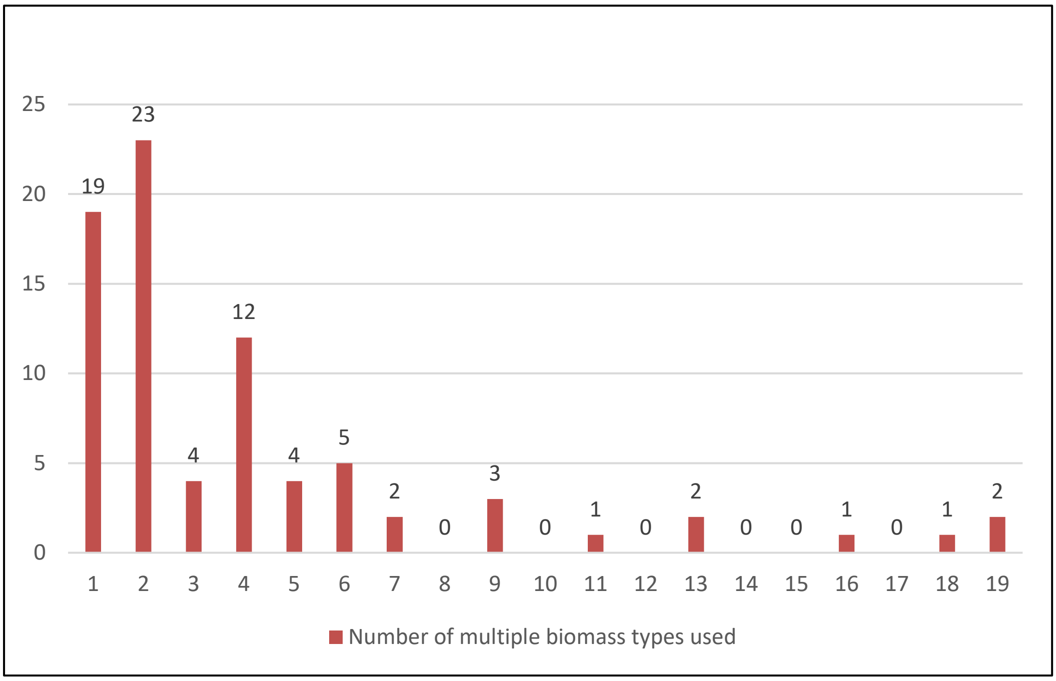
Note: The total sample number of biomass power plants is 79.
Source: DEDE (2023a).

Amongst the various biomass types, bagasse appears to be the most commonly employed for power generation, with 37 power plants utilising this resource. Wooden wings/chopped wood of rubber trees and chopped wood/wood wings of other mixed trees also stand out as popular choices, with 34 and 31 power plants, respectively, relying on them. Conversely, wood pellets seem to be less frequently used, with zero or very few power plants utilising them.

The data reveal regional variations in biomass utilisation. For example, rice straw is a prominent choice in some regions, with 21 power plants using it, whilst others favour palm trunk or palm fibre. It is worth noting that some biomass types, such as 'others,' have not been clearly categorised, warranting further investigation to determine the nature and extent of their usage. Additionally, the presence of multiple power plants relying on a single biomass type underscores the significance of sustainable biomass management practices to ensure a consistent and reliable energy supply.

Dependence on multiple types of biomass

Figure 4.8. Number of Power Plants Using Multiple Types of Biomass



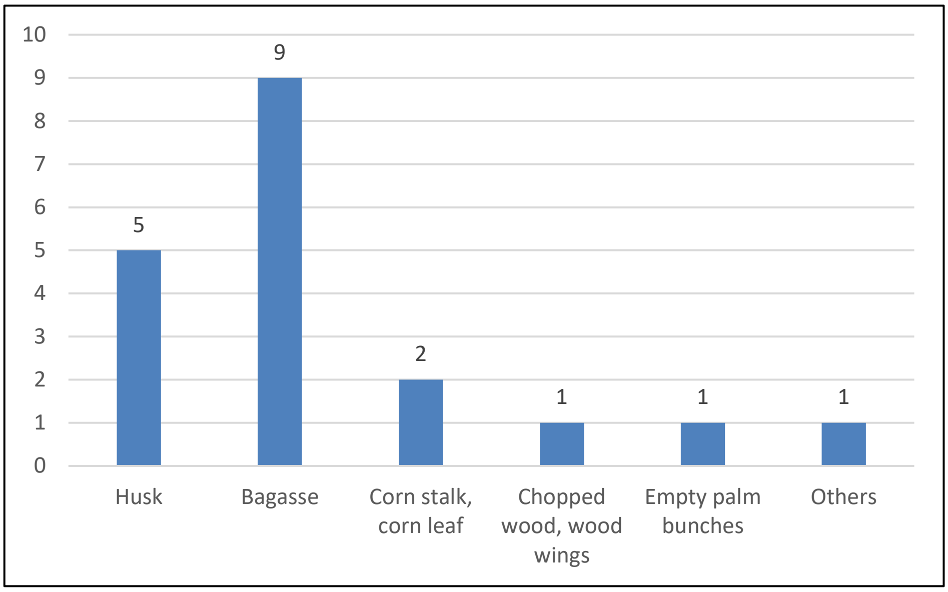
Note: The total sample number of biomass power plants is 79.
Source: DEDE (2023a).

Figure 4.8, it is evident that the majority of power plants, specifically 23 of them, rely on two different biomass types for their energy production. This suggests that a substantial portion of biomass power plants value diversification in biomass sources to enhance reliability and sustainability. Moreover, the presence of power plants employing up to five different biomass types underscores the adaptability and versatility of energy generation systems in incorporating multiple resources.

It is notable that a significant number of power plants, 19 to be precise, use only one type of biomass. This could signify specialisation or a focus on a particular biomass source that aligns with regional availability or economic considerations. The biomass diversity and the varying distribution of power plants across various biomass-type utilisation categories highlight the complexity of the supply chain as well as the importance of ensuring a stable and sustainable energy supply.

Dependence on a single biomass type

Figure 4.9. Number of Power Plants Using a Single Type of Biomass



Note: The total sample number of biomass power plants is 79.

Source: DEDE (2023a).

Power plants that exclusively rely on a single type of biomass for energy generation are an integral part of the renewable energy landscape. Amongst these, bagasse emerges as the most prevalent choice, with nine power plants utilising this resource as their sole biomass feedstock, as shown in Figure 4.9. Bagasse, a by-product of sugarcane processing, is highly regarded for its environmental sustainability and economic viability. Its extensive use highlights its availability and effectiveness in generating renewable energy, particularly in regions with thriving sugarcane industries.

Following closely is husk, with five power plants exclusively using it for energy production. Husk, often derived from rice or other grains, is another popular biomass source known for its energy efficiency and reduced environmental impact. It is favoured in regions with abundant rice cultivation, where it serves as both a renewable energy source and a means of waste management.

In addition to these major biomass types, there are single power plants, each utilising corn stalk, corn leaf, chopped wood, wood wings, empty palm bunches, and 'others'. These singular choices may reflect the availability of specific biomass resources in their respective regions or unique operational preferences.

Public engagement and challenges

Public engagement and the challenges facing the development of biomass power plants, particularly in Thailand's Northeastern region, have become increasingly visible through protests, petitions, and parliamentary discussions. The surge in activity can be partially attributed to the government's Community Power Plant programme (NHCO, 2020).

Local communities have organised petitions to express concerns over environmental impacts and the construction of new biomass power plants. Despite biomass being considered a cleaner alternative to fossil fuels, the association with sugar factories, and thus the abundance of sugarcane leaves and bagasse, has led to conflict. Moreover, the use of coal in bioenergy, allowed to account for no more than 25% of total fuel input during system startup, raises significant concerns amongst villagers about air quality and health impacts.

Furthermore, regulatory loopholes have been identified, such as the exemption of power plants with a capacity not exceeding 10 MW from conducting Environmental Impact Assessments, subjecting them instead to a Code of Practice with weaker control and inspection criteria. This has allowed for the construction of multiple small-capacity power plants in close proximity without comprehensive environmental oversight, exacerbating local concerns.

It is apparent that whilst the development of biomass power plants forms a key component of Thailand's strategy for renewable energy, public unrest has led to barriers in biomass development and highlighted the need for more inclusive planning, better regulatory oversight, and a greater emphasis on health and environmental impacts. The government has already taken steps to address these challenges, but continuous progress is worthy of notice.

Results of the questionnaire survey for understanding the latest challenges

An online questionnaire survey was conducted to study the most recent biomass development situation (see Section 4.9, Appendix 2 for more detail). One response was received from a biomass power plant company that utilises a variety of biomass materials, including rubber wood scraps, mixed hardwood, palm fronds, and palm shells, for electricity production. The responses are summarised as follows.

- Biomass utilisation overview
    - Biomass types used: The company uses rubber wood scraps, mixed hardwood, palm fronds, and palm shells as primary biomass sources.

- Usage pattern: Biomass is primarily used for electricity production, utilising wood chips and logs from rubber and mixed hardwood trees. The average consumption is approximately 380 tonnes/day, equivalent to 9.9 MW.
- Costs: The cost of wood chips is around B1,300/tonne, and logs (rubber, mixed hardwood) average B900/tonne.

- Challenges and solutions
    - Supply stability: The company faces challenges in biomass supply stability, particularly in the central region due to competition for fuel resources, whilst the southern region experiences issues related to price and quality.
    - Seasonal and regional Issues: High moisture content during the rainy season affects transportation, with no trucks available during the harvest season. The company addresses these challenges by diversifying biomass types to reduce risk.
    - Transportation: Biomass is transported by trucks within a maximum distance of 200 km.
    - Moisture management: High moisture content during the rainy season is a significant issue. The company controls incoming biomass moisture and adjusts mixture ratios to maintain a maximum moisture content of 48%.
    - Quality management: The company sets standards for the moisture content of incoming fuel and mixed fuel before combustion.

- Future prospects and recommendations
    - Future biomass supply: The company plans to explore additional alternative fuel plants and manage the use and reserve quantities more effectively.
    - Environmental impact mitigation: Measures include covering transport trucks and requiring wheel washing before entry to reduce PM2.5 dust problems.
    - Community and supplier relations: Purchases are made from local farmers, fostering good relationships and community support.

The company's approach to biomass utilisation for energy production highlights a comprehensive strategy addressing supply stability, moisture content management, and environmental impact mitigation. The company's future plans include exploring alternative biomass sources and further enhancing supply chain and quality management processes. The challenges identified, such as policy continuity, inefficient biomass transportation, and utility infrastructure limitations, underscore the need for integrated solutions and supportive policies to promote sustainable bioenergy production.

4.4.3. Discussion and suggestions

In the above study on Thailand's biomass power plant sector, several key challenges and issues have been identified, affecting the sustainability and efficiency of bioenergy production.

Supply chain and technical challenges

Major supply chain and technical challenges include ensuring stable supply amidst seasonal variations and logistical complexities, optimising operational efficiency to overcome processing and combustion limitations, managing high moisture content in biomass for efficient energy production, maintaining consistent quality standards to enhance combustion efficiency and minimise environmental impact, developing adequate infrastructure for transportation and processing, and advancing technology to improve efficiency and explore new biomass sources.

Addressing these challenges is crucial for the sector's growth and its contribution to Thailand's renewable energy goals. To effectively manage these challenges, a structured approach involving targeted strategies has been proposed. The recommendations are consolidated in Table 4.8, which outlines key challenges such as supply stability, operational efficiency, moisture management, quality control, infrastructure development, and technology innovation. Each challenge is accompanied by proposed solutions aimed at fostering sustainable growth and efficiency in bioenergy production.

Table 4.8. Solutions to Address the Supply Chain and Technical Challenges

Challenges	Solutions to Address the Challenges
Supply stability	· Develop incentives for sustainable biomass cultivation and harvesting practices. · Support the establishment of cooperatives or partnerships between biomass producers and power plants to ensure a stable supply.
Operational efficiency	· Invest in research and development for advanced biomass processing and combustion technologies. · Provide technical assistance and training programmes for biomass power plant operators.
Moisture management	· Fund the development and adoption of pre-treatment technologies to reduce the moisture content of biomass fuels. · Facilitate the sharing of best practices in moisture management amongst biomass power plants.

Challenges	Solutions to Address the Challenges
Quality control	· Develop and enforce quality standards for biomass fuels to ensure high efficiency and minimal environmental impact · Establish certification programmes for biomass producers that meet these quality standards.
Infrastructure development	· Invest in the development of infrastructure for efficient biomass transportation, storage, and processing. · Support the integration of biomass power plants into the national grid with appropriate technical and regulatory frameworks.
Technology and innovation	· Develop incentives for sustainable biomass cultivation and harvesting practices. · Create innovation funds or grants for research into new biomass technologies and applications. · Promote collaboration between academic institutions, industry, and government agencies to accelerate technology transfer.

Sustainability and public awareness challenges

Major sustainability and public awareness challenges include ensuring comprehensive environmental assessments for all biomass projects to mitigate negative impacts, implementing strict environmental standards throughout production and utilisation, building public awareness and acceptance of biomass as a sustainable energy source through education campaigns, and engaging local communities to ensure their involvement and support.

Similarly, structured approaches are employed to effectively manage and address these challenges, as shown in Table 4.9. The recommendations consolidated in the table outline key challenges, such as environmental assessments, environmental sustainability, public awareness and acceptance, and community engagement. Each challenge is accompanied by proposed solutions aimed at fostering sustainable growth and efficiency in bioenergy production.

Table 4.9. Solutions to Address the Sustainability and Public Awareness Challenges

Challenges	Solutions to Address the Challenges
Environmental assessments	· Mandate thorough environmental impact assessments for biomass projects, regardless of size, with public disclosure of results. · Ensure that assessments consider cumulative impacts and offer mitigation strategies.
Environmental sustainability	· Implement strict environmental standards for biomass production and utilisation, including lifecycle assessments to minimise negative impacts. · Encourage the use of waste biomass and residues to reduce land use changes and biodiversity loss.
Public awareness and acceptance	· Launch public awareness campaigns to educate the public about the benefits and sustainability of bioenergy. · Address public concerns transparently and incorporate community feedback into biomass project planning.
Community engagement	· Implement mandatory community consultation and engagement processes for all new biomass projects. · Provide platforms for ongoing dialogue and grievance resolution between biomass power plants and local communities.

Market and competitiveness challenges

Major market and competitiveness challenges include overcoming economic viability hurdles, such as high initial investment costs, biomass transportation expenses, and market competitiveness against other renewable energy sources like solar and wind. Adapting to market dynamics that influence bioenergy demand and navigating regulatory frameworks to facilitate biomass power plant development are also critical.

Addressing these challenges is essential for advancing Thailand's renewable energy goals and fostering a sustainable bioenergy sector. To effectively manage these challenges, a similar structured approach involving targeted strategies has been proposed, as shown in Table 4.10. The recommendations consolidated in the table outline the key challenges, such as economic viability, market dynamics, and regulatory frameworks. Each challenge is accompanied by proposed solutions aimed at enhancing market competitiveness and ensuring sustainable growth in bioenergy production.

Table 4.10. Solutions to Address the Market and Competitiveness Challenges

Challenges	Solutions to Address the Challenges
Economic viability	· Offer financial incentives, such as grants, low-interest loans, or tax exemption for the development of biomass power plants. · Continue the programme of feed-in tariffs and power purchase agreements to ensure competitive pricing for biomass-generated electricity. · Promote an investment in research and development for advanced bioenergy technologies and efficiency improvements.
Market dynamics	· Monitor and analyse global and local market trends to adapt policies and incentives for bioenergy accordingly. · Enhance the competitiveness of bioenergy through market-based mechanisms and international cooperation.
Regulatory and policy frameworks	· Streamline regulatory processes for the approval and operation of biomass power plants. · Update policies to reflect the latest technological advancements and sustainability criteria in the biomass sector. · Study the benefit of expanding the SPP programme's capacity limit from 10 MW to 20 MW, which might better utilise the Bubbling Fluidised Bed technology in terms of cost and energy efficiency. · Harmonise important policies, like existing feed-in tariffs and the in-discussion utility green tariff or carbon tax. · Promote the development of sustainable biomass feedstock sources through government-backed initiatives. · Reflect the actual power production cost on feed-in tariffs. · Establish an efficient energy monitoring system. · Distribute proper benefits to nearby communities to strengthen public acceptance. · Additionally, examine the biomass supply chain for usage as a co-firing fuel in both coal-fired power plants and thermal manufacturing processes.

By implementing these policy recommendations, Thailand can address the multifaceted challenges facing its biomass power plant sector, paving the way for a more sustainable, efficient, and socially responsible energy landscape.

4.5. Biomass Heat Usage

4.5.1. General situation

Biomass can play a crucial role in the industrial process as a source of renewable energy, especially in the production of heat. Industries like agricultural processing use biomass residues like cassava sheets and palm for basic boiler operations. Enhancing biomass value through processes like pelletisation or torrefaction can lead to higher market prices.

With Thailand's commitment to carbon neutrality by 2050, there is a growing interest in decarbonising industrial heating processes. This shift has attracted companies to introduce solutions like ammonia-assisted boilers and bio coal. There is potential to develop the domestic biomass market, especially for industries with high heat requirements like cement and steel, which face new carbon footprint regulations.

The trend towards decarbonisation is prompting industries to explore more sustainable heating solutions. However, biomass heat usage in Thailand is still very limited, and its governmental target remains the most underachieved compared with the other two usage pillars, namely biomass power plants and biofuels. Creating a domestic market for bioenergy, instead of exportation, could significantly contribute to reducing GHG emissions but remains a substantial challenge.

4.5.2. Supply chain and challenges

Supply chain

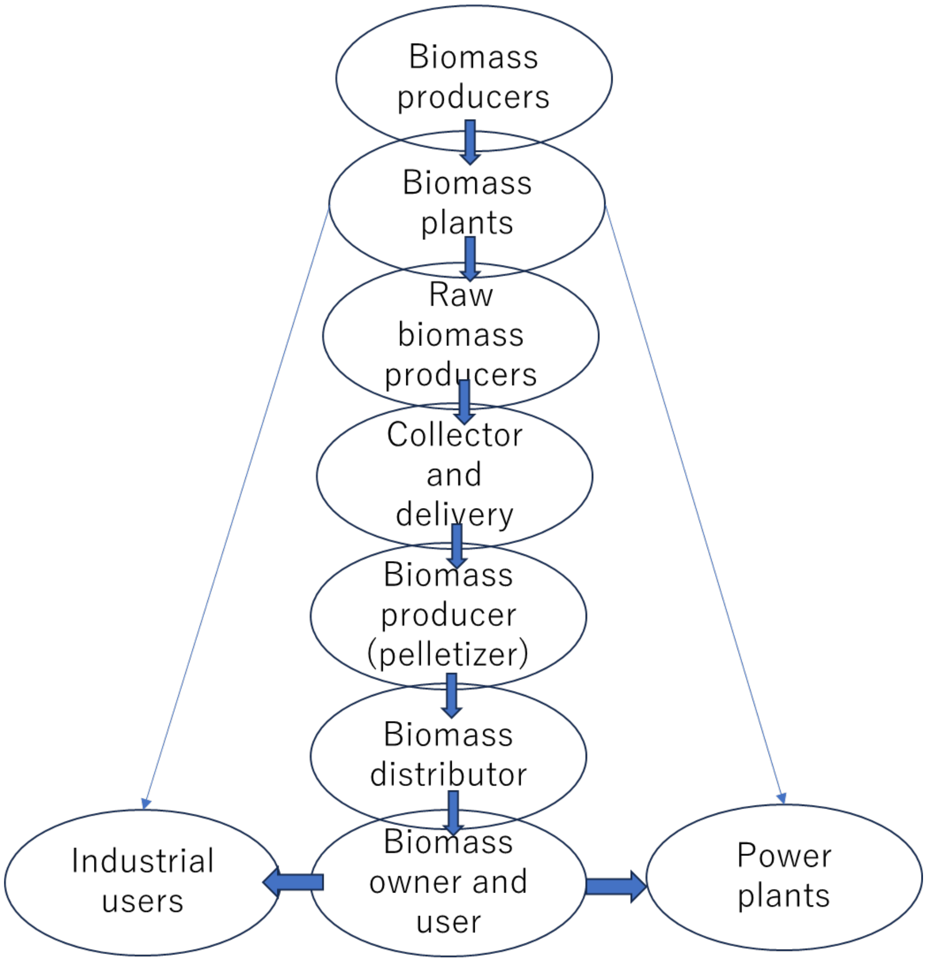
Whilst the biomass pellet industry as an alternative fuel source in Thailand is still in its early stages, a study of the current state of the biomass pellet industry has been conducted and compared with the development of biomass pellet industries in other countries that have progressed in this field (DEDE, 2012). From this analysis, trends in the biomass pellet supply chain for Thailand, when the industry reaches full-scale production of biomass pellets, are identified. These trends indicate that there will be significant involvement by and impact on various stakeholders in the biomass pellet supply chain, as illustrated in Figure 4.10. This includes the following stakeholders:

1. Raw biomass producers
    - Agricultural producers of biomass

- Processing facilities and agricultural industries
- Collectors and distributors of biomass raw materials
- Local communities involved in biomass production and transportation

2. Biomass pellet producers
    - Biomass pellet producers
    - Suppliers of machinery and equipment for biomass pellet production
3. Biomass consumers or users
    - Buyers and users of biomass pellets
    - Brokers or intermediaries in biomass pellet trading
    - Local communities involved in biomass pellet utilisation
4. Supportive entities for the biomass pellet industry
    - Transport service providers for biomass pellet transportation
    - Energy service providers for biomass pellet energy
    - Primary energy providers, such as electricity and fuels for biomass pellet production
    - Providers of factors in biomass raw material production
    - Financial institutions supporting financial transactions along the biomass supply chain
    - Support for research, development, and education by government agencies

Figure 4.10. Simplified Supply Chain of Wood Pellets Using Fast-growing Trees Like Eucalyptus



Source: DEDE (2012).

The relationship amongst these entities and stakeholders in the biomass pellet supply chain may create a network in driving the development of the biomass pellet industry in Thailand. The government, through the Ministry of Energy, should play a role in planning and coordinating the comprehensive biomass pellet supply chain, as further discussed in the subsequent sections. This could involve establishing a committee to oversee and coordinate activities, provide support throughout the biomass supply chain, and promote the development of a robust biomass pellet energy economy. However, it should be noted that the involvement of the private sector in various aspects of this chain may lead to high costs in certain activities. For example, research into biomass raw materials to find suitable technologies for biomass pellet production may not be economically viable. Continuous research and development are essential for achieving high-quality and efficient operations across all units within the biomass pellet supply chain, from biomass raw material to utilisation. Studying the data collected from nine biomass pellet production facilities, it was found that there are essentially two main channels for biomass pellet trading, as presented below (DEDE, 2012).

Direct trading between producers and users

This channel involves direct trading between biomass pellet producers and industrial users who already use biomass as a fuel source in their manufacturing processes. Biomass pellet producers may offer conditions for industrial users to try biomass pellets to ensure that they can be used as a fuel source without negatively impacting their production processes and costs. Afterwards, negotiations take place for the delivery of biomass pellets based on agreed-upon quantities, timing, and prices. Conversely, industrial users contact biomass pellet producers, which is the case when there are already biomass pellet production facilities in operation, either for domestic use or export purposes. In such cases, industrial users may request samples for testing, ensuring that they meet the required standards and will not disrupt their production processes and costs.

Trading through biomass pellet buying agents

This channel involves biomass pellet producers dealing with buying agents who specialise in purchasing and trading biomass pellets within the market. Biomass pellet producers may offer conditions for these buying agents to test the biomass pellets to ensure they meet market standards. Afterwards, negotiations occur for the delivery of biomass pellets based on agreed-upon quantities, timing, and prices. Alternatively, buying agents may contact biomass pellet producers to request samples for testing and negotiation regarding the delivery of biomass pellets. These buying agents typically act as intermediaries, connecting producers with end users, both domestically and internationally. They usually do not hold inventory but facilitate the buying and selling of various types of biomass products. Furthermore, some biomass pellet producers with significant market presence may also contact other biomass pellet producers to consolidate biomass pellets and deliver them to end users as agreed upon.

Based on the information gathered from the nine surveyed facilities, it is worth noting that the combined production capacity of all these facilities is only 98,400 tonnes per year. This production capacity can support a biomass power plant with a capacity of just 10.7 MW. It is clear that the current biomass pellet production in Thailand is significantly lower than the targets set for 2024, which aim to produce enough biomass pellets to generate up to 1,878 MW of electricity or 3,630 MW if relying solely on biomass pellets. Moreover, there are additional goals to utilise biomass pellets as a substitute for providing heat energy in industrial processes, equivalent to 4,914 ktoe or 8,200 ktoe if relying solely on biomass pellets.

Whilst there is potential in the biomass pellet market, successful testing and adoption of biomass pellets as a fuel source are crucial. Developing biomass pellet trading channels can be a valuable way to create added value within the system. Hence, it is essential to focus on ensuring the quality and standards of biomass pellet production and effective marketing and outreach to end users.

Supply cost

When analysing the biomass pellet supply chain, as shown in Figure 4.10, it becomes evident that activities contributing to value addition involve activities that translate into costs for biomass pellet production. These activities include expenses related to:

- purchasing biomass raw materials;
- collecting and transporting biomass to pellet production facilities;
- investing in building biomass pellet production plants;
- biomass pellet production costs;
- marketing and management costs;
- storing biomass pellets; and
- delivering biomass pellets from producers to buyers, with buyers or users bearing the entire cost of the biomass pellets.

The available data from the survey of the nine facilities in the biomass pellet supply chain in Thailand, which is still in its early stages, may not provide a complete or precise picture of the costs involved (DEDE, 2012). However, an analysis of the cost structure of biomass pellet production can be based on cost calculations from the production of biomass pellets using eucalyptus bark, as presented in the document 'Proceedings of the 13th National Agricultural Engineering Conference' on 4–5 April 2012, in Chiang Mai, Thailand, under the topic 'Energy Potential from Eucalyptus Bark in the Northeastern Region.'

This document can serve as a guideline for cost analysis in conjunction with data from the survey of the nine participating facilities for an overall assessment. The specific details of the prototype facility used for the cost analysis are shown in Table 4.12, which serves as a model for cost analysis in biomass pellet production.

From the results of the cost calculations for biomass pellet production, it is found that the cost of biomass pellet production was approximately B2,517 per tonne in 2010, as shown in Table 4.12. The survey argued that this price was equivalent to the price that Thai Cement Company purchases from general biomass pellet producers under a 5-year purchase agreement. However, it is important to note that the price paid by buyers or users of biomass pellets includes the factory's profit margin and marketing management costs. These costs are part of the actual costs according to the cost calculation table.

Furthermore, in the detailed breakdown, costs may vary depending on factors such as location, quality of raw materials, quality, and production capacity of machinery. For example, the cost of biomass raw materials may vary from between B150 to B1,200 per tonne. The quality of raw materials can impact production efficiency and yield. The cost of drying wood chips depends on the moisture content in the raw material. The cost of biomass pellet production machinery and factories can also vary based on preferences and specifications. For instance, European machinery generally has higher prices compared to machinery from Asian countries.

In summary, the cost of biomass pellet production involves a complex interplay of factors, including raw material quality, machinery efficiency, factory specifications, and regional variations.

Based on this document, the cost in 2023 is roughly estimated by assuming that the average minimum wage increases from B169/day in 2010 to B300/day in 2023, electricity price increases from B3.2/kWh to B3.99/kWh, and other costs are the same during the same period. By doing so, the total cost of producing biomass pellets in 2023 is estimated to be B2,903/tonne, and the selling price of biomass pellets to buyers/users is B4,209/tonne, as detailed in Tables 4.11 and 4.12.

Table 4.11. Previous Cost Survey and Updates

	2010		2023
	Detail	**Cost**	**Cost**
		(B/tonne)	(B/tonne)
Cost of biomass pellets from eucalyptus bark			
Production capacity	2,000.00 kg/hr		
Number of working hours per day	20.00 hrs/day		
Number of working days per year	300.00 days/year		
Total production capacity	12,000.00 tonnes/year		
Cost of biomass to pellet production plant		450.00	450.00
Cost of downsizing			
Electrical consumption for crushing raw materials	100.00 kWh/t		
Price of electrical energy used	3.20 B/kWh		
Cost of reducing raw material size		320.00	399.00

	2010		2023
	Detail	Cost	Cost
		(B/tonne)	(B/tonne)
Cost of drying ground wood			
Steam usage for drying ground wood	200.00 kg/hr		
Steam production cost	B1.50/hr		
Electrical energy used	12.50 kWh/hr		
Price of electrical energy used	B3.20/kWh		
Cost of drying ground biomass		170.00	211.97
Cost of pelletising			
Rate of compressing biomass into pellets	1,000.00 kg/hr		
Energy consumption for compressing into pellets	100.50 kWh/tonne		
Price of electrical energy used	B3.20/kWh		
Energy consumption for transporting pellets	7.50 kWh/tonne		
Cost of compressing biomass into pellets		345.60	430.92
Cost of a complete set of machinery for pelleting			
Depreciation cost of machinery as an expense	B800.00/hour		
Machine cost to produces 2 tonnes/hour		400.00	400.00
Cost of remaining machinery and factory		600.00	600.00
Labour costs in pelletising			
Biomass pellet production capacity	2.00 tonnes/hour		
Number of working hours per shift	8.00 hours/shift		
Production capacity of biomass pellets	16.00 hours/shift		
Employees controlling the pelletising section	4.00 hours /shift		
Employees who take care of raw material inputs, packaging, maintenance, and office	5.00 hours /shift		
Labour wage rate	B300.00/tonne		
Labour costs for pelletising		168.75	299.56
Machine maintenance costs		60.00	106.51
Factory insurance cost 0.75%		3.00	5.33
Total cost of producing biomass		2,517.35	2,903.28

	2010		2023
	Detail	Cost	Cost
		(B/tonne)	(B/tonne)
pellets is			
Profit 15% Market management expenses 30%		377.60 755.21	435.49 870.98
Selling price of biomass pellets to buyers/users is		3,650.16	4,209.75

Note: It is assumed that the average minimum wage increases from B169/day in 2010 to B300 /day in 2023, electricity price increases from B3.2 /kWh to B3.99 /kWh, and other costs are the same in the same period.
Source: Compiled from DEDE (2012) and updated by the author.

Table 4.12. Cost Share of Biomass Pellets from Eucalyptus Bark

Cost of Biomass Pellets from Eucalyptus Bark	2010	2023
Raw material	17.90%	17.90%
Downsizing	12.71%	13.74%
Drying ground wood	6.75%	7.30%
Pelletising	13.73%	14.84%
Pelletising machine	15.89%	13.78%
Other machinery and factory	23.83%	20.67%
Pelletising labour	6.70%	10.32%
Machine maintenance	2.38%	3.67%
Factory insurance fee	0.12%	0.18%
Total cost of producing biomass pellets	100.00%	100.00%

Source: Compiled from DEDE (2012) and updated by the author.

Market balance of wood pellets

As outlined previously, the utilisation of biomass for heating purposes in Thailand is markedly underdeveloped, with its achievement of governmental targets lagging significantly behind the other two main applications of bioenergy. Research conducted by Saosee et al. (2020) highlights this issue, indicating that domestic consumption of wood pellets stood at a mere 72,320 tonnes in 2017, as shown in Table 4.13 and Figure 4.11. This figure represents just 20% of the country's total wood pellet production, which amounted to 361,600 tonnes, also detailed in the same table below.

Although Thailand boasts an ample feedstock supply for wood pellets, production constraints have emerged. A primary factor is the limited diversity in feedstock supply. This issue is exacerbated by the geographic concentration of para-rubber trees in the southern regions, leading to logistical challenges that hinder production efficiency.

Moreover, the domestic market's negligible consumption of wood pellets is further compounded by the preference for exporting to international markets such as Korea and Japan, as illustrated in Table 4.14, Table 4.15, Figure 4.11, and Figure 4.12. This export trend is driven by economic incentives; whilst the domestic selling price for wood pellets stands at approximately B4,209 /tonne, the average export price has climbed to B4,783/tonne, as indicated in the average export price in Table 4.15. This disparity in pricing underscores the need for strategic adjustments to balance both domestic consumption and export demands, ensuring sustainable growth within Thailand's biomass sector.

Table 4.13. Wood Pallet Supply and Demand Balance, 2017

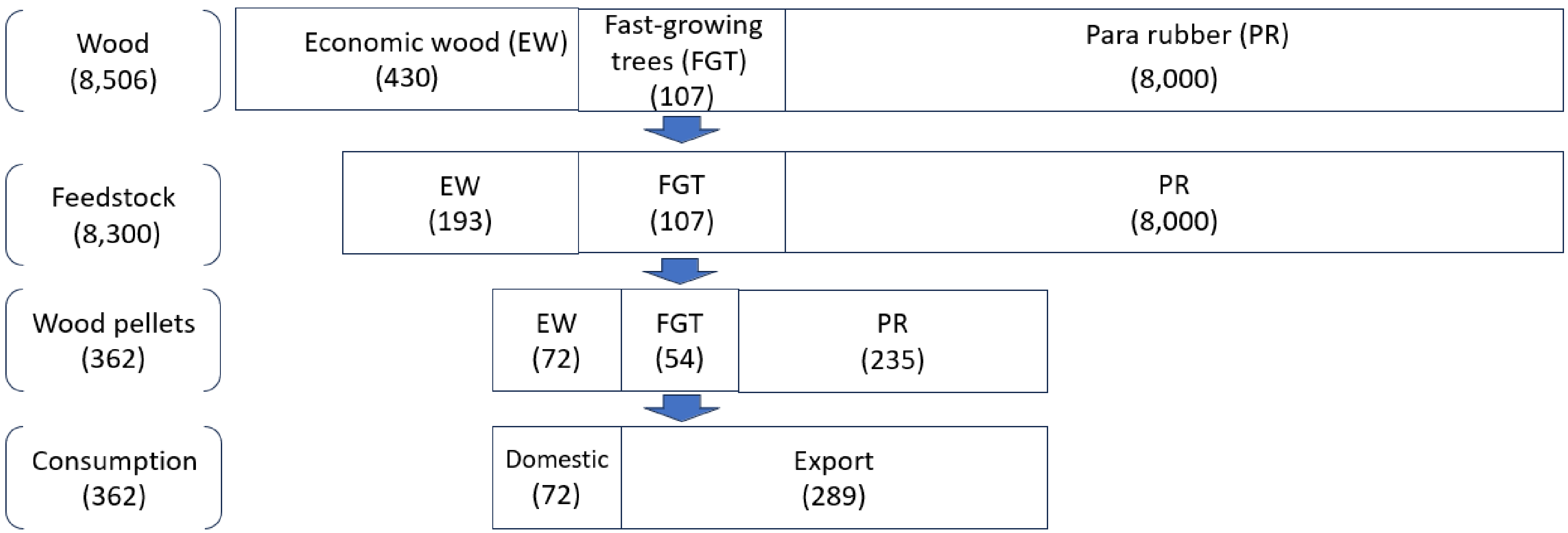
Unit: tonnes

	Imported Wood (A)	Domestic Wood (B)	Total Wood (C)	Total Feedstock (D)	Wood Pellet Products (E)	Used Feedstock (F)	Remaining Feedstock (G)
Economic wood (EW)	7,769	422,320	430,089	193,540	72,320	112,819	80,721
Fast-growing trees (FGT)	22,485	84,030	106,515	106,515	54,240	84,614	21,901
Para rubber (PR)		8,000,000	8,000,000	8,000,000	235,040	366,662	7,633,338
Total		8,506,350	8,506,350	8,300,055	361,600	564,096	7,735,959
Domestic consumption					72,320		
Export					289,280		

Note: C=A+B; D for EW=Cx0.45 (*); D for FGT and PR =C; E for EW, FGT, and PR are calculated from their composition ratios (*) of 20%, 15%, and 65% with respect to total production. F = E*1.56, where 1.56 is an average production ratio (*); G=D-F; domestic consumption and export of wood pellets are calculated from their ratios (*) of 20% and 80% with respect to total production. The (*) marks represent that these values are based on the source paper.

Source: Compiled from Saosee et al. (2020).

Figure 4.11. Wood Pellet Supply and Demand Balance, 2017



Source: Compiled from Saosee et al. (2020).

Table 4.14. Average Export Amount of Wood Pellets in Thailand

Unit: kilotonnes

Export Amount	2018	2019	2020	2021	2022
Global	289.2	172.4	61.2	30.2	133.2
Japan	12.5	42.8	11.6	0.0	4.7
Rep. of Korea	275.9	129.4	49.2	30.1	105.2
Others	0.7	0.3	0.4	0.1	23.3

Source: Thai Customs (https://www.customs.go.th).

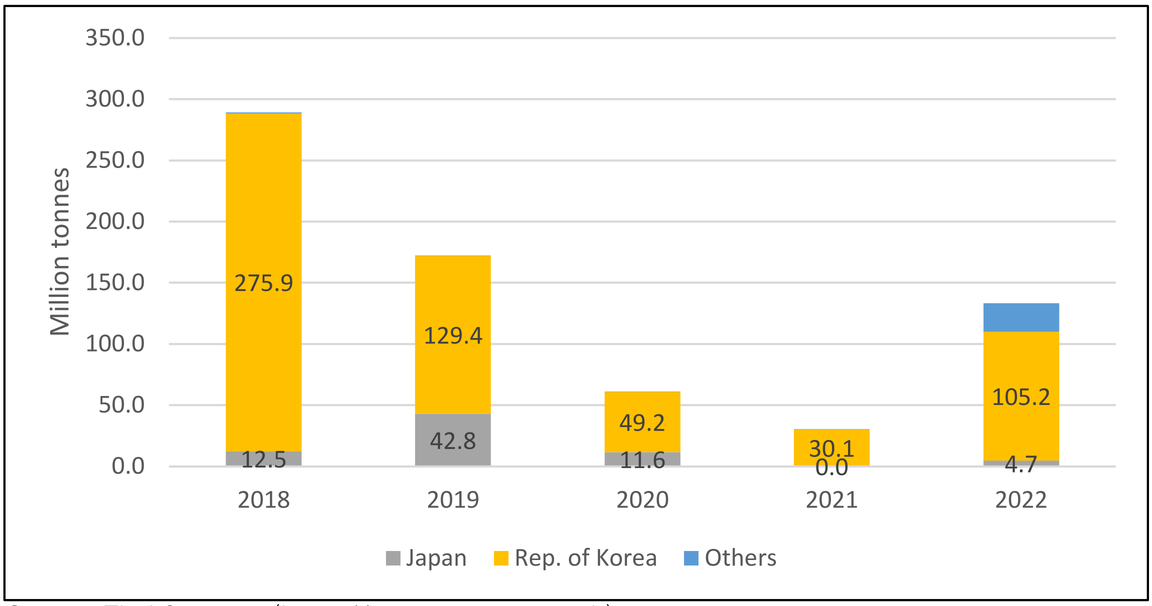
Table 4.15. Average Export Price of Wood Pellets in Thailand

Unit: B/tonne

Average Price	2018	2019	2020	2021	2022
Global	4,115	3,612	3,334	3,426	4,783
Japan	4,177	4,396	4,772	428	4,851
Rep. of Korea	4,110	3,355	2,995	3,392	4,675
Others	4,806	2,562	3,395	12,585	5,256

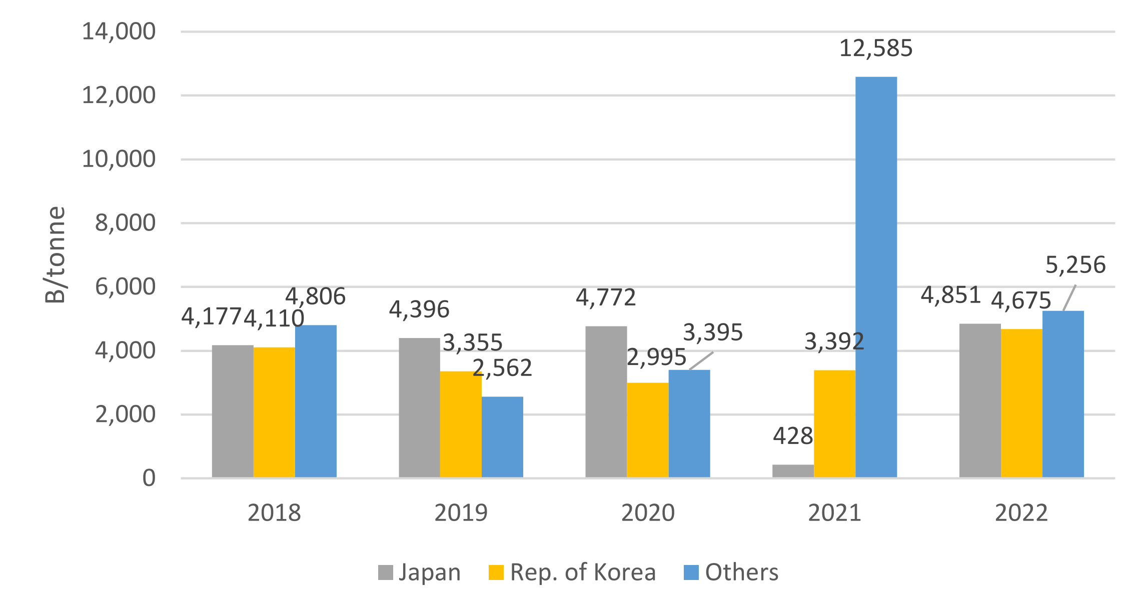
Source: Thai Customs (https://www.customs.go.th).

Figure 4.12. Average Export Amount of Wood Pellets in Thailand



Source: Thai Customs (https://www.customs.go.th).

Figure 4.13. Average Export Price of Wood Pellets in Thailand



Source: Thai Customs (https://www.customs.go.th).

Questionnaire survey to understand the latest challenges

Our online questionnaire received one response from a private company specialising in the production and export of wood chips for energy generation. The company is based in the Eastern region of Thailand and currently produces 180 tonnes of wood chips per day, with procurement expenses of B100,000 per day. They transport the biomass over a distance of 180 km using 10-wheel trucks. The company is looking into increased demand for biomass and is working with local communities for sustainable biomass cultivation. No technical problems have been reported, and no use of standards or regulations has been specified. Some of the detailed entries are shown in Table 4.16.

Table 4.16. Questionnaire Survey Issues and Answers

Issues	Answers
Supply stability and challenges	• Stability issues: Insufficient wood for production • Seasonal and regional procurement issues: Wood biomass has low resource issues due to scarcity • Management techniques: Searching for new biomass sources
Transportation and logistics	• Type of transportation: 10-wheel trucks • Distance for transport: 180 kilometres • High moisture biomass issues: No issues experienced

Issues	Answers
	• Variability in biomass properties: No issues experienced
Technical and quality management	• Future demand expectation: Increased demand anticipated • Sustainable procurement planning: Encourages local communities to cultivate forests • Environmental impact minimisation: Covers goods with tarpaulin during transportation
Standards and regulations	• Reference to biomass standards: No standards referenced • Regulations related to biomass collection: No information provided • Legal and regulatory barriers: No barriers reported
Community and security	• Cooperation with stakeholders/communities: Provides knowledge to the community
Future biomass sourcing	• Economic plants for biomass: Rubber trees, giant sensitive plants, and other types • Wood type biomass sourcing: Rubber wood scraps, giant sensitive plants, and mixed wood scraps • Most used biomass type: Rubber tree wood scraps, giant sensitive plants, and mixed wood scraps • Plans for future biomass sourcing: Same as currently used types • Biomass types recommended for energy production include sugarcane tops/leaves, cassava rhizomes, and empty palm bunches • Challenges for promoting biomass for energy production: Inefficient biomass procurement

The company faces challenges in the biomass supply chain due to insufficient wood for production and regional procurement issues, but efforts are underway to find new biomass sources. As demand for biomass is expected to rise, there is a focus on sustainable procurement by encouraging local communities to cultivate forests and minimising environmental impact through tarpaulin coverage during transport.

4.5.3. Discussion and suggestions

Biomass heating, essential for achieving Thailand's net-zero ambitions, remains significantly underutilised, particularly when compared to other biomass applications. Furthermore, heat production, which relies heavily on oil and bunker fuel, is an important area for decarbonisation since solar energy, being primarily for electricity, does not address the heat production sector. Therefore, transitioning from fossil-based to biomass-based heating is crucial. The limited usage of biomass heat in Thailand needs to be addressed on both the supply side and demand side.

Addressing the supply-side challenges

The supply chain for biomass intended for heating applications, particularly in the form of wood pellets, exhibits a higher level of complexity compared to the supply chain for biomass used in power plants. This complexity arises from several factors that impact both the supply and the logistical aspects of biomass distribution. Understanding these factors is crucial for recognising why government intervention and the organisation of a comprehensive stakeholder network are essential for enhancing efficiency and reducing costs in the supply chain. The complexity of the biomass heating supply chain includes the following:

1. Diverse sources of biomass: Unlike biomass for power plants, which can often rely on a more homogeneous feedstock, heating applications can utilise a wide variety of biomass materials. This includes everything from agricultural residues to specifically grown energy crops and wood trees. Managing this diversity requires a more sophisticated supply chain capable of handling different types of biomass with varying characteristics.
2. Quality and standardisation: For heating purposes, particularly in residential and commercial settings, the quality and consistency of biomass pellets are paramount. Parameters such as moisture content, energy density, content levels of sodium (Na) and potassium (K), and ash content need to be standardised to ensure efficient combustion and minimal environmental impact. Ensuring this standardisation across a diverse range of biomass sources adds complexity to the supply chain.
3. Geographical distribution: Biomass sources are often widely distributed geographically and may not be located near the areas of demand. This is particularly challenging for Thailand, where key biomass sources like para-rubber wood are not evenly distributed. Efficiently connecting these disparate sources with pellet production facilities and end users requires a well-coordinated logistics network.
4. Seasonality: The availability of certain types of biomass feedstock can be highly seasonal, especially for agricultural residues. This seasonality affects the stability of supply throughout the year, necessitating strategic planning for storage and transportation to ensure a consistent supply to meet heating demand.
5. Market fragmentation: The biomass market, especially for heating, is highly fragmented, with numerous small producers and a wide range of consumers. This fragmentation complicates efforts to streamline the supply chain and achieve economies of scale that could lower costs.
6. Regulatory and environmental considerations: Biomass for heating must meet regulatory standards related to emissions and air quality. Additionally, the

sustainability of biomass sourcing has environmental implications. Navigating these regulatory landscapes and ensuring environmentally responsible sourcing further complicates the supply chain.

Given these complexities, the role of the government becomes crucial in coordinating an efficient biomass supply chain for heating. By organising a network of stakeholders – including biomass producers, pellet manufacturers, logistics providers, and end users – the government can facilitate the following:

1. Plantation: The government is expected to launch development strategies to address the uneven distribution of resources to meet the increasing demand in the long term. Increasing the fast-growing tree plantation area for eucalyptus, acacia, Leucaena, and others strategically is an important role that the government can play.
2. Standardisation: Implementing and enforcing standards for biomass pellet quality to ensure compatibility with heating systems and regulatory compliance.
3. Infrastructure development: Investing in infrastructure to improve storage and transportation and addressing the geographical and seasonal challenges of biomass supply.
4. Market coordination: Creating platforms for market interaction to reduce fragmentation, such as online marketplaces or cooperative associations that can negotiate better prices and ensure a stable supply.
5. Incentives and subsidies: Offering incentives to encourage the plantation, production, and use of biomass for heating, as well as subsidies to offset the costs of transitioning to biomass heating systems or developing the necessary supply chain infrastructure.
6. Research and development (R&D) support: Funding R&D to innovate in biomass processing, pelletisation, and combustion technologies to increase efficiency and reduce costs.

Through these interventions, the government could play a pivotal role in simplifying the complex supply chain for biomass heating, ensuring that wood pellets and other forms of biomass can be supplied more efficiently, in sufficient amounts, and at a lower price to meet the country's heating needs sustainably.

Addressing demand side challenges

On the demand side, the Thai energy market struggles to stimulate domestic demand for biomass heating despite its abundance and potential added value through CO_2 reduction. Previously, the biomass heating market in Thailand was not attractive due to low decarbonisation pressure. However, with increasing emphasis on decarbonisation, industries that require intense heat are now actively seeking biomass alternatives. These industries face both technical limitations in completely switching to biomass, as current heating systems are often not designed for non-conventional feedstocks, and market limitations, as the domestic biomass heating market is very limited.

The Thai government is providing a financial scheme by subsidising 30%–50% of the cost for companies converting boilers to biomass and improving boiler efficiency in various industries, including pilot projects in the military and civil energy sectors. University professors are working on boiler efficiency, focusing on maintenance and training, or even replacing boilers. These ongoing supportive policies are important but not sufficient and need to be strengthened.

1. Creating standardised regulations for biomass usage in Thailand

Given that Thailand has established standards for biomass wood pellets under TIS 2772-2560, as detailed in Table 4.17, which currently include only two types – unlike the more varied classifications found in countries such as Europe, Japan, and Korea – there is a clear need for enhancements. The absence of comprehensive standards creates challenges in the domestic market and often results in the export of upgraded biomass to countries with more defined renewable energy requirements.

Industries evaluate biomass pellets based on criteria such as density, heating value, water content, as well as mineral content, such as sodium (Na) and potassium (K). The aim is to reduce the use of fuel oil in boilers as a part of decarbonisation efforts, but achieving the right balance is crucial to maintain sufficient heating value for industrial processes. This balance also considers factors like the cost of biomass feedstock and equipment maintenance. Thus, establishing a broader range of standards that align with both the needs of end users and the characteristics and regulatory conditions of the domestic market is essential for increasing domestic demand.

Table 4.17. Thailand's Biomass Pellet Standards

Property	Quality Level 1	Quality Level 2
Density	Not less than 600 kg/m^3	Not less than 600 kg/m^3
Moisture content	Not more than 15% by weight	Not more than 15% by weight
Heating value	Not less than 14.50 MJ/kg	Not less than 14.50 MJ/kg
Ash	Not more than 10% by weight	Not more than 18% by weight
Average length	3.15–40 mm for 6–10 mm diameter 3.15–50 mm for 12–25 mm diameter	3.15–40 mm
Durability	Not less than 96%	Not less than 96%
Dust content	Not more than 3%	Not more than 6%

Source: Based on information provided by DEDE.

2. Creating an initial market for biomass heating in Thailand

It should be noted that there is a need for regulation and market pressures to enhance the use of bioenergy in energy-intensive industries like cement and steel. This is part of the broader goal of decarbonising their products. There is an understanding that these industries, though facing technical limitations, need to start considering bioenergy due to their heating requirements. In Thailand's National Determined Contributions (NDCs), there are not many commitments in these sectors due to their complexity. Despite this, many heat-intensive factories are voluntarily moving towards bioenergy use, driven by international pressures like the Carbon Border Adjustment Mechanism and competitive acts from other countries. The private sector's willingness to pay for bioenergy use is increasing, but it is uncertain whether this can justify the costs associated with the conversion, transportation, and management of biomass.

It is not surprising that these hard-to-decarbonise industries like cement and steel would have a higher willingness to pay for quality bioenergy. For industries not under such pressures, the incentive to change might be lower. The lack of clear data on the demand that could justify the use of bioenergy in Thailand's heating industry should be addressed. A possible approach is to facilitate meetings with relevant sectors to understand their willingness to pay and to fine-tune the balance between regulation, pricing, and the industry's ability to remain competitive in the international market focused on decarbonisation.

Therefore, focusing on and starting with hard-to-decarbonise industries like cement, steel, and aluminium, which are difficult to decarbonise due to their inability to use solar power for heating processes, it is critical to create an initial market for biomass heating in Thailand.

3. Creating a common platform for the biomass heating market in Thailand

It is necessary to create a supply chain for bioenergy in Thailand by resolving the issue of a lack of standardisation. Standardisation of bioenergy quality, like a grading system (such as grades A and B), would facilitate trade in the market. This system would help in pricing bioenergy appropriately for both buyers and sellers.

A significant gap is the absence of a dedicated market for bioenergy, unlike established markets for rice, palm, sugarcane, or cassava. To create such a market, a common platform is needed where buyers and sellers can interact directly, moving beyond business-to-business transactions. This platform would help in determining the real market value of bioenergy. The government's role could be in establishing this platform and setting technical standards to differentiate biomass quality, akin to distinguishing between 'gold' and 'copper' quality. Not all biomass types are suitable for use in every industry's boiler, indicating a need for industry-specific information. A step-by-step project approach would be practicable by focusing initially on industries that use a lot of heat and are under external pressure to decarbonise.

The launch of government-backed initiatives is also proposed to promote the development of sustainable biomass feedstock sources and establish a compulsory scheme to promote biomass heat usage.

4.6. Biomass for Biofuel

4.6.1. General situation

Thailand has been using biofuels since 2003, starting with ethanol. The current subsidy scheme for biofuels, supported by an oil fund collected from fossil fuel sales, is set to end in 2026. This change is due to a new law that replaces a temporary measure initially set up to promote indigenous fuel use. The future of these subsidies is uncertain, as any extension beyond 2026 would require parliamentary approval.

Work is ongoing with DEDE to prepare for the 2026 deadline. The aim is to transition to sustainable biofuel usage without relying on subsidies. There is an acknowledgement that the agricultural sector often receives subsidies, directly or indirectly, and this needs to be addressed in the context of biofuel policy.

On the other hand, Thailand is upgrading its fuel quality to Euro 5 standards, which will impact biofuel blending levels. For palm-based biofuel, the blending ratio will decrease from 10% to 7% due to pricing and the readiness of the car industry to adopt these new standards. These changes reflect ongoing developments in biofuel materialisation and the automotive industry's response to evolving fuel standards.

Currently, B5, B7, and B20 biodiesel is promoted, produced, and sold in Thailand. In 2023, palm oil production areas covered 5.81 million rai (approximately 930,560 hectares). By December 2023, the extraction rate was an average of 18.13%, yielding a crude palm oil production of 211,812 tonnes, or 3.12 tonnes per rai. Exports of crude palm oil were about 29,348 tonnes, with domestic demand for consumption and other industries at 110,317 tonnes and biodiesel production at 89,496 tonnes. In December 2023, daily diesel consumption was approximately 70.41 million litres, with biodiesel B100 usage being 4.62 million litres per day. Biodiesel production in the same month was around 5.09 million litres per day.

On the other side, currently, E10, E20 and E85 bioethanol are promoted, produced, and sold in Thailand. Specifically, E20 is being promoted to be the base petrol, whereas E85 will be phased down using the oil fund subsidy mechanism. There are 27 ethanol factories focused on producing ethanol for use as fuel. These factories have a combined installed production capacity of 6.57 million litres per day. In November

2023, the actual production of ethanol was 2.54 million litres per day. The consumption of ethanol in the fuel sector for November 2023 was 3.51 million litres per day.

4.6.2. Discussion and suggestions

Given the impending changes and uncertainties in Thailand's biofuel policy landscape, the following policy recommendations are proposed to ensure a smooth transition towards sustainable biofuel usage and to align with both domestic agricultural interests and environmental standards:

1. Establish a clear roadmap post-2026: Develop a comprehensive strategy for the biofuel sector beyond the expiration of the current subsidy scheme in 2026. This roadmap should outline the transition plan from subsidy reliance to market-driven mechanisms that ensure the sustainability of biofuel production and usage.
2. Legislative support for biofuel policies: Work towards securing legislative backing for any extension or modification of biofuel subsidies beyond 2026. This involves engaging with policymakers, stakeholders in the biofuel supply chain, and the public to build consensus on the future direction of biofuel policy.
3. Promote agricultural innovation and diversification: Encourage R&D in agricultural practices that increase the efficiency and sustainability of biofuel feedstock production. This includes diversification strategies to reduce dependency on single crops and exploring alternative feedstocks that may offer better environmental benefits and market stability.
4. Adjust blending ratios in line with Euro 5 standards: Align biofuel blending policies with the upgrade to Euro 5 fuel quality standards. Ensure that the blending ratios for palm-based biofuels and other bioethanol products are set at levels that balance environmental goals, fuel pricing, and the automotive industry's readiness.
5. Strengthen the domestic biofuel market: Develop policies that strengthen the demand for biofuels within Thailand. This could involve incentives for the adoption of vehicles compatible with higher biofuel blends and initiatives to increase consumer awareness of the benefits of biofuels.
6. Support for biofuel infrastructure and technology: Invest in infrastructure and technology that facilitate the efficient production, distribution, and usage of biofuels. This includes upgrading fuel distribution networks to handle higher biofuel blends and supporting the development of advanced biofuel technologies.
7. Environmental and economic impact assessments: Conduct comprehensive assessments of the environmental and economic impacts of biofuel policies.

These assessments should inform policy adjustments to ensure that biofuel usage contributes positively to Thailand's environmental goals without adversely affecting the economy.

8. International collaboration and best practices: Engage in international collaboration to learn from global best practices in biofuel policy and technology. This can help Thailand adopt innovative approaches to biofuel production and usage that are both sustainable and economically viable.
9. Preparing for the transition toward more electric vehicles (EVs): Whilst prioritising biofuel development in the short-to-medium term, Thailand should also prepare for future coexistence with or even the transition to EVs in the long term. This can be done by establishing a strategic approach that considers factors such as infrastructure readiness, consumer acceptance, and market dynamics. Furthermore, seeking other applications like aviation fuel or hydrogen feedstock can open up new opportunities for innovation and economic growth whilst simultaneously addressing environmental concerns and reducing dependence on traditional fossil fuels.
10. Exploring advanced biomass utilisation technologies like torrefied biomass, hydrogen production feedstock, and Sustainable Aviation Fuel.

By implementing these policy recommendations, Thailand is expected to navigate the uncertainties surrounding the future of biofuel subsidies and establish a sustainable, economically viable, and environmentally friendly biofuel sector that aligns with global standards and practices.

4.7. Conclusions

4.7.1. Overall Conclusions

The bioenergy sector in Thailand showcases a robust commitment to renewable energy, with biomass playing a pivotal role in diversifying the country's energy mix. A comprehensive policy framework taken by the government, including the Alternative Energy Development Plan and the Power Development Plan, alongside incentives such as feed-in tariffs and the Small Power Producer and Very Small Power Producer programmes, have significantly contributed to the growth of bioenergy. This strategic policy framework not only aligns with global sustainability goals but also positions Thailand as a leader in ASEAN for renewable energy adoption. The biomass resource potential in the country, notably from agricultural by-products, offers a vast, untapped energy reserve that can further enhance energy security, reduce environmental impacts, and support rural economies.

4.7.2. Biomass power plant sector

The biomass power plant sector in Thailand, whilst demonstrating promising growth, faces challenges, including feedstock supply stability and environmental concerns. The expansion of the sector has been driven by government incentives, yet it encounters limitations due to supply chain instability and complexity, regulatory hurdles, environmental concerns, competition for feedstock, and a shift towards other renewable sources such as solar and wind. Addressing these challenges requires a balanced approach that includes strengthening supply chain management, enhancing operational efficiency, fostering public acceptance, ensuring environmental sustainability and community engagement, and continuously promoting R&D for advanced biomass technologies and efficiency-improving innovations. These efforts are critical to ensuring the sustainable growth of the sector.

4.7.3. Biomass heat usage

Biomass heat usage in Thailand, crucial for decarbonising industrial heating processes, remains underutilised compared to its potential. Despite Thailand's commitment to carbon neutrality, the adoption of biomass for heating faces obstacles such as limited market demand, supply chain complexities, a lack of broader standards, limited market demand, uneven distribution of biomass resources across regions, financial obstacles such as limited finance accessibility, and even challenges in bioenergy usage monitoring, especially in the industries. Government intervention to organise a network of stakeholders and implement supportive policies, including increasing fast-growing trees, can address these challenges, promoting a more efficient and lower-cost biomass supply for heating. Additionally, focusing on hard-to-decarbonise industries, establishing broader standards for wood pellets, and creating a common platform for the biomass heating market can catalyse demand and support the energy transition goals of Thailand.

4.7.4. Biomass for biofuel

The biofuel sector in Thailand, underpinned by policies promoting ethanol and biodiesel usage, stands at a crossroads with the impending expiration of subsidy schemes and the alignment with Euro 5 fuel quality standards. Transitioning towards sustainable biofuel usage requires clear policy direction, support for agricultural innovation, and adjustments to blending ratios in line with Euro 5 standards. Strengthening the domestic biofuel market, investing in infrastructure, and balancing agricultural interests and environmental goals are essential strategies. These efforts, coupled with seeking other applications like aviation fuel or hydrogen feedstock, can ensure the sustainable growth of the biofuel sector in Thailand, contributing to energy security and environmental sustainability.

To conclude, the bioenergy sector in Thailand has significant potential to contribute to renewable energy goals, energy security, rural development, and climate action. Addressing the challenges through targeted policies, investments, and stakeholder engagement is crucial for sustainable growth. Key priorities include strengthening supply chains, promoting sustainable production, enhancing market demand, and ensuring environmental and social integrity. Unlocking the full potential of Thailand's bioenergy sector requires a collaborative effort from the government, industry, academia, and civil society. By implementing the recommended policies and actions, Thailand is expected to continue to hold its position as a regional leader in sustainable bioenergy development, as well as contribute to the achievement and assessment of the regional target of achieving 23% renewable energy in ASEAN countries by 2025.

4.8. Appendix 1: Tables of biomass usage by biomass power plants

Table 4.18. Biomass Usage by Biomass Power Plants (1/2)

		1. Biomass from economic crops															
		1.1 rice		1.2 sugar cane		1.3 corn			1.4 cassava		1.5 coconut			1.6 palm			
		Rice straw	Husk	Sugarcane leaves	Bagasse	Corn stalk, corn leaf	Corn husks	Corn cob	Cassava stem/joint/stem	Oily rhizome	Coconut tree	Coconut shell	Coconut shell	Palm trunk	Palm fiber	Empty palm bunches	Palm shell
No	Region	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Northern		✓														
2	Northern			✓	✓			✓									
3	Northern			✓	✓												
4	Northern		✓				✓	✓									
5	Northern		✓			✓	✓	✓									
6	Western																
7	Western																
8	Western				✓												
9	Western				✓												
10	Western				✓										✓		
11	Western				✓												
12	Western														✓	✓	
13	Western			✓	✓										✓		
14	Western			✓	✓	✓		✓									
15	Western				✓												
16	Eastern				✓												
17	Eastern				✓												
18	Eastern				✓												
19	Eastern															✓	
20	Eastern				✓												
21	Eastern			✓	✓												
22	Eastern			✓	✓												
23	Central		✓	✓	✓												
24	Central		✓	✓	✓												
25	Central		✓	✓													
26	Central			✓	✓												
27	Central			✓	✓												
28	Central	✓	✓	✓						✓						✓	
29	Central			✓	✓												
30	Central		✓														
31	Central																
32	Central		✓	✓									✓				
33	Central	✓	✓	✓	✓	✓	✓	✓					✓			✓	
34	Central	✓		✓	✓	✓				✓		✓	✓	✓	✓	✓	✓
35	Central	✓		✓	✓	✓				✓		✓	✓	✓	✓	✓	✓
36	Central			✓	✓												
37	Central			✓	✓												
38	Central			✓	✓												
39	Central			✓	✓												
40	Northeastern																
41	Northeastern				✓			✓	✓				✓			✓	
42	Northeastern	✓	✓	✓				✓		✓						✓	
43	Northeastern			✓	✓												
44	Northeastern				✓												
45	Northeastern		✓														
46	Northeastern			✓	✓												
47	Northeastern												✓				
48	Northeastern				✓												
49	Northeastern	✓	✓	✓									✓				
50	Northeastern		✓														
51	Northeastern			✓	✓												
52	Northeastern					✓											
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56	Northeastern		✓														
57	Northeastern		✓														
58	Northeastern			✓	✓												
59	Northeastern		✓														
60	Northeastern		✓														
61	Northeastern									✓						✓	
62	Northeastern				✓												
63	Northeastern				✓												
64	Northeastern		✓								✓						
65	Northeastern				✓												
66	Southern														✓	✓	✓
67	Southern														✓	✓	✓
68	Southern														✓	✓	
69	Southern																
70	Southern																
71	Southern															✓	
72	Southern																
73	Southern														✓	✓	✓
74	Southern														✓	✓	
75	Southern																
76	Southern																
77	Southern																
78	Southern															✓	
79	Southern																
	Total Numbers	**6**	**21**	**27**	**37**	**7**	**3**	**7**	**1**	**5**	**1**	**2**	**7**	**2**	**10**	**16**	**5**

Note: The total sample number of biomass power plants is 79.
Source: DEDE (2023a).

Table 4.19. Biomass Usage by Biomass Power Plants (2/2)

		2. Woody biomass											3. Other biomass (3nd)			
		2.1 rubber				2.2 eucalyptus			2.3 mixed trees and other types of wood				3.1 Grass Ne Peir	3.2 Bamboo	3.3 Others (specify)	
		Firewood	Chopped wood, wood wings	Sawdust	Wood pellets	Firewood, scrap wood	Eucalyptus bark	Eucalyptus wings, chopped wood	Scrap wood, firewood + wood chips	Wooden wings, chopped wood	Slithering	Wood pellets	Napier grass	Bamboo leaves	Others	**Total Numbes**
No	Region	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
1	Northern															**1**
2	Northern								✓	✓						**5**
3	Northern								✓	✓						**4**
4	Northern	✓	✓	✓					✓	✓	✓					**9**
5	Northern								✓	✓						**6**
6	Western		✓							✓					✓	**3**
7	Western		✓							✓						**2**
8	Western															**1**
9	Western															**1**
10	Western		✓	✓						✓	✓					**6**
11	Western															**1**
12	Western															**2**
13	Western		✓													**4**
14	Western									✓	✓					**6**
15	Western															**1**
16	Eastern															**1**
17	Eastern															**1**
18	Eastern	✓	✓			✓		✓	✓	✓						**7**
19	Eastern		✓				✓			✓						**4**
20	Eastern															**1**
21	Eastern															**2**
22	Eastern															**2**
23	Central								✓	✓						**5**
24	Central															**3**
25	Central								✓	✓	✓					**5**
26	Central															**2**
27	Central															**2**
28	Central		✓				✓		✓	✓	✓				✓	**11**
29	Central															**2**
30	Central															**1**
31	Central		✓				✓	✓		✓						**4**
32	Central															**3**
33	Central	✓	✓			✓	✓	✓	✓	✓	✓	✓				**18**
34	Central		✓			✓	✓	✓		✓	✓		✓		✓	**19**
35	Central		✓			✓	✓	✓		✓	✓		✓		✓	**19**
36	Central															**2**
37	Central															**2**
38	Central															**2**
39	Central															**2**
40	Northeastern														✓	**1**
41	Northeastern	✓	✓	✓		✓	✓		✓	✓	✓					**13**
42	Northeastern	✓	✓	✓		✓	✓	✓	✓	✓	✓				✓	**16**
43	Northeastern															**2**
44	Northeastern															**1**
45	Northeastern							✓		✓	✓					**4**
46	Northeastern															**2**
47	Northeastern	✓	✓	✓		✓	✓	✓	✓	✓						**9**
48	Northeastern									✓						**2**
49	Northeastern	✓	✓	✓		✓	✓	✓	✓	✓	✓					**13**
50	Northeastern									✓						**2**
51	Northeastern															**2**
52	Northeastern															**1**
53	Northeastern															**1**
54	Northeastern	✓				✓			✓							**4**
55	Northeastern															**1**
56	Northeastern															**1**
57	Northeastern		✓	✓				✓		✓	✓					**6**
58	Northeastern															**2**
59	Northeastern	✓	✓			✓		✓	✓	✓						**7**
60	Northeastern															**1**
61	Northeastern		✓				✓			✓						**5**
62	Northeastern									✓						**2**
63	Northeastern									✓						**2**
64	Northeastern	✓	✓	✓		✓			✓	✓	✓					**9**
65	Northeastern															**1**
66	Southern		✓													**4**
67	Southern															**3**
68	Southern	✓	✓						✓	✓						**6**
69	Southern	✓	✓						✓	✓						**4**
70	Southern		✓													**1**
71	Southern	✓	✓	✓												**4**
72	Southern	✓	✓						✓	✓						**4**
73	Southern		✓													**4**
74	Southern															**2**
75	Southern	✓	✓													**2**
76	Southern	✓	✓							✓					✓	**4**
77	Southern	✓	✓													**2**
78	Southern															**1**
79	Southern	✓	✓													**2**
	Total Numbers	**18**	**31**	**9**	**0**	**11**	**11**	**11**	**19**	**34**	**14**	**1**	**2**	**0**	**7**	

Note: The total sample number of biomass power plants is 79.
Source: DEDE (2023a).

4.9. Appendix 2: Online questionnaire survey to study bioenergy supply chain challenges

To understand the most recent bioenergy supply chain challenges, we carried out a questionnaire survey. The questionnaire survey was conducted online via Google Forms in the Thai local language.

The primary objective of the survey was to gather valuable insights into the utilisation of biomass for energy production, with a focus on both current practices and future plans. By engaging with individuals and organisations involved in biomass-based energy production, it aimed to assess the types of biomass materials commonly used, identify the obstacles and challenges in their procurement and utilisation, and explore opportunities for promoting the sustainable growth of this renewable energy sector.

The survey employs a structured questionnaire to capture a wide range of information from respondents who play pivotal roles in the bioenergy domain. It is designed to be inclusive and informative, covering multiple aspects of biomass utilisation, the challenges faced, and potential solutions. The survey participants included those engaged in the production of energy from various biomass sources, ranging from agricultural residues to forestry by-products.

Beginning with the survey introduction, the survey comprises several question parts that address different facets of bioenergy utilisation.

Figure 4.14. Online Questionnaire Survey

แบบสอบถามเกี่ยวกับการบริหารจัดการห่วงโซ่อุปทานเชื้อเพลิงชีวมวล เพื่อเป็นข้อมูลประกอบการศึกษาโครงการ Development of Bioenergy Supply Chain in the AZEC partner countries

ด้วยสถาบัน Institute
of Energy Economics, Japan (IEEJ) ประเทศญี่ปุ่น
ร่วมกับ สถาบัน Economic Research Institute for ASEAN and East Asia
(ERIA) ดำเนินโครงการศึกษาพัฒนาห่วงโซ่อุปทานของเชื้อเพลิงชีวมวลในกลุ่มประเทศสมาชิกอาเซียน
(Development of Bioenergy Supply Chain in the AZEC partner countries) โดยมีวัตถุประสงค์
เพื่อศึกษา รวบรวมข้อมูลการจัดการห่วงโซ่อุปทานของเชื้อเพลิงชีวมวล
เช่น การผลิต การเก็บรวบรวม การขนส่ง การบริหารจัดการและใช้งานเพื่อผลิตพลังงาน
ตลอดจนจัดทำข้อเสนอแนะเชิงนโยบายในการส่งเสริมสนับสนุนการผลิตและใช้ชีวมวลเพื่อผลิตพลังงาน
เพื่อให้บรรลุเป้าหมายการลดการปลดปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ โดยมีกองวิจัย
ค้นคว้าพลังงาน กรมพัฒนาพลังงานทดแทนและอนุรักษ์พลังงาน (พพ.)
ร่วมเป็นคณะทำงานโครงการฯ

โครงการฯ
ได้จัดทำแบบสอบถามเพื่อสำรวจ รวบรวมข้อมูลด้านการจัดหา การรวบรวม การขนส่ง
และใช้งานชีวมวลในโรงไฟฟ้าและโรงงานอุตสาหกรรม รวมถึงประเด็นปัญหา อุปสรรค
และความท้าทาย ในการผลิตพลังงานจากชีวมวล
จากผู้ประกอบกิจการและผู้ใช้ชีวมวลในประเทศ

ในการนี้ โครงการฯ ใคร่ขอความอนุเคราะห์ท่านในการตอบแบบสอบถามดังกล่าว
ทั้งนี้ข้อมูลของท่านจะถูกนำไปใช้เพื่อการศึกษาในโครงการฯ เท่านั้น
และข้อมูลทั้งหมดจะถูกเก็บเป็นความลับ

Source: IEEJ and DEDE (2023).

4.9.1. Survey introduction

The Institute of Energy Economics, Japan (IEEJ), in collaboration with the Economic Research Institute for ASEAN and East Asia (ERIA), is undertaking a project titled 'Development of Bioenergy Supply Chain in the ASEAN Member Countries.' The project aims to study and collect data on the management of the biofuel supply chain, such as production, collection, transportation, management, and utilisation for energy production. Additionally, it aims to develop policy recommendations to promote the production and use of biomass for energy production, with the goal of achieving net-zero GHG emissions. The Energy Research and Development Division of DEDE is also participating in the project team.

The project has created a questionnaire to survey and collect data on the procurement, collection, transportation, and utilisation of biomass in power plants and industrial factories, including the issues, obstacles, and challenges in energy production from biomass from operators and biomass users in the country.

For this purpose, the project kindly requests your assistance in answering the aforementioned questionnaire. Your information will be used solely for the study within this project, and all data will be kept confidential.

In case you do not have information or are not convenient to answer questions on any given topic, please select 'Other' or enter a message so that you can proceed to answer questions in the next section.

The project would like to thank you for your kind cooperation in providing information for this study.

4.9.2. Part 1: Basic information

1-1. Please describe an overview of your business/operations.

1-2. What type of biomass do you currently use in your operations?

1-3. What is the pattern of biomass use in your operations? Please specify the type of biomass usage.

1-4. Please specify the amount of biomass used in your operations (tonnes/day, tonnes/month, tonnes/year).

1-5. What are your expenses for procuring biomass (per day/month/year)? What is the value (in Thai baht or US dollars)?

1-6. Please specify the type of your business.

1-7. Please specify the region where your organisation/business is located.

4.9.3. Part 2: Biomass fuel supply chain management

- Ability to procure biomass fuel

  2-1. From your experience, please identify the type of biomass that you have encountered stability issues within sourcing for your business.

2-2. Have you experienced stability and security issues in procuring biomass for energy production in your operations? How? (Please specify)

2-3. What issues have you faced in procuring biomass related to seasons or the region where your business is located? (Please specify the type of biomass and the problems encountered)

2-4. How do you manage biomass to ensure stability and continuity of energy production in your operations?

- Biomass fuel transportation

2-5. Please specify the type of transportation used for biomass fuel from the source (or collection point) to your business location.

2-6. Please specify the distance for transporting biomass fuel from the source (or collection point) to your business location (in kilometres).

- Management of biomass for energy production

2-7. Have you experienced problems with using biomass with high moisture content? How do you manage and prepare the fuel? (Please specify the average moisture content of the biomass used)

2-8. Have you encountered problems related to the varying properties of biomass (e.g. the different moisture content in each usage)? How do you manage or solve these issues?

2-8. How do you manage the quality of the biomass used in your operations? Do you have a minimum standard for the biomass fuel you use? How?

- Using biomass to produce energy

2-9. What technical problems have you encountered in producing energy using biomass as fuel? (Please specify)

2-10. Do you think the demand for biomass for energy production will increase in the future? (Please provide your opinion on the future demand for biomass)

- Environmental and sustainability issues of using biomass for energy production

2-11. Please outline your planning approach for sustainable biomass procurement in your operations.

2-12. How do you minimise environmental impacts in the management process of biomass used in your operations? (e.g. reducing PM2.5 dust problems in transportation and collection)

2-13. Do you reference standards in procuring or purchasing biomass fuel for use in your operations? (If yes, please specify)

- Rules and regulations

2-14. What regulations are related to biomass collection?

2-15. Have you encountered any legal or regulatory barriers and obstacles related to biomass procurement? How?

- Other issues

2-16. Please specify issues related to biomass security in cases where biomass is used in other operations (e.g. industrial processes, agriculture).

2-17. How have you initiated cooperation or built good relationships with stakeholders or communities regarding biomass procurement for use in your operations?

4.9.4. Part 3: Biomass-type specific questions (multiple choices amongst 28 types of biomass)

3-1. What kind of economic plants do you procure biomass from for energy production in your operations?

3-2. What type of woody biomass do you procure for energy production in your operations?

3-3. Please specify the type of biomass you use the most.

3-4. What biomass do you plan to procure for use in your operations in the future?

3-5. From your perspective, what type of biomass should be promoted for increased energy production?

3-6. What factors do you think pose a challenge to promoting the use of biomass for energy production? Please specify any additional issues/obstacles.

4.9.5. Part 4: Other information and additional suggestions

Please provide your information/opinions/recommendations that you believe will be beneficial for this survey.

Chapter 5
Findings: Viet Nam

Viet Nam successfully recovered from the COVID-19 pandemic and achieved robust economic growth with an annual GDP growth rate of 8.02% in 2022, a substantial bounceback from 2.56% in 2021 (Viet Nam General Statistics Office, 2023). Agriculture is an important economic activity for the country. In 2022, the agriculture, forestry, and fishing sectors accounted for 11.9% of GDP at current market prices and 27.5% of the employed workforce. The share of agricultural land and forestry was 39.4% and 47.0% of the total land area of 313,429 km^2, respectively, as of 2021 (World Bank, n.d.-b).

5.1. Overall Mapping of Bioenergy Supply and Demand at Present

5.1.1. Policy and regulatory framework

Power development plan

Viet Nam has implemented policies to promote and support bioenergy development. The fundamental policy that encourages renewable energy utilisation is 'The Development Strategy on Renewable Energy of Vietnam by 2030 with a Vision to 2050' (Decision No. 2068/2015/QD-TTg), approved in November 2015. With medium- and long-term development orientations and targets, this strategy aims to develop and utilise renewable energy for the public that is accessible at affordable prices to reduce dependence on fossil fuels, ensure energy security, and mitigate climate change.

The use of bioenergy is prioritised for power generation, heat production, and biofuels. The strategy sets a target to increase the share of biomass power generation from approximately 1.0% in 2015 to about 6.3% by 2030 and 8.1% by 2050 in total power generation whilst expanding the share of industrial and agricultural crop waste for energy production to 60% in 2030 and 70% in 2050. The bioenergy use for heat production is estimated to increase to around 16.8 Mtoe by 2030 and 23 Mtoe by 2050, although the share is anticipated to gradually decrease because of the shift away from traditional biomass resource use.

Focusing on the power sector, Viet Nam formulates the National Power Development Plan and revises it periodically. The latest National Power Development Plan VIII (hereinafter called the PDP8), officially named 'The National Power Development Plan for the Period of 2021–2030, with a Vision to 2050' (Decision No. 500/QD-TTg), was approved in 2023 (Table 5.1). The PDP8 is the basis for power development, laying out the power and grid development plans.

Table 5.1. Power Generation Capacity in the PDP8

	2030		2050	
	Capacity (MW)	Share (%)	Capacity (MW)	Share (%)
Coal	30,127	20.0	-	-
Conversion to biomass and ammonia	-	-	25,632–32,432	4.5–6.6
Hydro	31,746	21.1	36,016	6.3–7.3
Domestic gas	14,930	9.9	-	-
Conversion to liquified natural gas	-	-	7,900	1.4–1.6
Conversion to hydrogen	-	-	7,030	1.2–1.4
Liquified natural gas	22,400	14.9	-	-
Hydrogen co-firing	-	-	4,500–9,000	0.8–1.8
Conversion to hydrogen	-	-	16,400–20,900	3.3–3.6
Renewables	42,986	28.6	304,659–363,859	60.5–65
Solar	12,836	8.5	168,594–189,294	33.0–34.4
Wind	27,880	18.5	130,050–168,550	26.5–29.4
Onshore wind	21,880	14.5	60,050–77,050	12.2–13.4
Offshore wind	6,000	4.0	70,000–91,500	14.3–16
Biomass	2,270	1.5	6,015	1–1.2
Co-generation electricity	2,700	1.8	4,500	0.8–0.9
Storage battery	300	0.2	30,650–45,550	6.2–7.9
Import	5,000	3.3	11,042	1.9–2.3
Flexible power source	300	0.2	30,900–46,200	6.3–8.1
Total	150,489	100	490,529–573,129	-

Note: The shares of each energy in 2050 are based on the PDP8 and do not amount to 100%.
Source: Compiled by the IEEJ based on the PDP8.

The PDP8 ambitiously sets a target of renewable energy sources for power generation at a share of about 30.9%–39.2% by 2030, a significant upward revision from 10.7% of the revised PDP7, and 67.5%–71.5% by 2050. Furthermore, the target share of renewable energy could be expanded to 47% on the condition that commitments are fully implemented by international partners under the Just Energy Transition

Partnership (JETP).[18]

The PDP8 prioritises and encourages the power development of various biomass resources, noting that biomass power potential is about 7,000 MW, specifically, with possible power of 1,800 MW generated from garbage and solid waste, such as agricultural, forestry, and processing by-products. The target of biomass power generation capacity is set at 2,270 MW (1.5%) in 2030, which includes biomass power plants of 1,088 MW and domestic solid waste power plants of 1,182 MW, and 6,015 MW (1.0%–1.2%) in 2050.

In addition, the PDP8 specifies that the coal-fired power plants that have been in operation for more than 20 years would convert fuels to biomass and ammonia if economically feasible. For decarbonisation, all coal-fired power plants would be converted to alternative fuels or stop operation by 2050.[19] Thermal power using biomass and ammonia is planned to reach 25,632–32,432 MW (4.5%–6.6%) by 2050.

In April 2024, the PDP8 implementation plan (Decision No. 262/QD-TTg) was approved. Biomass power projects are planned with a total capacity of 1,088 MW and newly constructed biomass power projects are listed as presented in Table 5.2

Table 5.2. Biomass Power Projects in the PDP8 Implementation Plan

Province	Biomass Power Plant	Capacity (MW)	Year of Operation
Ca Mau	Khan An	24	2026–2030
Lang Son	Bac Son	12	2026–2030
	Lang Son	18	2026–2030
Yen Bai	Yen Bai 1	50	2026–2030
	Truong Minh	58	2026–2030
Tuyen Quang	Tuyen Quang	50	2023–2030
Nghe An	Quy Hop	10	2026–2030
Ha Tinh	Hung Anh	5	2026–2030
Binh Phuoc	Binh Phuoc	10	2026–2030
Dong Nai	Ajinomoto Bien Hoa	12	2026–2030
Vinh Long	Vinh Long	10	2026–2030
Ben Tre	Ben Tre	10	2026–2030

[18] In December 2023, Viet Nam launched the Resource Mobilisation Plan (RMP) which is the first step towards the implementation of the JETP. The RMP includes an assessment of priority investments and identifies priority investment projects in JETP-related areas (European Commission, 2023).

[19] In February 2024, Viet Nam adopted the Hydrogen Energy Development Strategy for the period to 2030 and a vision to 2050 (Decision No.165/QD-TTg), which aims to produce 100,000–500,000 tonnes of hydrogen annually by 2030 and replace coal and natural gas for power generation.

Province	Biomass Power Plant	Capacity (MW)	Year of Operation
Hau Giang	Hau Giang (biomass)	20	2026–2030
	Hau Giang (rice husk)	10	2026–2030

Source: Compiled by the IEEJ based on the PDP8 implementation plan.

Financial support policy

To financially support biomass power plants, a feed-in tariff (FIT) scheme has been in place since 2014. The 'Support Mechanism for the Development of Biomass Power Projects in Vietnam' (Decision No.24/2014/QD-TTg) required Vietnam Electricity (EVN) to purchase power produced from the grid-connected combined heat and power (CHP) projects using biomass resources at D1,220 (US$0.058)/kWh, indexed to the Vietnamese dong-US dollar exchange rate. For non-CHP projects, an avoided cost tariff was applied as the electricity purchasing price.[20]

In 2020, Decision No.08/2020/QD-TTg, an amendment to the 2014 decision, raised the FIT for CHP biomass projects to D1,634/kWh (US$0.0703/kWh) and replaced the avoided cost tariff with a FIT of D1,968/kWh (US$0.0847/kWh) for non-CHP projects. However, this decision repealed all the financial support measures, such as import tax exemption, exemption or reduction of corporate income tax, and exemption or reduction of land use or land lease, to which the biomass projects were entitled.

Biofuel development plan

In 2012, Viet Nam issued the 'Roadmap for Application of Ratios for Blending Biofuels with Traditional Fuels' (Decision No. 53/2012/QD-TTg). This roadmap planned to introduce E5 in seven provinces (Hanoi, Ho Chi Minh City, Hai Phong, Da Nang, Can Tho, Quang Ngai, and Ba Ria - Vung Tau) from December 2014 and nationwide from December 2015. The roadmap also proposed an E10 implementation in the same seven provinces in December 2016 to be expanded nationwide in December 2017. However, the E5 roll-out was delayed and the mandate was eventually implemented in 2018. E10 has not been adopted yet.

Climate change policy

To fulfil the commitment to carbon neutrality by 2050, Viet Nam has developed policies to reduce GHG emissions. In January 2022, the government adopted Decree 06/2022/ND-CP, which requires certain facilities to conduct a GHG inventory. Specifically, the facilities are those with annual GHG emissions above 3,000 t-CO_2 or

[20] The Ministry of Industry and Trade (MOIT) annually calculated avoided cost tariffs based on the marginal cost of a coal power plant using imported coal.

thermal power plants and industrial production facilities with a total annual energy consumption of 1,000 tonnes of oil equivalent (toe) or more (VP Carbon, 2024).[21]

Decision No. 01/2022/QD-TTg followed, which listed sectors and facilities that must conduct GHG inventories.[22] In 2023, the list of sectors and facilities was updated, increasing the number of target facilities in all fields to 2,893, about 50% up from 1,912 of the 2022 list. Bioenergy for industrial use is currently limited, but this regulatory requirement is expected to encourage the energy transition of the energy-intensive industry by using biomass resources for heat production.

5.1.2. Resource availability

Viet Nam is endowed with various bioenergy resources. As it is an agricultural country and dedicates about 40% of its total land area to agricultural production, biomass resource potential can be found in crop production. Previous studies found large amounts of biomass resources across the nation that can be used for energy (ADB, 2015; IRENA, 2022a).

Amongst others, rice husk (a by-product of rice milling) and rice straw have been identified as having the largest theoretical energy potential, followed by sugarcane bagasse, tops, and leaves. In addition, maize residues (cobs, husks, stover, and straw), cassava stalk and pulp, rubber, and eucalyptus can also be possible biomass resources for energy. The availability of biomass resources differs by region due to the country-specific geography. With an elongated 'S' form of 1,650 km in distance from north to south, the northern areas are mostly mountainous, whereas the southern parts are plains.

Figure 5.1 shows the trend of main crop production in Viet Nam. Paddy and cassava have been produced stably at almost the same level. Although sugarcane production has declined in recent years due to planted area reductions, the yield has improved in the last two years (Figure 5.2). When it comes to bioenergy, however, the balance between energy and food security is an essential issue, especially in developing countries. Therefore, agricultural residues and wastes should be considered as Viet Nam's main biomass resources for energy production.

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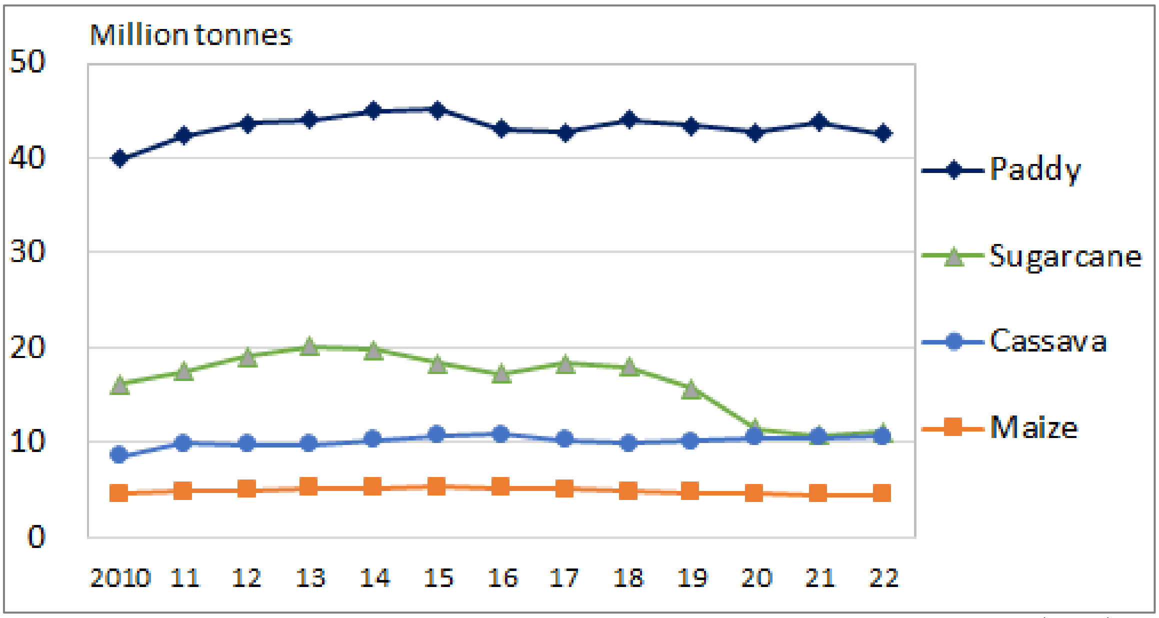
[21] The other facilities subject to the decree are freight transport trading business and commercial buildings with annual energy consumption of 1,000 toe or more, and solid waste treatment facilities with an annual operating capacity of 65,000 tonnes or more.

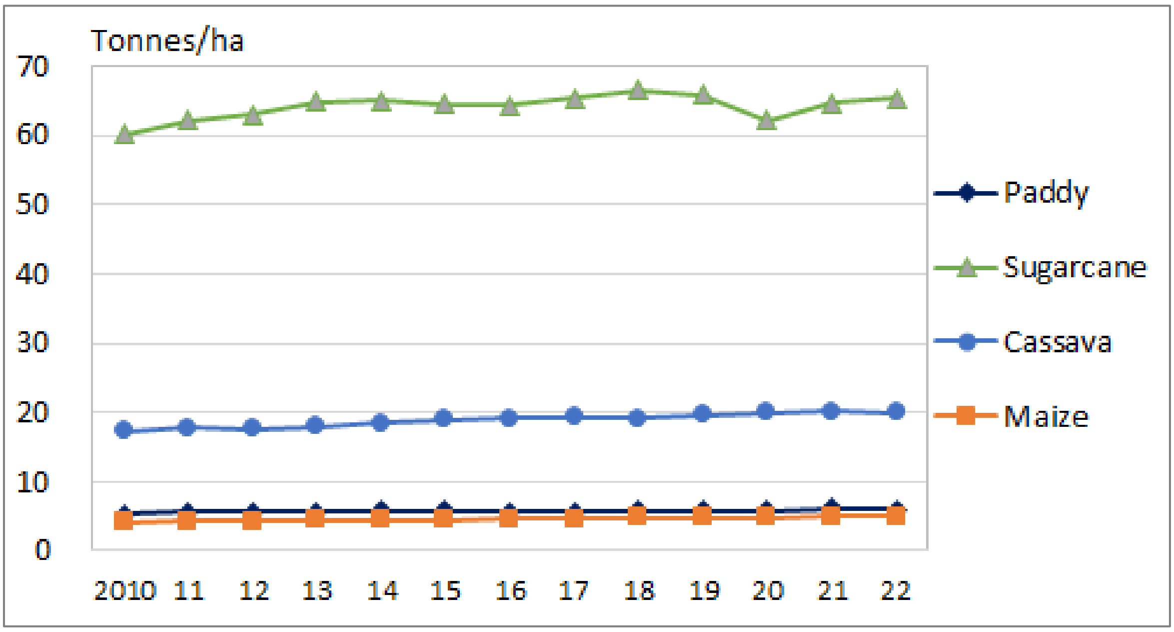
[22] The sectors with inventory obligations are (i) energy; (ii) transportation; (iii) construction; (iv) industry; (v) agriculture, forestry, and land use; and (vi) waste. The facilities include (i) industry and trade, (ii) transport, (iii) construction, and (iv) natural resources and the environment.

Figure 5.1, Production of Main Crops in Viet Nam, 2010–2022



Source: Compiled by the IEEJ based on data from the Viet Nam General Statistics Office (2023).

Figure 5.2. Yield of Main Crops in Viet Nam, 2010–2022



Source: Compiled by the IEEJ based on data from the Viet Nam General Statistics Office (2023).

Many factors, such as topography, temperature, and soil conditions, influence crop production and make some regions advantageous to produce certain crops. In Viet Nam, the Red River Delta areas and the Mekong River Delta areas are the centres of agricultural production. Adding the North Central and Central Coastal areas to the agricultural centres, these three regions are the major rice production areas, which account for 85% of the total rice production (Cuong et al., 2021). Regarding sugarcane production, the average yield is higher in the southern region compared with the northern part of the country since the latter has limited land for planting due to the mountainous terrain (Nguyen et al., 2022).

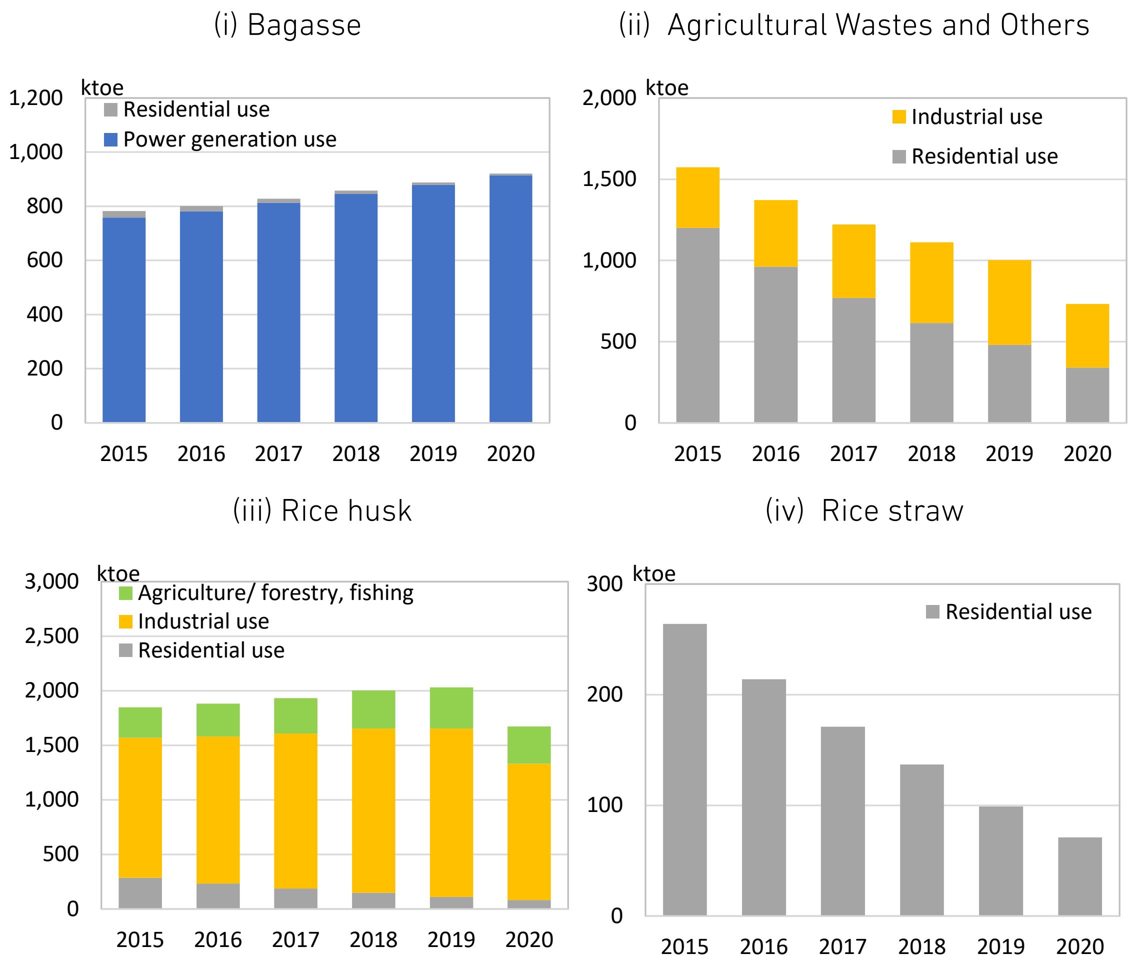
Substantial potential also lies in the wood manufacturing industry as the feedstock is already available at reasonable costs and can be used for kiln for heat production on site (IRENA, 2012). In Viet Nam, there are many furniture and plywood workshops and mills that produce plenty of wood by-products from timber, including sawdust, shaving, and twigs, and these by-products can be used to make wood pellets (To and Cao, 2021). Inputs for wood pellets are expected to increase along with the expansion of timber plantations.

5.1.3. Commercial production

In Viet Nam, the use of bioenergy has decreased as the country has better access to commercial energy. The primary solid biofuels in the total energy supply decreased from 14.7 million tonnes of oil equivalent (Mtoe) in 2010 to 9.8 Mtoe in 2021, and in terms of the share, from 25.1% in 2010 to 10.3% in 2021 (IEA, 2023a).[23] This reduction is explained largely by the change in energy use in the residential sector. Figure 5.3 shows that consumption of agricultural wastes, rice husks, and rice straw in the residential sector has continuously decreased. Conventionally, biomass resources such as firewood and rice straw have been used for cooking and heating in the residential sector, especially in rural areas. However, households have shifted energy fuels from traditional biomass to commercial energy.

[23] The IEA defines primary solid biofuels as 'any plant matter used directly as fuel or converted into other forms before combustion' (IEA, 2023a).

Figure 5.3. Bioenergy Use in Viet Nam, 2015–2020



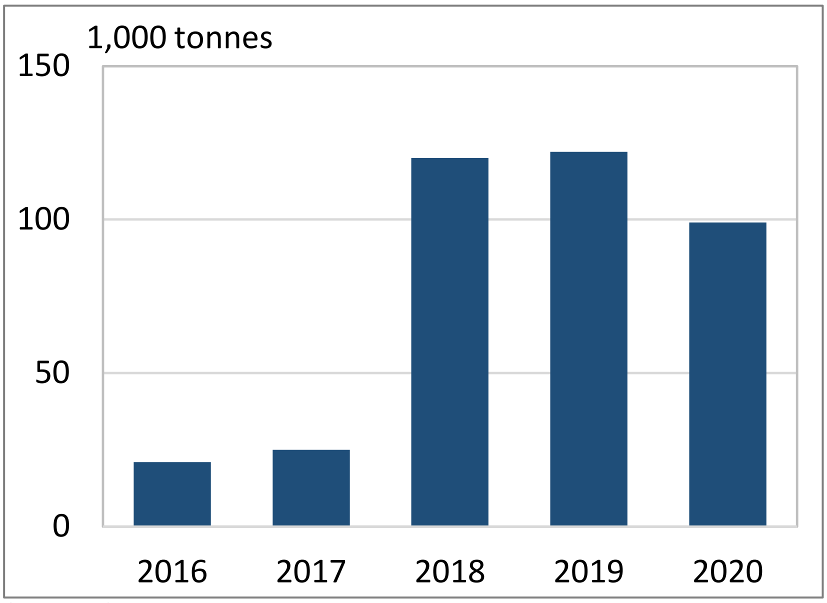
Source: Compiled by the IEEJ based on data from the Institute of Energy (2021).

Viet Nam achieved universal access to electricity at the district and commune levels in 2022, whilst the share of rural households with electricity and households with electricity was 99.53% and 99.7%, respectively (EVN, 2023). Access to clean fuels and technologies for cooking significantly improved from 51.2% in 2010 to 96.1% in 2021 (World Bank, n.d.-b).

On the other hand, the industry sector keeps using bioenergy for electricity and heat production, although bioenergy is limited to some industries that do not require high temperatures for manufacturing processes. For example, bagasse consumption has gradually increased, as illustrated in Figure 5.3 (i), and bagasse is the main fuel for the CHP system in sugar mills.

In the transport sector, a small amount of ethanol-blended petrol has been consumed. Ethanol consumption in the transport sector shot up in 2018 when the E5 mandate was implemented and then dropped in 2020 (Figure 5.4). In Viet Nam, the ethanol plants rely totally on cassava harvested domestically for production.

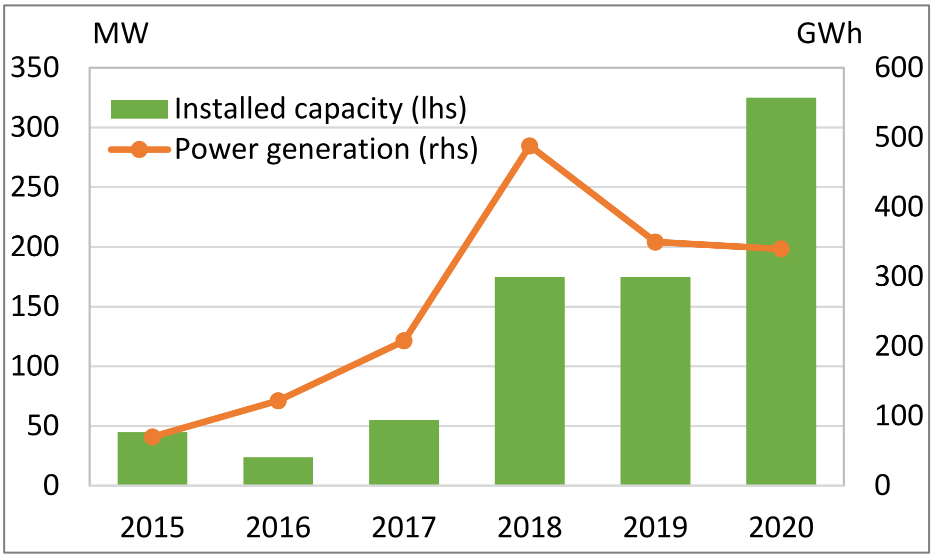
Figure 5.4. Ethanol Use in the Transport Sector in Viet Nam, 2016–2020



Source: Compiled by the IEEJ based on data from the Institute of Energy (2021).

Viet Nam had a biomass power generation capacity of 325 MW in 2020 (Figure 5.5). Bagasse is the main fuel, with a share of 85% in biomass power generation in 2021 (IRENA, 2024). At present, the CHP systems in sugarcane plants use bagasse as the main fuel, whilst there are no mono-firing biomass power generation plants in the country. By the end of 2021, 12 sugar plants provided surplus electricity to the grid after self-consumption on-site (GIZ, 2022). As the latest development, a new biomass power plant with a capacity of 20 MW is under construction in Hau Giang Province and is planned to start commercial operation by December 2024 (erex, 2022). This biomass power plant will utilise rice husk as the main fuel and the selling price will be US$0.0847/kWh under the FIT scheme.

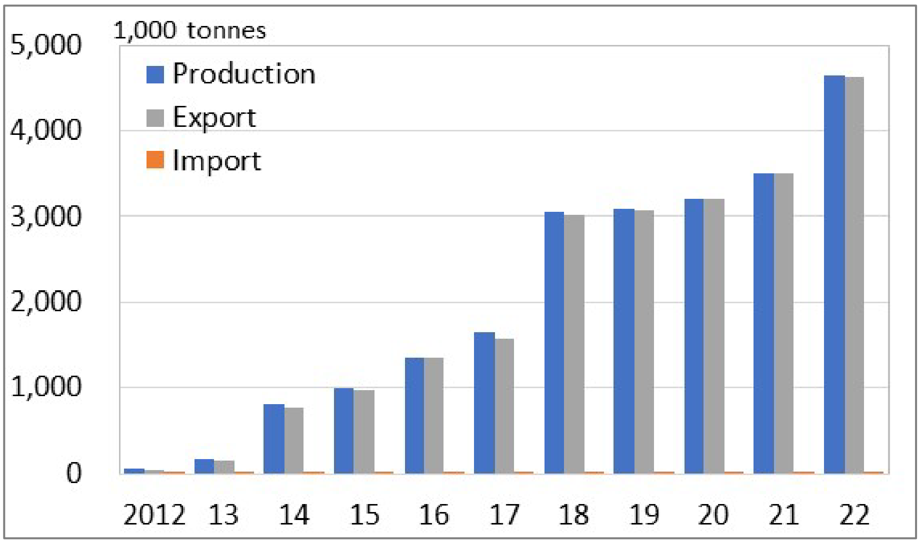
Figure 5.5. Biomass Power Generation Capacity and Power Generation in Viet Nam, 2015–2020



Lhs = left-hand scale, rhs = right-hand scale.
Source: Compiled by the IEEJ based on data from the Institute of Energy (2021).

Viet Nam is the leading export country for wood and wood products. Wood pellet manufacturing is centred around the northern provinces (To and Cao, 2021). The country was the second largest country for production and export amounts of wood pellets worldwide in 2022 (FAOSTAT, 2023). As Figure 5.6 shows, wood pellet production has robustly increased. Almost all the production is exported primarily to Korea and Japan. This is mainly because Viet Nam has a geographical advantage for export, that is, a long, narrow country with a width of 50 km across at its narrowest point with a coastline of 3,260 km. Wood processing factories have convenient access to export seaports, which contributes to efficiency in transportation.

Figure 5.6. Wood Pellet Production, Exports, and Imports



Source: Compiled by the IEEJ based on data from FAOSTAT (2023).

Woody biomass is about to stand at the dawn of sustainable energy business for the domestic market. There is a sign of a demand increase for woody biomass. Some coal-fired power plants have been tested and partially converted to using wood chips and pellets (Ky, 2023). Idemitsu Kosan, Japan's second-largest oil wholesaler, constructed the first commercial plant to produce black pellets, also called torrefied pellets, in Binh Dinh Province in July 2023. The production capacity is 120,000 tonnes, and acacia wood residues and sawdust are utilised as feedstock (Idemitsu Kosan, 2021). In this business model, the black pellets are export-oriented, but this case implies the possibility of utilising wood residues from the manufacturing process as fuel inputs for energy production in Viet Nam.

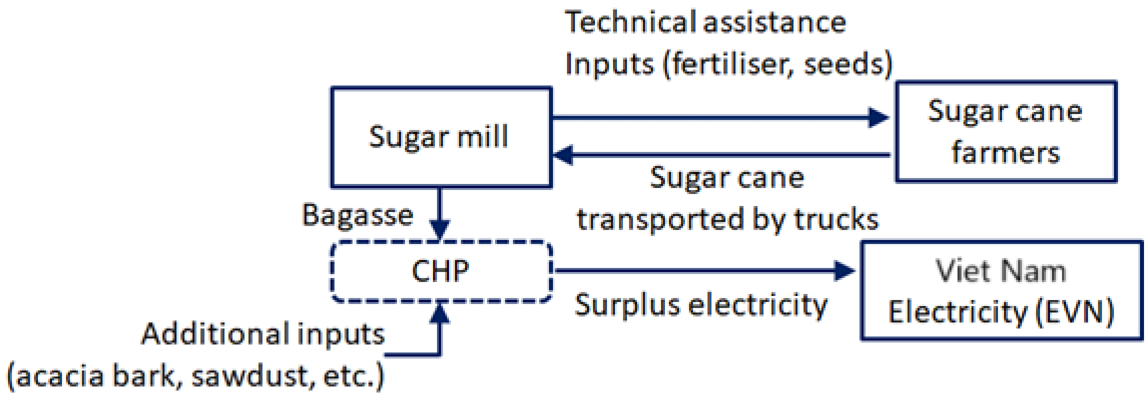
5.1.4. Existing supply chain

Heat and power

In Viet Nam, the sugar mills rely mainly on bagasse for the CHP system. There are 39 sugar mills with a total installed processing capacity of 157,000 tonnes of sugarcane per day as of March 2022 (GIZ, 2022). The latest information shows that only 10 CHP systems of sugar mills with a total installed capacity of 361.6MW sell surplus electricity to the grid (GIZ, 2024). Bagasse is available for three or four months only in the season when sugarcane is crushed. The time to generate heat and power can be extended if additional feedstock is used. Thus, the sugar factories need to purchase other supplemental biomass resources to operate the CHP system longer.

The sugar factories purchase sugarcane from the local contracted farmers, as seen in Figure 5.7. In general, the sugar mills assist the farmers technically, from planting to harvesting sugarcane and provide them with necessary inputs (Nguyen et al., 2022). The harvested sugarcane is transported to the sugar mills by trucks and then processed to produce sugars and co-products. 0.3 tonnes of bagasse can be produced from 1 tonne of sugarcane and could generate 100–120 kWh of electricity (Nguyen et al., 2022). For example, the Lam Son Sugar Cane Joint Stock Corporation (LASUCO) in Than Hoa Province supplies surplus power generated from the CHP system of the sugar factory to the local community and assists farmers in sugarcane cultivation (Box 5.1).

Figure 5.7. Supply Chain of the Bagasse-based CHP System



Source: Depicted by the IEEJ.

Box 5.1. Lam Son Sugar Cane Joint Stock Corporation*

Lam Son Sugar Cane Joint Stock Corporation (LASUCO) manufactures sugar and agricultural products in Than Hoa Province and can process 7,500–8,000 tonnes per day. The sugar factory has a CHP system with a total installed capacity of 33.5 MW (12.5 MW, 15 MW, and 6 MW) in the production line, using bagasse as the main feedstock, in which 18.5 MW (12.5 MW and 6 MW) is connected to the grid for sale to Vietnam Electricity (EVN). In actual operation, LASUCO generates more than 20 MW of electricity, out of which the electricity consumed for the sugar mill's operation is nearly 50% and the rest is sold to EVN.

LASUCO also utilises acacia bark and sawdust, which are purchased from wood production facilities nearby as supplemental fuels when bagasse is not enough to operate the boilers. Additional feedstock helps the CHP system to extend the operation period three months longer. Acacia bark is purchased at D400,000–D600,000 (US$16–US$24)/tonne, depending on the seasonal availability.

LASUCO had contracts with 10,400 farming households in 56 villages as of January 2024. There are about 40 experts who oversee 350–400 hectares each and provide technical support to contracted farmers in growing sugarcane, from supplying inputs such as sugar cane seeds and fertilisers to planning when to water and harvest.

* This information was obtained through an interview with the company conducted on 1 February 2024.

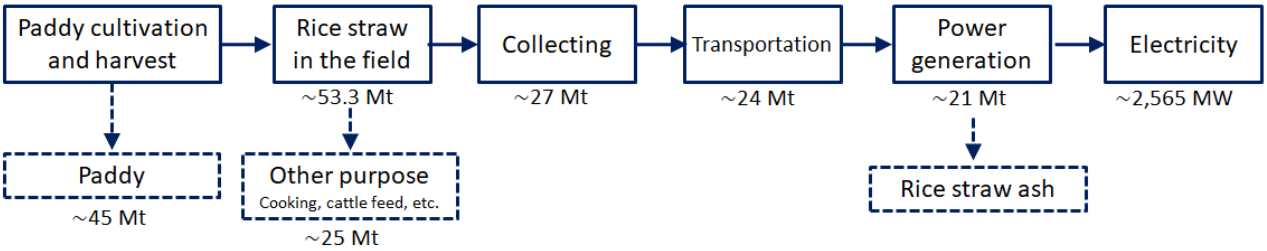
Large amounts of agricultural residues are usually found at processing and milling sites, such as for bagasse and rice husks (ADB, 2015). On the other hand, the volume of agricultural residues generated in the field could be low because the farm size is relatively small in Viet Nam, which makes it difficult to collect them.[24] If the agricultural residues were collected efficiently and sufficiently to be utilised as fuels, they would not be left in the field, and, rather, they could bring environmental benefits by preventing the open burning of agricultural residues and might generate commercial value as traded materials.

In some cases, rice husk is consumed as fuel input for brick kilns and fertiliser. Yet, currently, no biomass power plants use rice straw or rice husk as a primary fuel (GIZ, 2022). Viet Nam harvested 42.7 million tonnes of rice in 2022. As rice husk accounts for generally 20% of the paddy, approximately 8.6 million tonnes of rice husk were yielded. Cuong et al. (2021) estimated that the potential power generation capacity that

[24] In Viet Nam, 89% are small family farmers who cultivate land, averaging 0.4 hectares (Schenck, 2018).

uses rice straw as fuel from 45 million tonnes of rice production would be 2.6 GW in Viet Nam, as presented in Figure 5.8.

Figure 5.8. Supply Chain of the Potential Use of Rice Straw for Power Generation



Source: Adapted from Cuong et al. (2021: Figure 4).

There are several stakeholders involved in the wood pellet supply chain in Viet Nam. Forest growers supply timber to wood pellet manufacturing factories, and dealers are engaged in collecting and transporting the raw materials.[25] The wood processing factories also utilise waste wood as inputs for wood pellet manufacturing. Most of the wood processing factories are small or medium-sized.

New woody biomass power projects are in progress. Japan's renewable energy company erex plans two 50 MW biomass power plants in Yen Bai and Tuyen Quang Provinces, both of which will utilise wood residues as the main fuels (erex, 2024). These two projects are selected for the PDP8 implementation plan. To secure the feedstock, erex has started the construction of two wood pellet plants to process wood residues with a capacity of 150,000 tonnes per year, respectively, in both provinces[26]. The wood pellet plants are expected to be completed in the 2nd half of 2024.

The supply chain for wood pellets has been established in Viet Nam, although almost all are export oriented. Presumably, the country could utilise the supply chain for domestic use with minor changes when biomass power plants fuelled by wood pellets are economically within reach.

Transport fuels

In Viet Nam, as dry cassava chips are used to produce ethanol, cassava is handled by dry chip makers before reaching the dealers, whereas fresh cassava is processed for starch production, as seen in Figure 5.9. There are two ways of delivering cassava to

[25] From an interview with the Vietnam Timber and Forest Product Association conducted on 29 January 2024.

[26] Wood pellets are planned to fuel not only biomass power plants but also co-firing coal power plants. The company will also export the wood pellets.

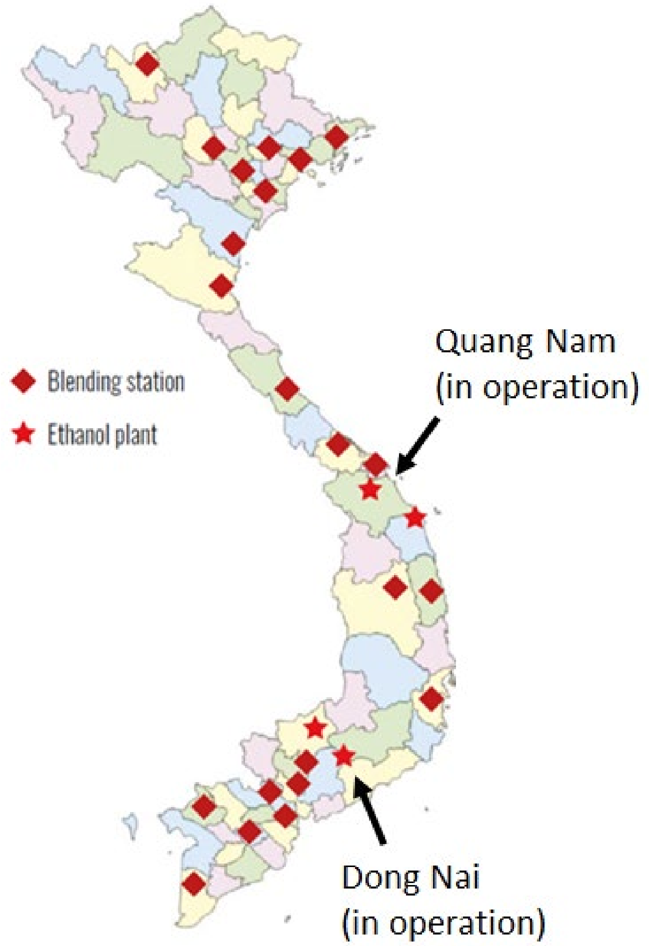
ethanol plants; one is to transport the feedstock directly from the harvested field to the ethanol plant, and the other is to deliver it from the main trading ports to the ethanol plant. The former is cost-effective but unreliable in delivery, thereby making ethanol producers prefer the latter to ensure that the feedstock is provided regularly (Pirelli et al., 2018). Still, an unstable feedstock supply is raised as an obstacle to ethanol plant operation.

Figure 5.9. Ethanol Supply Chain

Source: Compiled by the IEEJ from Pirelli et al. (2018).

There were seven bioethanol plants with a total capacity of 612 million litres per year in Viet Nam by 2019 (Nghiem et al., 2021). However, only two plants owned by Tung Lam Company are operational in Dong Nai and Quang Nam Provinces, as exhibited in Figure 5.10. The four ethanol plants have stopped production, and one plant did not reach operation. The ethanol production business stagnated mainly because ethanol demand remained low, and the operators faced financial difficulty.

Figure 5.10. Ethanol Plants and Blending Stations



Source: Adapted from Pirelli et al. (2018: p.246, Figure 63).

Petrolimex and PVOil play a major role in petroleum product distribution. Petrolimex manages seven blending stations with a capacity of 1.8 million m^3, and PVOil has 12 blending stations with a capacity of 1.67 million m^3 (Nghiem et al., 2021). Mostly, petrol and ethanol are blended directly (the in-line blend method) before transportation and then shipped out to the petrol stations (Pirelli et al., 2018). Finally, ethanol is delivered to the blending stations of oil companies by truck.

5.1.5. Cost

Heat and power

The total installation costs of bioenergy are affected by many factors, such as the technology to be applied, feedstock, logistics, and country/region. The cost of biomass-based heat and power generation mainly entails input fuel, capital investment, and operation and maintenance (O&M) (IEA-ESTAP and IRENA, 2015). In particular, the feedstock cost represents generally 40%–50% of the total cost of biomass power generation (IRENA, 2012).

Given the large share in biomass power generation costs, the feedstock cost could have impacts on a project, depending on how it is stably secured at affordable costs. When agricultural residues like rice straw are collected at harvest and bagasse produced at sugar factories is utilised, these costs are almost zero or relatively low. In most cases, however, some factors would raise the feedstock cost. In addition to bagasse, if the sugar mills use supplemental fuels, they bear additional purchasing and transportation costs of the inputs. The pre-treatment, such as torrefaction, pelletising, or briquetting, also adds extra costs for transforming the agricultural or wood residues into more efficient fuel inputs.

Tromso and Hiroshima Prefecture (2020) surveyed the sales price of rice husks, which are treated as valuable materials in Kan Tho, the main city of the Mekong Delta region. In Kan Tho, the rice mills sell the surplus rice husks for around D500–1,000/kg and deal the rice husk briquette for D1,500–2,000/kg (Table 5.3).

Table 5.3. Sales Price of Rice Husk

Rice Mill	Sales Price of Rice Husk	Sales Price of Rice Husk Briquette	Purchase Price of Rice Husk Briquette
Company A	D500–1,000/kg	D1,800/kg	In-house production
Company B	D500–700/kg	D1,500–1,700/kg	In-house production
Company C	D600–800/kg (Low available time: D1,200/kg)	None	D2,000/kg

Source: Tromso and Hiroshima Prefecture (2020, p.35 Table 13).

EREA and DEA (2021) report the costs of two biomass CHP projects, namely KCP in Phu Yen Province and An Khe 1&2 in Gia Lai Province, as presented in Table 5.4. These two projects demonstrate that the investment cost would be approximately US$1 million/MW for the bagasse-based CHP system in Viet Nam.

Table 5.4. Biomass CHP Project Costs

Parameter	KCP Phu Yen Province	An Khe 1&2 Gia Lai Province
Capacity (MW)	30 MW	40 MW + 55 MW
Fuel input	Bagasse: 8,000 tonnes/hour	Bagasse (90%): 540,000 tonnes/year Other biomass resources, such as shell and coffee grounds (10%): 60,000 tonnes/year
Nominal investment cost (2019 US$/MWe)	US$1 million/MWe	US$1.08 million/MWe
Fixed O&M (2019 US$/MWe/year)	Not available	US$29,000/MWe/year
Variable O&M (2019 US$/MWh)	Not available	US$2.9/MWh
Year of operation	2017	2018

Source: Compiled by the IEEJ based on EREA and DEA (2021, pp.136–8).

Transport fuels

Ethanol production cost has not been clearly identified since it involves commercially sensitive information for ethanol plants (Pirelli et al., 2018). One piece of information found from some studies is that the cost of raw materials, dry cassava chips, accounts for about 60%–64% (Pirelli et al., 2018; Nghiem et al., 2021).

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

There is a high potential for biomass resources in Viet Nam since a wide range of residues and by-products are yielded from the agricultural and forestry sectors. Nevertheless, they have not been fully exploited yet as bioenergy resources. The benefits of utilising bioenergy are highlighted in terms of the environment and sustainable development.

Most importantly, bioenergy will help Viet Nam to decarbonise the economy. Bioenergy is regarded as carbon neutral and an alternative to fossil fuels. Fossil fuels are still dominant in Viet Nam, accounting for 84.6% of the primary energy supply in 2020 (Institute of Energy, 2021). In particular, the country's dependence on coal is high, with 52.0% in primary energy and 50.1% in power generation in 2020. Viet Nam needs to reduce coal consumption, aiming for the target of carbon neutrality by 2050. Bioenergy can substitute coal for generating power and heat. Consequently, this will also lead to the improvement of energy security by reducing fossil fuel imports.

Another benefit is to reduce the negative environmental impacts by treating agricultural residues appropriately. For example, rice straw is often burned in the field after harvest, although it is often used for heat production as an alternative to coal when the fossil fuel cost is high. The open burning of rice straw is an uncontrolled and incomplete combustion method that releases toxic air pollutants, such as particulate matter and carbon monoxide. It also emits GHGs, such as methane and nitrous oxide (Nguyen, 2021). This practice spreads air pollution, consequently harming human health. If rice straw is utilised for energy, possibly by converting it to pellets, this detrimental influence can be lessened.

Furthermore, many biomass power generation technologies are mature and commercialised. The co-firing of ammonia in coal power plants has received attention lately as a promising means to reduce CO_2 emissions, with minor adjustments to coal power plants. Even with the advancement, however, this has just reached technology readiness level 5, a large prototype level (IEA, 2023b). Given the uncertainty of the maturity of the advanced technology, co-firing biomass in coal power plants is a more realistic and practical approach.

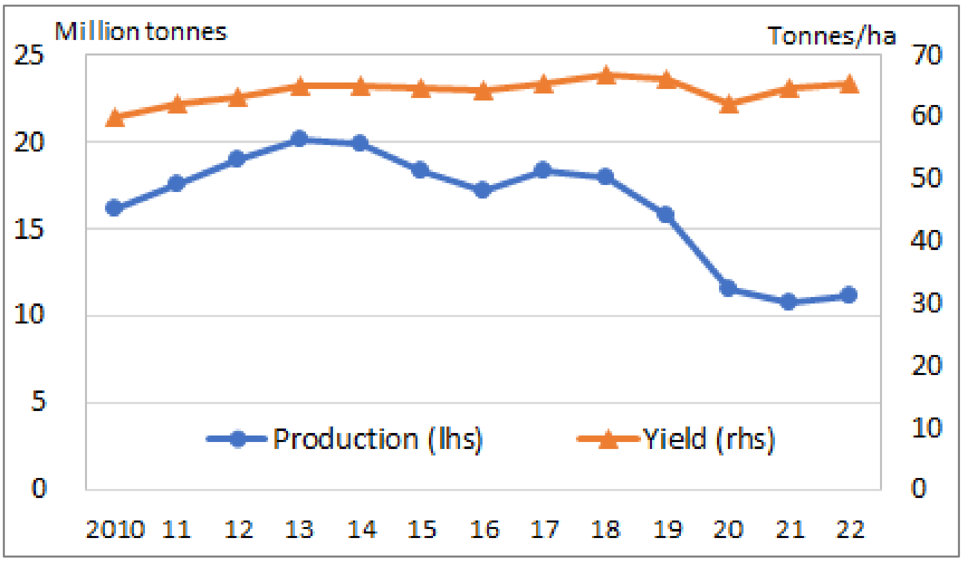
5.1.7. Selection of focused bioenergy

Heat and power

This study focuses on bagasse, rice husk, rice straw, and woody biomass as possible biomass resources for power generation and heat production in Viet Nam.

Bagasse will continuously be the main fuel for CHP. Sugar factories with the CHP system make the most of the by-products of processing sugarcane for their own use of heat and power and sell the surplus power to the grid. A concern is the recent trend that the harvest area has declined, although the yield level has been almost the same (Figure 5.11).

Figure 5.11. Sugarcane Production and Yield, 2010–2022



Lhs = left-hand scale, rhs = right-hand scale.
Source: Compiled by the IEEJ based on data from the Viet Nam General Statistics Office (2023).

In addition, rice husk and rice straw are also potential resources that can be utilised for energy. They are abundant residues yielded from rice production in Viet Nam. Based on the residue-to-crop ratio and lower heating values found by the World Bank (2018), the annual theoretical energy potentials of some agricultural residues can be calculated (Table 5.5 and Table 5.6). It is seen that rice husk and rice straw have high potential as bioenergy resources.

Table 5.5. Residue-to-crop Ratio and Lower Heating Values

Crop	Residue	Residue-to-crop Ratio	Moisture Content of Residues (%)	Lower Heating Value (MJ/kg)	Lower Heating Value (MWh_{th}/tonne)
Paddy	Rice straw	1.0	12.0	12.60	3.50
Paddy	Rice husk	0.2	10.5	13.00	3.61
Sugarcane	Bagasse	0.3	50.0	7.50	2.08
Maize	Maize trash	2.2	16.0	12.50	3.47

Source: Compiled by the IEEJ based on World Bank (2018: p.17, Table 2; p.18, Table 3).

Table 5.6. Annual Theoretical Energy Potential of Crop Residues

Crop	Residue	Annual Crop Production (2022)	Annual Production of Residues	Energy Potential of Residues	
		(tonnes)	(tonnes)	(TJ/year)	(GWh_{th}/year)
Paddy	Rice straw	42,660,700	42,660,700	537,525	149,312
Paddy	Rice husk	42,660,700	8,532,140	110,918	30,801
Sugarcane	Bagasse	11,083,000	3,324,900	24,937	6,916
Maize	Maize trash	4,423,200	9,731,040	121,638	33,767

Source: Estimated by the IEEJ.

These agricultural residues are inexpensive and available across the nation, especially in the Mekong River Delta region, a major rice production area. A rice husk steam power plant built by Dinh Hai Cogen Joint Stock Company in Can Tho City provided heat to companies in the Tra Noc Industrial Park (Leinonen and Nguyen, 2013; Nguyen et al., 2018). Although the plant stopped operation due to economic difficulty, this precedent shows the possibility of rice husk as energy fuel in Viet Nam. For efficient transportation and utilisation, however, rice husk and rice straw need to be transformed into energy fuels in the form of pellets or briquettes. How they are efficiently collected is also a critical issue in establishing a supply chain.

Attention is also given to woody biomass because it can be a potential fuel for boilers in the industry sector and power generation. In power generation, woody biomass can be singly combusted or co-fired with coal or other biomass resources. From an environmental viewpoint, if wood residues including thinned wood, pruned branches, or sawdust find a route to be utilised, deforestation can be prevented by applying these resources that could be left in woods otherwise. The wood industry has already established a supply chain for wood pellet exports and gained knowledge and experience in wood manufacturing. Therefore, the industry can find a business opportunity by applying or modifying the existing supply chain to develop a new path for domestic energy use. The new business model is expected to benefit the local economy and create job opportunities as well.

Transport fuels

For biofuel in the transport sector, cassava will remain the main feedstock for ethanol production. Compared with other possible resources for biofuels, including sugarcane molasses and maize, cassava is considered better in terms of productivity, production costs, and efficiency (Nghiem et al., 2021). It would be difficult to secure maize and molasses for energy use in the first place as they are in a declining production trend and are also used for other purposes.

5.2. Expected supply and demand of focused bioenergy in 2030

5.2.1. Identifying the gaps between supply and demand

Heat and power

Whilst biomass resource potential is abundant in Viet Nam, to materialise it as feedstock for generating heat and power is a different story. It is vital to meet increasing energy demand to maintain the robust economic growth of the country and to understand how much bioenergy could contribute to the energy supply.

For the power sector, the PDP8 target set by the government is assumed to indicate the electricity demand in the future. The 2030 target capacity for biomass power generation is 2,270 MW, which is ambitious given the current capacity of biomass power generation at 325 MW in 2020. In other words, the biomass power generation capacity must increase by approximately seven times to achieve the target. If the 2050 target is put into perspective, biomass power generation capacity will be expanded to 6,015 MW. In addition, bioenergy, which will replace fossil fuels as feedstock for thermal power plants, will need to be taken into consideration.

Looking at the supply side, however, it is unlikely that supply will meet this demand if bagasse is the only fuel for power generation including the CHP system. The capacity factor was 11.9% for biomass heat and power generation in 2020 in the case of Viet Nam. Based on this capacity factor, power generation is estimated to be 2,400 GWh in 2030 if the PDP8 targeted biomass power generation capacity is applied. On the other hand, about 1,200 GWh of biomass power generation fuelled with bagasse is estimated to be supplied to the national grid by 2030 (Nguyen et al., 2022). Consequently, there will be a gap between demand and supply in bagasse-fired heat and power generation. Therefore, additional biomass feedstock other than bagasse will be needed to fill the gap and meet the demand in 2030 and thereafter.

There are unexploited bioenergy resources in Viet Nam. The Ministry of Industry and Trade (MOIT) calculated that the total potential of all biomass resources would be more than 9,600 MW by 2035, including 370 MW of rice husks, 1,300 MW of rice straw, and 3,360 MW of wood by-products (Nguyen, 2022). Amongst others, the high potential of woody biomass was found for energy use.

Transport fuels

Country analysis of Viet Nam, part of ERIA's *Energy Outlook and Energy Saving Potential in East Asia 2023* (Kimura et al., 2023), is used to estimate the bioethanol consumption of the transport sector. In this country analysis, the final energy demand of the transport sector is projected to grow at 6.7% annually on average between 2020 and 2030 under the business-as-usual scenario. Applying this average annual growth rate, ethanol use is estimated to be 189,360 tonnes (150 million litres) in 2030. In 2015, 66,376 tonnes of dry cassava chips were used for ethanol production, which was 5% of the 1.3 million tonnes of domestically consumed dry cassava chips (Pirelli et al., 2018). There seems to be enough supply of dry cassava chips since the percentage of the material for ethanol production is relatively small. Still, the multiple usages of the crop necessitate ethanol producers' efforts to ensure that the feedstock is delivered at a competitive price.

Cost estimation

Total biomass power generation capacity is planned to be 1,088 MW in the PDP8 implementation plan. The investment cost mentioned above is approximately US$1 million/MW for the biomass-based CHP system in Viet Nam. Taking these figures into consideration, the investment cost would be about US$1 billion if all biomass power projects in the PDP8 implementation plan were carried out. IEA-ESTAP and IRENA (2015) report that co-firing biomass in coal power plants that require boiler retrofitting and specific equipment would increase investment costs within a range of US$140–850/kW. Nevertheless, the incremental investment costs would be regarded as relatively low.

5.3. Requirements for Development of the Supply Chain (to Fill the Supply-Demand Gap)

5.3.1. Addressing technical barriers

Appropriate infrastructure: heat and power

Currently, infrastructure is not suitably established for bioenergy systems in Viet Nam. Developing a systematic infrastructure to produce heat and power from biomass resources is challenging because it is difficult to efficiently collect and transport scattered agricultural and wood residues. The farm size, which is mostly small in the country, complicates this matter unless the farmers are cooperative in collecting the crop harvesting or processing residues.

The bulk density of biomass resources impacts the efficiency of transportation and storage. The bulk density of the biomass resources focused on in this study – rice straw, rice husk, and bagasse – is relatively low, as presented in Table 5.7. When the bulk density is low, the load that a truck can carry at one time is smaller than those with high bulk density resources. More trucks are needed to deliver rice straw or rice husk than the number of trucks for wood products, which consequently increases transportation costs, fuels, and CO_2 emissions.

Table 5.7. Biomass Resource Bulk Density

Biomass Resource	Bulk Density, Wet (kg/loose-m^3)
Rice straw	75
Rice husk	70–110
Bagasse	120
Wood chips	250–350
Sawdust	250–300
Wood pellets	640–690

Source: Compiled by the IEEJ based on Leinonen and Nguyen (2013: p.15, Table 2).

In addition, the low bulk density resources require a large storage capacity that accommodates enough feedstock to keep the operation running smoothly. Since moisture is one of the important properties that affect the operation of biomass power plants, an adequate roof and walls for storage are necessary to maintain the moisture content. Storing the feedstock in the field should be avoided to prevent adverse effects, such as odour or pests. The close proximity of the storage facility to the bioenergy establishment is preferable for delivering the feedstock when it is needed. One caveat is that the storage must be equipped with appropriate fire prevention systems, as biomass resources are flammable (GIZ, 2022).

Integrating pre-treatment processes, such as torrefaction, pelletising, or briquetting, into the bioenergy supply chain would be beneficial as such treatment improves the bulk density of agricultural and wood residues. This process enables more feedstock to be transported and stored in the form of pellets or briquettes. These pre-treatment technologies are already available in Viet Nam, although the wood pellets are mainly export-oriented.

Appropriate infrastructure: transport fuels

There is substantial room for improvement in transportation in the ethanol supply chain. Ethanol is transported by trucks regardless of the distances between the trading ports, ethanol plants, and blending stations. Since the existing distribution systems are designed for petrol, they are not suitable for delivering ethanol fuels. In the case of petrol, sea transport is used from the refinery to the main petrol terminals near the seaport, and then petrol is delivered by trucks to the petrol distribution stations (Pirelli et al., 2018).

If ethanol is transported by ship or train, the quantity of the fuel delivered will increase, and energy consumption and transportation costs can be saved. A study by the FAO (Pirelli et al., 2018) indicates that transporting ethanol over a long distance from central Viet Nam to the north, where no ethanol plants are operational, would be inefficient due to high fuel consumption and transportation costs (Table 5.8). Furthermore, the lack of ethanol plants in the northern region may cause a supply shortage when E5 demand increases in the future.

Table 5.8. Distance, Fuel Consumption, and Costs of Ethanol Transport

From Ethanol Plants to Terminals	Distance to Terminals (km)	Fuel Consumption (MJ/tonne)	Transportation Cost (US$/m^3)
From Centre to North	876–1,028 km	539–625 MJ/tonne	US$57.4–76.6/m^3
Centre	50–118 km	30–72 MJ/tonne	US$5.0–9.8/m^3
South	100–310 km	61–189 MJ/tonne	US$10.6–27.3/m^3

Source: Adapted from Pirelli *et al*. (2018: p.247, Table 124)

Securing biomass feedstock

Securing biomass feedstock is essential for energy use to improve operating rates and economic efficiency. Collecting or purchasing biomass resources throughout the year or at affordable prices can be challenging due to the following factors.

The first issue is that the agricultural residues are seasonal and climate dependent. The cultivation seasons of rice vary depending on the geological location (Cuong et al., 2021). For rice production, in the northern regions with a subtropical climate, rice is cultivated in spring and winter twice a year. The central and southern regions with tropical monsoon climates have one or more cultivation seasons of rice production, that is, autumn or the autumn-winter season. Bagasse is available for around a half year, only during the time of the sugarcane crushing. In the case of cassava, the crop is farmed with one crop season per year in the northern and central regions, and three crop seasons every two years in the southern region (Pirelli et al., 2018). The seasonal availability of feedstock limits the operating time of the energy systems and affects the input costs. To cope with this issue, it is necessary to identify what other biomass resources are available as supplemental fuels from the planning phase and prepare facilities that could store these different fuels appropriately.

Another issue is that multiple uses of biomass resources could entail competition with other purposes, such as food production, animal feed, and exports. For example, rice straw is used for animal feed, mushroom production, and fertiliser. Bagasse can be a feedstock for buffalo and cattle feeding. Cassava is used not only for ethanol production but also for many applications in industrial processing, such as food, alcohol, adhesives, and food additives (Pirelli et al., 2018).

Emerging competition has also been observed in certain biomass products that are directed for exports as they are more valued in the international market. The wood industry exports most wood pellets and products, mainly to East Asia. In expanding the export business, the Vietnamese food industry has increased the demand for cassava, thereby leading to a cassava price rise, making it more expensive for domestic users.

Technical capacity

In Viet Nam, bioenergy technologies are not yet widespread. Most of the renewable technologies including bioenergy are imported, and domestic renewable energy equipment and service suppliers are few (Cuong et al., 2021). Dependence on imports has resulted in a lack of human resources who have knowledge and skills in operation and maintenance, especially in rural areas where bioenergy resources are abundant (Cuong et al., 2021). This limitation is one of the factors that has kept project costs high and prevented the country from achieving bioenergy development.

5.3.2. Addressing policy and regulatory barriers

Policy incentives

In Viet Nam, the government support to which bioenergy projects are entitled is not sufficient to encourage the development of a bioenergy supply chain. The FIT scheme worked effectively for solar and wind energy but not for bioenergy projects. Biomass power generation capacity has not increased as much as solar and wind. Although the FIT for CHP biomass projects was raised from D1,220 (US$0.058)/kWh to D1,634/kWh (US$0.0703/kWh) under Decision No.08/2020/QD-TTg, this was not attractive enough to draw investment. At the same time, this decision repealed the preferential treatments in tax and land use/lease that were stipulated in Decision No.24/2014/QD-TTg.

Biofuels are also in the same situation. Even after E5 (labelled as E5 RON 92) became mandatory, the uptake of bioethanol blended fuel remained low. There are mainly two reasons behind this slow adoption.

First, the price difference between E5 and petrol (RON 95) is too small to motivate consumers to choose E5 over petrol. The price gap between them is D1,400–1,600 (US$0.05–0.06) per litre (Nghiem et al., 2021). The excise tax and environmental protection tax imposed on petrol are 2% and D200 (US$0.008) per litre higher than those on E5, respectively.[27] These differences are insufficient to encourage

[27] The environmental protection tax on petrol has been reduced from D4,000 (US$0.08) to D2,000 (US$0.08) per litre since April 2022, and this tax reduction will be effective until the end of 2024.

consumers to switch to E5.

Second, consumers are still concerned about the damage to their vehicles, probably because most vehicles are second-hand, and questions about the quality of E5 have not been cleared yet. To change consumers' behaviour, the government is required continuously to provide the public with reliable information on the environmental benefits and impacts on vehicles.

Meanwhile, the petroleum industry needs incentives to develop the infrastructure for bioethanol production. However, there are no specific subsidies or support for biofuel projects nor preferential loan interest rates for investments in ethanol plants in Viet Nam (ADB, 2015).

Certainty in investment environments

Clarity in policy and pricing concerning bioenergy projects is necessary in Viet Nam because uncertainty is not desirable for the investment environment. For example, the 'take or pay' clause is not included in the power purchase agreement (PPA) in the country, in other words, EVN, a single off-taker of electricity, pays only for the electricity received. This ambiguity of the PPA puts investors at risk of possible curtailment without compensation.

In January 2024, the Ministry of Industry and Trade (MOIT) proposed a new pricing framework for biomass and municipal solid waste power plants, suggesting that EVN and investors negotiate the purchase price (Nguyen, 2024). This new framework would make room for arbitrary decisions on the price and could deter the parties from reaching an agreement, consequently, delaying the realisation of a project.

The impacts caused by inconsistent policy implementation should not be underestimated. The change in the FIT scheme for solar power exemplifies how influential it was in renewable energy development. In Viet Nam, solar PV generation capacity substantially increased in 2018 since the FIT scheme for solar PV took effect in 2017. However, with the termination of this measure in 2020, solar PV development has stagnated.

In January 2023, alternatively, the MOIT set new ceiling prices for solar PV and wind projects that failed to apply for the FIT scheme, which was a tentative measure until the new tariff framework was introduced.[28] The solar PV and wind projects were

[28] The FIT scheme was effective until December 2020 for ground-mounted solar PV and October 2021 for onshore wind projects. The wind and solar PV projects, which completed investment and construction but did not start operation by the effective date of the FIT scheme, were called 'transitional' wind or solar PV projects. The ceiling prices were substantially decreased from D1,644/kWh to D1,184.90/kWh for ground-mounted solar PV projects and from D1,928/kWh to D1,587.12/kWh for onshore wind projects.

allowed to sell electricity to EVN through PPAs below the ceiling price set by the MOIT. However, the renewable projects that were subject to the ceiling prices and EVN had difficulty in finding a purchasing price that both parties could agree on because these ceiling prices were substantially lower than those of the FIT scheme, which stalled the start of commercial operation.

Institutional coordination and capacity building

The institutional issue is raised as one of the reasons for the small share of biomass in power generation (Cuong et al., 2021). One area that necessitates institutional coordination is data development. Presently, no authority in the local government oversees data collection on bioenergy consumption and usage. The central and local governments could cooperate in developing systematic data collection and related capacity building because local data and information are indispensable for assessing the potential of biomass resources, bioenergy demand, and the feasibility of bioenergy projects.

Moreover, policy coordination between the central and local governments is fundamental for promoting bioenergy nationwide. Investors, as well as the public, would be confused if the central government and local authorities took different policy stances. An institution that is designated to coordinate and harmonise bioenergy policy measures of different government bodies will be necessary to propel bioenergy project development.

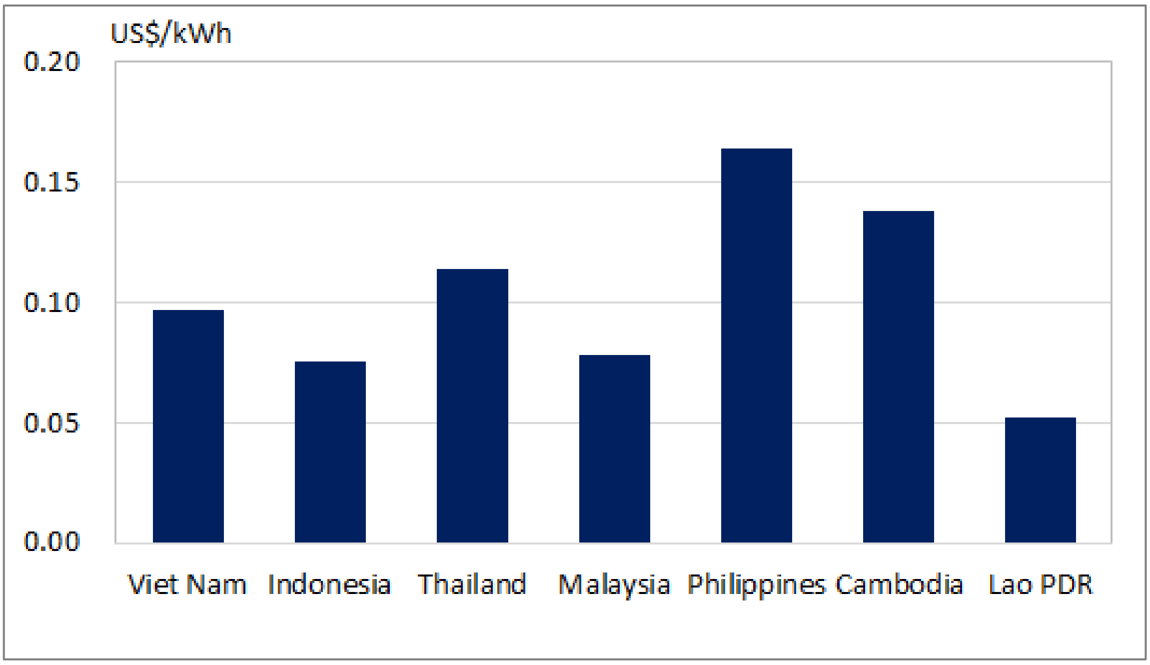
5.3.3. Addressing market and investment barriers

Financial constraints

One of the biggest barriers to bioenergy projects, probably to renewable energy projects overall, is the difficulty of making them economically plausible, given the current circumstances. The commercial feasibility of bioenergy projects is not certain due to economic difficulty. The electricity price is an important factor that affects the economics of power development projects, but it is relatively lower in Viet Nam compared with other countries in Southeast Asia, as indicated in Figure 5.12.[29]

[29] On 8 November 2023, the MOIT issued Decision No. 2941/QD-BCT on regulating electricity selling prices. Accordingly, EVN's current average retail electricity price is D2,006.79 (US$0.08)/kWh (excluding value-added tax).

Figure 5.12. Average Electricity Price in Southeast Asian Countries, 2022



Source: Compiled by the IEEJ based on data from BloombergNEF (n.d.).

On the other hand, EVN is facing financial difficulty, influenced by the recently surging fossil fuel prices.[30] EVN has struggled to recover from the financial losses because the selling price is lower than the group's cost, even though the electricity prices were raised twice in 2023 (EVN, 2024).[31] EVN's financial predicament is likely to limit the company's ability to invest in infrastructure that helps renewable energy development, a possible factor of uncertainty in the electricity market.

Even with the financial support of the FIT scheme, the economic feasibility is not favourable to bioenergy projects in Viet Nam. The unattractive FIT level explains why many sugar factories are not interested in investing in the biomass-based CHP system. Out of 39 sugar plants, only 10 factories with the CHP system supply surplus power to the grid, as mentioned earlier. The sugar factories may not be able to maintain the CHP system if they are not eligible for the FIT scheme.

In the case of the erex biomass power projects in Viet Nam, in addition to the FIT scheme, Japan's financial support programme assists the company's bioenergy

[30] EVN wholly owns the National Power Transmission Corporation and the five distribution companies, namely Northern Power Corporation (EVNNPC), Central Power Corporation (EVNCPC), Southern Power Corporation (EVNSPC), Hanoi Power Corporation (EVNHANOI), and Ho Chi Minh City Power Corporation (EVNHCMC). EVN also manages three power generation corporations (GENCOs 1, 2, 3) (EVN, 2023).

[31] EVN's average selling price was D1,950.32 (US$0.07)/kWh although the total average cost of electricity generation, transmission, and distribution was D2092.78 (US$0.08)/kWh.

business. The Japanese government selected the company's three projects (20 MW Hau Giang Biomass Power Plant, 50MW Yen Bai 1 Biomass Power Plant, and 50MW Tuyen Quang Biomass Power Plant) to be entitled to the Financing Programme for Joint Crediting Mechanism (JCM) Model Projects, which provided funding for up to half of the initial investment costs.[32] Similar international financial support programmes can help realise bioenergy projects in Viet Nam.

Regarding biofuels, similarly, the economic difficulty is the main reason for the suspended operation of ethanol plants. It is difficult for bioethanol businesses to make a profit without adequate financial support for developing the necessary infrastructure and maintaining operations.

Data and information

There is a lack of data and information about bioenergy for both domestic and international investors. This is not unusual as biomass resources such as agricultural and wood residues are not traded in the market. Nevertheless, data and information are critical in assessing the feasibility of bioenergy projects. Problems are commonly observed in many developing countries in that the available bioenergy data are sometimes found to be inconsistent or insufficient, and accessible information may be outdated.

The Vietnamese market receives attention from foreign investors who expect a high potential for economic development in the country. However, with limited data and information, investors encounter difficulties in making decisions unless they have support in understanding the market from domestic companies. It is even possible that information may not reflect the latest market situation by the time it becomes available in English.

Although renewable energy technology is commercially available, information about it remains limited (Cuong et al., 2021). Biomass power generation, for instance, is a well-established technology, and agricultural residues can serve as efficient fuel sources with pre-treatment. However, the benefits of bioenergy technologies may not have been adequately shared within the industry, which could explain the low adoption of bioenergy technology in Viet Nam.

[32] The JCM model aims to financially support a project that will contribute to reducing GHG emissions or reductions in partner countries through leading decarbonising technologies of Japanese entities, whilst Japan will acquire a part of the JCM credits in return for the investment. Viet Nam is one of the JCM partner countries.

Certification and standards

In Viet Nam, sustainable forest management has been pursued proactively, and three forest certification schemes have been put in place. The Vietnam Forest Certification System (VFCS) was introduced under Decision No. 1288/2018/QD-TTg in 2018 and endorsed by the Program for Endorsement of Forest Certification (PEFC) in 2020 (PEFC, n.d.). When forest areas are certified as VFCS, they will be PEFC-certified at the same time. In addition, the country introduced the Forest Stewardship Council (FSC) certification, which verifies environmental responsibility, social benefits, and economic viability in forest management.

However, the certified forest areas are still limited. The VFCS/PEFC-certified forests were 172,825 ha as of May 2024, accounting for only 1.2% of the total forest area (Vietnam Forest Certification Office, n.d.). The availability of FSC-certified wood products has not met the increasing demand from abroad, either (To and Cao, 2021). The FSC-certified forests covered slightly over 220,000 ha by 2021, which is a small share of the 7.9 million ha of productive forests (IRENA, 2022b; FAO 2020a). It may be demanding for small growers to obtain certifications that are costly and require complex processes (IRENA, 2022b).

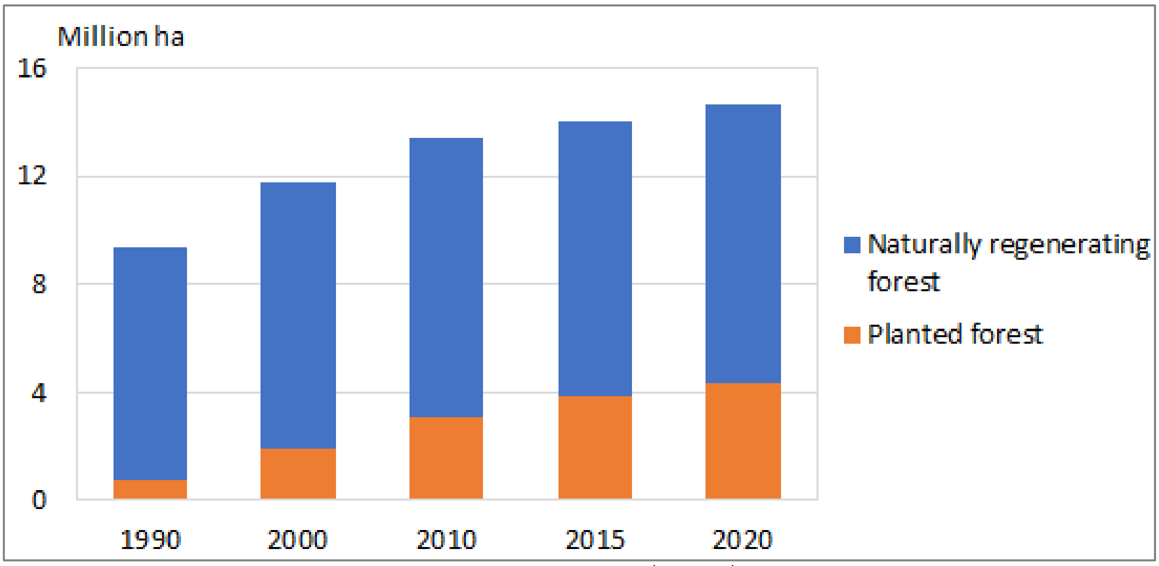
The wood pellet industry export structure makes it difficult to trace whether exported wood pellets are certified. In Viet Nam, a small number of companies export large volumes. Specifically, the total exported volume of six companies, each of which exported more than 100,000 tonnes, accounted for 67.6% of the country's total exports in 2020 (To and Cao, 2021). If a large-scale supplier exported wood pellets jointly with those provided by a small-sized company, it would become more difficult to fully confirm traceability.

In principle, the wood industry must ensure that the wood pellets are sustainably and legally processed. Sustainable forest management and quality control are important for investor confidence. For instance, Vietnamese wood pellet exports to Japan have increased, and this trend is likely to continue because, in Japan, to benefit from the FIT scheme, the imported fuel inputs must be sustainably and legally certified. For this reason, Vietnamese wood pellets with the FSC certificate will meet the conditions that Japan's power generators need. Official certification schemes are crucial to enhance the credibility of the market.

Sustainability criteria

Viet Nam has committed to sustainable forest management and protection. In 'The Sustainable Forestry Development Program for the Period of 2021–2025' (Decision No.809/QD-TTg), Viet Nam aims to maintain a national forest coverage rate of about 42%. The forest area expanded to 14.6 million ha in 2020, an increase of 5.3 million ha from the 1990 level, and both naturally regenerating forests and planted forests have steadily increased for the last three decades, as shown in Figure 5.13. Viet Nam was ranked fifth in the world in the average annual net gain in forest area between 2010 and 2020 (FAO, 2020b). Accordingly, the country's sustainable forest management will help prove that woody biomass projects are environmentally acceptable.

Figure 5.13. Changes in Forested Areas in Viet Nam



Source: Compiled by the IEEJ based on data from FAO (2020a).

5.4. Recommendations for the development of the bioenergy supply chain

It is rational for Viet Nam to work on bioenergy development. First, there are abundant untapped biomass resources that could become value-added materials. Second, the country must carry out the PDP8 to support economic growth whilst pursuing carbon neutrality by 2050. Third, the industry and consumers need energy at affordable prices. Fourth, foreign investors are interested in investing in the country's energy market, which is expected to grow. Nevertheless, bioenergy has not been utilised as much as expected. The following are suggestions for the development of the bioenergy supply chain.

Clear and consistent policy implementation

Clarity and consistency in policy implementation are the foundation for a sound investment environment. A stable long-term policy perspective is critical in investment decisions for power development projects as these projects involve high initial capital expenditures and plan for a long investment recovery time. The latent uncertainty in policy implementation could affect the project management and revenue streams, which can be an investment risk.

To overcome this barrier, policies and regulations should not be put in place in a scattered manner. As described earlier, there was an unclear period in the policy direction for solar PV and wind power projects that were not eligible to benefit from the FIT scheme. In the case of the PDP8, the announcement was delayed two years. The relevant policies or regulations need to be prepared promptly and appropriately so that investors can have foreseeability in business. Investors do not take risks by proceeding without reliable information about what comes next.

In the PDP8 implementation plan, the MOIT is expected to prepare new regulations by 2025 that will include the new tariff framework for power generation by source, the direct power purchase agreement, and the carbon credit market mechanism. The policy delivery as planned is a signal to the market, supporting reliable investment conditions.

Furthermore, it is about time to update and revise the 2015 Renewable Energy Development Strategy and the 2012 Biofuel Roadmap. They may be too old to reflect the current market, or the milestones may be no longer appropriate. Although the Power Development Plan is revised periodically, it does not specifically cover energy use for heat and transportation. Therefore, the policy direction related to bioenergy for heat use in the industry sector and biofuels in the transport sector needs to be addressed to provide perspectives that demonstrate the pathway towards decarbonisation.

Financial market development

The financial market needs to be developed in compliance with international standards. Although the country has transitioned to become a middle-income country, this classification reduces the availability of highly concessional financing (Gerner et al., 2018). Meanwhile, the current financial measures for renewable energy projects are not attractive enough for investors. Against this backdrop, developing bankable conditions is vital for the country to mobilise public and private funds.

In the PDP8, total investment is estimated to amount to US$134.7 billion, comprised of US$119.8 billion for power development and US$15.0 billion for grid development. As the National Assembly has set a public debt ceiling of 60%, the government intends to rely on capital sources other than public investment for the costs of power sector development (Thu, 2023). This raises the question of how Viet Nam will draw capital investment from commercial financial institutions and private companies as well as multilateral or bilateral development and financial agencies.

One of the challenges is to set up a robust and standardised framework for the PPA. The problems identified by the investors in the proposed PPA model need to be fixed to attract investment. Investors have difficulty in reaching an agreement on risk allocation (Gerner et al., 2018), and foreign investors are concerned about foreign exchange restrictions. The tariff is paid in the local currency, the Vietnamese dong, whilst being indexed to the US dollar, but no regulations are stipulated to allow electricity price adjustments for alleviating the impacts of the foreign exchange rate fluctuations, and there are no guarantees about the convertibility of profits earned to US dollars (Gerner et al., 2018) (Nguyen, 2023). It is also necessary to develop clear-cut regulations that deal with cases such as the curtailment of renewable power generation and termination of the PPA.

In Viet Nam, international capital will be a useful financial means because the domestic financial market has not yet developed to offer a long-term programme for bioenergy projects despite progress in recent years. The Vietnamese financial market is small in scale, and the capital market is in a growing stage (Gerner et al., 2018). Commercial banks, the largest players in the Vietnamese domestic debt market, lack long-term deposits, indicating constraints in offering long-term finance. This is problematic for renewable energy projects as they are generally medium- or long-term projects involving infrastructure development in some cases, from which the cash flow does not match with the short-term finance.

At present, local banks do not have sufficient expertise to assess renewable energy projects adequately, which affects the perceived risks. It is almost impossible to arrange a finance scheme solely relying on the domestic financial market. Therefore, bankable conditions need to be improved so that renewable energy projects can receive finance from international investors or institutions. Access to international financial resources with reasonable loan terms will be key to the success of bioenergy project management.

Involvement of the local government and community

The involvement of the local government and community is indispensable to bioenergy supply chain development as their local knowledge and networks can be useful. The local government plays an important role, firstly, in the process of project registration and permission and, secondly, in social and economic planning, which includes land use, afforestation, and industry development. The local government could help bioenergy projects secure feedstock, such as agricultural or wood residues, through the planning of cultivated areas of possible agricultural products and afforestation and give guidance on how they can be transported and stored efficiently.

In particular, the local government will be critical in data collection on biomass resource production and consumption. Reliable data are fundamental to improving investors' confidence. Getting the local government involved in biomass data collection and bioenergy project planning can be a bridge between investors and the local economy.

Similarly, it is essential to facilitate the participation of the local community, especially farmers, in the development of the bioenergy supply chain. An enabling framework in which farmers are willing to cooperate will lead to the efficient collection and transportation of agricultural residues, and, probably, farmers' associations may be realistic candidates for frameworks that encourage farmers' participation in bioenergy projects. A study conducted by Minas et al. (2020) found an important role of farmers' associations in rice straw management in that they provide farmers with agricultural inputs such as seeds and fertilisers, handle rice and straw trading to ensure better prices for the farmers and assist them in accessing support and other resources from the government. Bioenergy supply chain development could be facilitated with the cooperation of farmers' associations as stakeholders, such as by using rice straw and husk as feedstock.

The private sector is also a key partner for the local economy. Private investment will help scale up the production capacity of agricultural products and enhance the development of fundamental infrastructure for the collection and transport of biomass resources, leading to improvements in productivity. The private sector's commitment will foster the support of the local community for bioenergy supply chain development.

Responding to the momentum of global decarbonisation efforts, in Viet Nam, the government takes a positive stance towards the development and deployment of renewable energy and advanced technologies like hydrogen and ammonia co-firing with fossil fuels for power generation. The pursuit of new technologies is critical and needs to be taken into consideration in the long term, but it is not yet certain whether the country will be ready to adopt them to replace fossil fuels by 2030. Focus should be placed on bioenergy, and it should be kept on the table as an effective means for reducing carbon emissions because it is a technology that is already commercially available at lower costs. Viet Nam should reconsider the possibilities of bioenergy and the socio-economic benefits that can contribute to sustainable development.

Chapter 6
Conclusion and Recommendations

6.1. Country-specific Conclusions and Recommendations

Indonesia

As discussed in Chapter 3 in detail, the key findings for Indonesia can be summarised as follows. In terms of the potential supply and demand gap in 2030, in most provinces in the country, potential biomass resources are predicted to be in surplus of the biomass supply required for co-firing at on-grid coal-fired plants in 2030. However, in the provinces with high electric power demand, where pulverised coal-fired (PC) boilers are the main power source, the potential sawdust supply is unlikely to sufficiently cover the co-firing needs in 2030. In other provinces largely employing stoker and circulating fluidised bed (CFB) boilers, the potential of palm kernel shell (PKS) supply could theoretically meet the co-firing demand in 2030. This implies that to meet demand, the supply of PKS needs to be increased substantially by 2030.

The bulkiness of biomass feedstock, such as sawdust and rice husks, is a major challenge for storage and transportation. There is enough PKS supply to cover the current volume for exports, without considering on-site consumption, but it will not be enough to cover the significant increases by 2030. In addition, it was also revealed that biomass demand for co-firing in industrial off-grid coal-fired boilers is difficult to identify but will require large amounts of biomass feedstock.

Addressing these challenges, it is recommended that the pelletisation of biomass feedstock near production areas could be a plausible solution for the transport and storage issues associated with bioenergy. Pelletisation would also be beneficial for shipping biomass feedstock within the country given the fact that Indonesia consists of a large number of islands. Interprovincial trade of biomass feedstock could be a solution for large-scale PC boilers located in the demand centres.

Finally, two different types of business models for co-firing in coal power plants are recommended to develop the bioenergy supply chain in Indonesia. The first model would be that PT PLN Energi Primer Indonesia (PLN EPI) manufactures pellets from local agricultural residue or industrial wood waste and sells part of the products to exporters at a higher price, allowing full utilisation of the margin to subsidise domestic biomass procurement and retrofit mills for higher co-firing rates.

The other recommended business model would centre on exporters of biomass feedstock by incentivising their investment in feedstock production. In this model, a manufacturer exporting pellets produces them from local agricultural residue or industrial wood waste collected by local farmers with relatively higher exported price to other Asian countries such as Japan and Korea. This would enable the exporting producers to sell part of the products to local power plants at a discounted price. Both models emphasise the role of the exporter in compensating for the higher cost of development of the bioenergy supply chain with a higher price for the importing countries, allowing maximum utilisation of the supply chain for domestic supply in parallel with the exporting supply. They would also require streamlining of the trackable collection and distribution systems of biomass feedstock.

Thailand

Described in Chapter 4 in length, the main findings for Thailand can be summarised as follows. The biomass potential in Thailand is found to be substantial at around 69.92 Mtoe/year. Five main biomass resources – sugarcane, rice, cassava, oil palm, and para wood – largely dominate total consumption, accounting for nearly 95%. Out of 69.92 Mtoe/year of the potential resource, nearly 40% has already been utilised. Biomass power plants, heat usage in manufacturing, and biofuels are the three key pillars of bioenergy usage in the country, but each of them has a different status. Biomass power plants are nearly saturating, biomass heat usage is least developed, and biofuels are characterised by an uncertain future.

Whilst Thailand has made commendable progress in its biomass development efforts, there is a significant gap between the current status and the ambitious targets set for 2037, implying a huge supply-demand gap in the 2030s. The supply deficit against demand is 37% for biomass power plants, 51% for biofuels, and 76% for biomass heat.

The development of the bioenergy supply chain faces a range of barriers in technical, policy, and market aspects. Notably, biomass power plants face instability and complexity of the supply chain, including fuel cost competitiveness, regulatory hurdles, environmental concerns, and public engagement issues. Biomass power plants also encounter gradual energy shifting towards solar PV and wind from bioenergy due to heavy cost competition between them.

Similarly, biomass heat usage faces diverse biomass sources with a complex supply chain and lack of broader quality standards, limited availability of efficient pelletisation technologies, limited market demand and unknown consumer willingness, uneven distribution of biomass resources across regions, financial obstacles such as limited in finance accessibility, and challenges in biomass usage monitoring, especially in industries.

Likewise, biofuels are challenged by the uncertainty around the continuation of the current biofuel subsidies beyond 2026, the need for alignment with the Euro 5 fuel quality standard and balancing agricultural interests and environmental sustainability, and limited flexibility/diversity in biofuel feedstocks for the existing vehicle engines. Finally, the high initial investment costs are identified as common challenges applicable to all forms of bioenergy.

Addressing these issues, the following recommendations are presented for Thailand. For biomass power plants, strengthening supply chain management associated with the promotion of sustainable biomass cultivation, streamlining regulatory processes, mandating comprehensive environmental assessments, strengthening economic viability including the continuation of the FIT scheme, and adapting market dynamics are recommended.

For biomass heat usage in the industrial sector, the demand side challenges could be resolved by planting fast-growing trees, standardising to ensure compatibility with heating systems, and coordinating the market by creating a common platform. It is also recommended that the technical and market limitations could be removed by broadening the current TIS 2772-2560 standards with more suitable specifications like sodium (Na) and potassium (K), creating an initial market for biomass heating targeting so-called hard-to-decarbonise industries, and creating a common platform for the biomass heating market in Thailand.

For biofuels, it is recommended to develop a comprehensive post-2026 strategy for the biofuel sector, adjust blending ratios in line with the Euro 5 standards, promote agricultural innovation and alternative feedstocks, prioritise and strengthen the domestic biofuel market, prepare for coexistence with or even a transition to electric vehicles in the long term, and seek other applications beyond road transport, such as aviation/bunker fuel.

Viet Nam

As discussed in Chapter 5 extensively, the key findings for Viet Nam can be outlined as follows. Viet Nam has a large amount of biomass resources across the nation that can be utilised for bioenergy. Whilst substantial potential is found particularly for agricultural and woody residues, use for bioenergy is still limited compared to such large potential. Bagasse is and will be the main fuel for the CHP system, yet additional biomass fuels will be needed to meet the targeted power generation capacity by 2030. Rice husk, rice straw, and woody biomass can be possible inputs for heat and power. Cassava is used for ethanol production. Bioethanol consumption has not increased much due to a lack of incentives for both producers and consumers.

The supply chains of the bagasse-fired CHP system and wood pellets for export have been well established. In contrast, for rice husk/straw and woody biomass, the supply chain is still underdeveloped and can be increasingly utilised for energy in the future.

It is challenging to collect and transport agricultural and woody residues that are scattered and then store them efficiently. The current governmental support measures seem insufficient to attract active investment in bioenergy projects for power, heat, and transport fuels. Significant uncertainties are observed in the policy implementation, leading to an investment risk. It is highlighted that it is difficult for bioenergy projects to attain commercial feasibility without financial support from the government.

The following are recommended countermeasures to these challenges. First, appropriate policies with underpinning regulatory frameworks promoting bioenergy should be implemented in a way that the investors can have predictability in the market. Although this has been repeatedly pointed out in the past literature, it has to be stressed again particularly for Viet Nam. Bankable conditions also need to be developed in compliance with international sustainable standards. The country needs international capital for long-term energy projects, including bioenergy development. Moreover, the local government and community should be encouraged to be involved in the bioenergy supply chain development so that bioenergy projects can be beneficial for the local economy.

6.2. Cross-country Common Issues and Recommendations

The discussions and analyses in this report have been conducted on a country-specific basis up to this point. The key findings from Indonesia, Thailand, and Viet Nam vary substantially, reflecting the countries' specific circumstances on energy and biomass resources. However, several key elements are common across the three countries. Accordingly, this final section considers such cross-country common issues derived from the country-specific analyses, as listed below.

- Abundant bioenergy supply potential compared to the current expectation of bioenergy demand in 2030.[33]
- Huge supply-demand gaps with a supply shortage in 2030 are identified, requiring large amounts of biomass feedstock.
- Higher cost of bioenergy and low competitiveness against not only conventional fossil fuel but also solar PV and wind for power generation.
- Lack of robust, solid, or specific policy and regulatory frameworks to develop the bioenergy supply chain.
- Absence of powerful incentive to invest and develop the bioenergy supply chain, leading to financial instability.

[33] 2037 for Thailand instead of 2030.

- Need for the adoption of international sustainable and quality standards for bioenergy.
- Weak cooperation and involvement of local communities and farmers in bioenergy supply chain development with economic and social benefits, particularly the collection and storage processes of biomass feedstock.

Recognising these commonly perceived issues across the three countries, a fundamental question arises: What are the appropriate policies, regulations, markets, technologies, and business models for building bioenergy supply chains? The subsequent sections provide some recommendations to answer this simple but important question through several aspects related to bioenergy.

Firstly, for the policy and regulation aspects, there is no doubt that unless adequate policy support and underpinning of a regulatory framework are in place, the bioenergy supply chain will never be created. Such a statement is nothing new and has been repeatedly noted in the past literature in various ways. Nevertheless, it is still worth recalling here once again since it is essential for the effective utilisation of the abundant biomass feedstock commonly found in the countries. A wide range of policy measures are available and have been adopted globally, including robust and strong, well-defined bioenergy target-setting, mandates for bioenergy use, biofuel standards, feed-in tariffs, Renewable Portfolio Standards, renewable energy auctions, tax incentives, subsidies, carbon credits, green bonds, and others. However, whatever the choice of the policy measure, the experience of Thailand's biomass power plant policy, as discussed in Chapter 4, proves how the role of the government with determined political will is vital for establishing a robust bioenergy supply chain.

The adoption and development of sustainable/quality standards certification schemes for the domestic bioenergy market in Southeast Asian countries are also consistently emphasised to promote the development of the bioenergy supply chain. Whilst most of the existing sustainable standards applied in the region are mainly for international trade, consideration may be needed for the establishment of standards for locally produced bioenergy reflecting local environmental circumstances and the increasing reliability and credibility of bioenergy in the countries (IRENA, 2022a). This can be discussed as a part of a whole package of policy support and regulatory frameworks for bioenergy development.

Looking at the market aspect, the involvement of the local community for realising the economic and social benefits from bioenergy projects is also repeatedly noted. This was pointed out to 'increase effectiveness and efficiency in the utilisation and production of biomass energy in rural communities' in the 'ASEAN Strategy on Sustainable Biomass Energy for Agriculture Communities and Rural Development in 2020-2030' (ASEAN, 2021) as part of Strategic Thrust 2, which presents several precise action plans that should be implemented, particularly stressing technology transfer. In addition, the formation of sales cooperatives and/or farmer cooperatives organised by local communities and farmers is recommended to collect, store, and deliver biomass feedstock to bioenergy producers. This allows the appropriate management of long-term biomass feedstock supply, minimising the adverse impacts of seasonal fluctuations. In this case, it is crucial to communicate with local communities and increase public awareness of the potential economic and social benefits of bioenergy-related activities.

The importance of streamlined and trackable collection, distribution, and storage systems for the biomass feedstock used for bioenergy is also highlighted as a common issue. To address this, the institutional arrangement of a public agency to collect and distribute the bioenergy feedstock, particularly agriculture residuals, is recommended (IRENA, 2023).

In terms of the business model aspects, the findings of Indonesia, Thailand, and Viet Nam generally suggest a 'two-step approach' to create a bioenergy supply chain. In this approach, the bioenergy supply chain is initially formed mainly for export, as is currently the case in the countries, particularly for wood pellets and KPS. In the second step, the focus gradually shifts to domestic bioenergy use with scaling up. This approach allows the counties to take advantage of creating a bioenergy supply chain, with importing countries bearing part of the costs involved since the export prices for bioenergy are generally much higher than the domestic prices. For instance, a large number of the biomass power plants, currently around 7.5 GW, operating under the feed-in tariff scheme in Japan are likely to continue purchasing the imported bioenergy at a higher price at least until 2032 or towards the end of the 2030s. The exporting countries could fully utilise this period to develop their bioenergy supply chains in preparation for shifting to the domestic bioenergy market in the near future.

The higher cost of bioenergy supply is also commonly observed as a key financial barrier across the countries. To overcome this barrier, the use of carbon crediting mechanisms, under UNFCCC Article 6 of the Paris Agreement, could be a recommended solution for bioenergy projects. As mentioned in Chapter 5 for Viet Nam, the Joint Crediting Mechanism led by the Japanese government could be one of such mechanism for bioenergy projects. As an example, for Indonesia, the methodology numbered ID_AM027 for the quantification of GHG emissions reductions applicable to biomass power plant projects, more precisely the displacement of grid electricity and/or captive electricity by biomass power plants occurring in Indonesia, has been approved and is ready for registration for actual projects.

Similarly, for Viet Nam, the methodology numbered VN_AM004 has been approved for biogas projects avoiding methane emissions from organic waste and supplying biogas to final users to displace fossil fuel use.

Finally, from a technology viewpoint, the pelletisation of biomass feedstock is also constantly identified as a key technology to solve the transport and storage issues related to the bioenergy supply chain across the countries, suggesting pelletisation should be focused on with sufficient policy support. In addition, compatibility technologies for bioenergy with existing infrastructures, namely higher shares of bioenergy for co-firing in coal power stations and 'drop-in' biofuels for existing internal combustion engine vehicles, are also found to be key technologies. Policy support from the government for these technologies is essential to develop the bioenergy supply chain.

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