調査報告書

ASEAN 地域 における非可食バイオマス資源の利用可能性調査

Study on the Availability of Non-edible Biomass Resources in ASEAN

NRI Consulting & Solutions (Thailand) Co., Ltd.
Consulting Division

2025/1/31

Envision the value,
Empower the change

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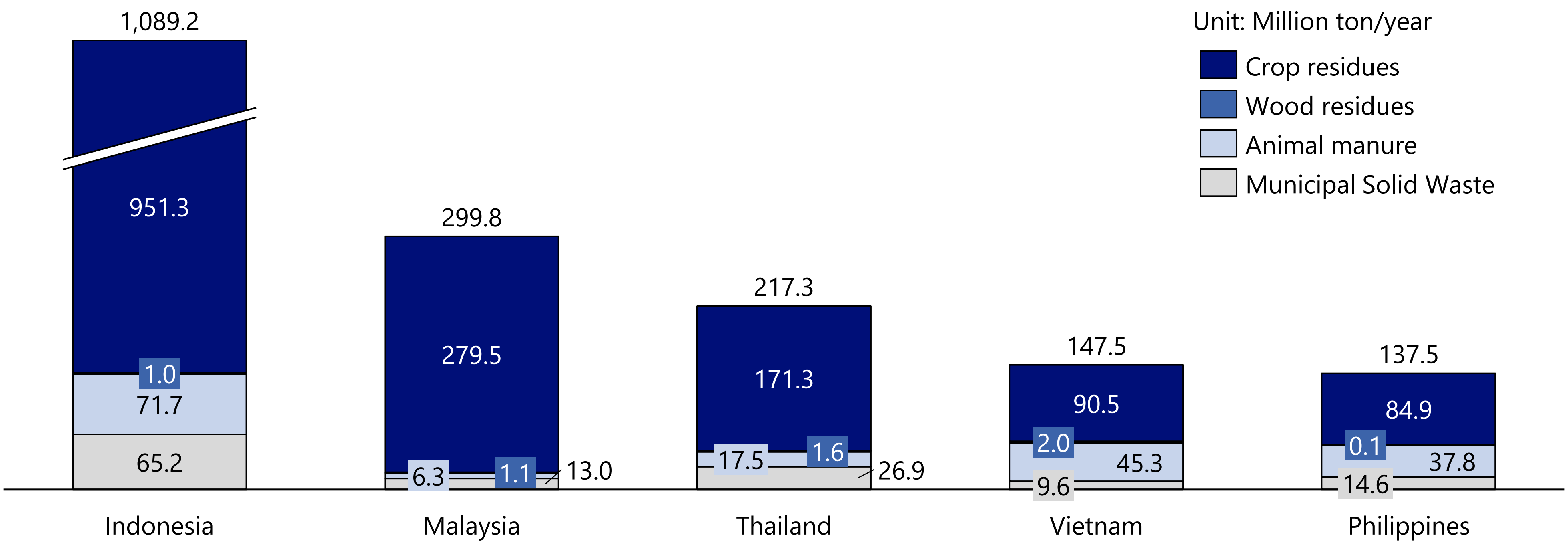
When observing the supply capacity of raw materials, crop residues have the highest potential within the raw materials for biomass

Supply Potential of Raw Materials for Biomass in ASEAN Countries



Notes:

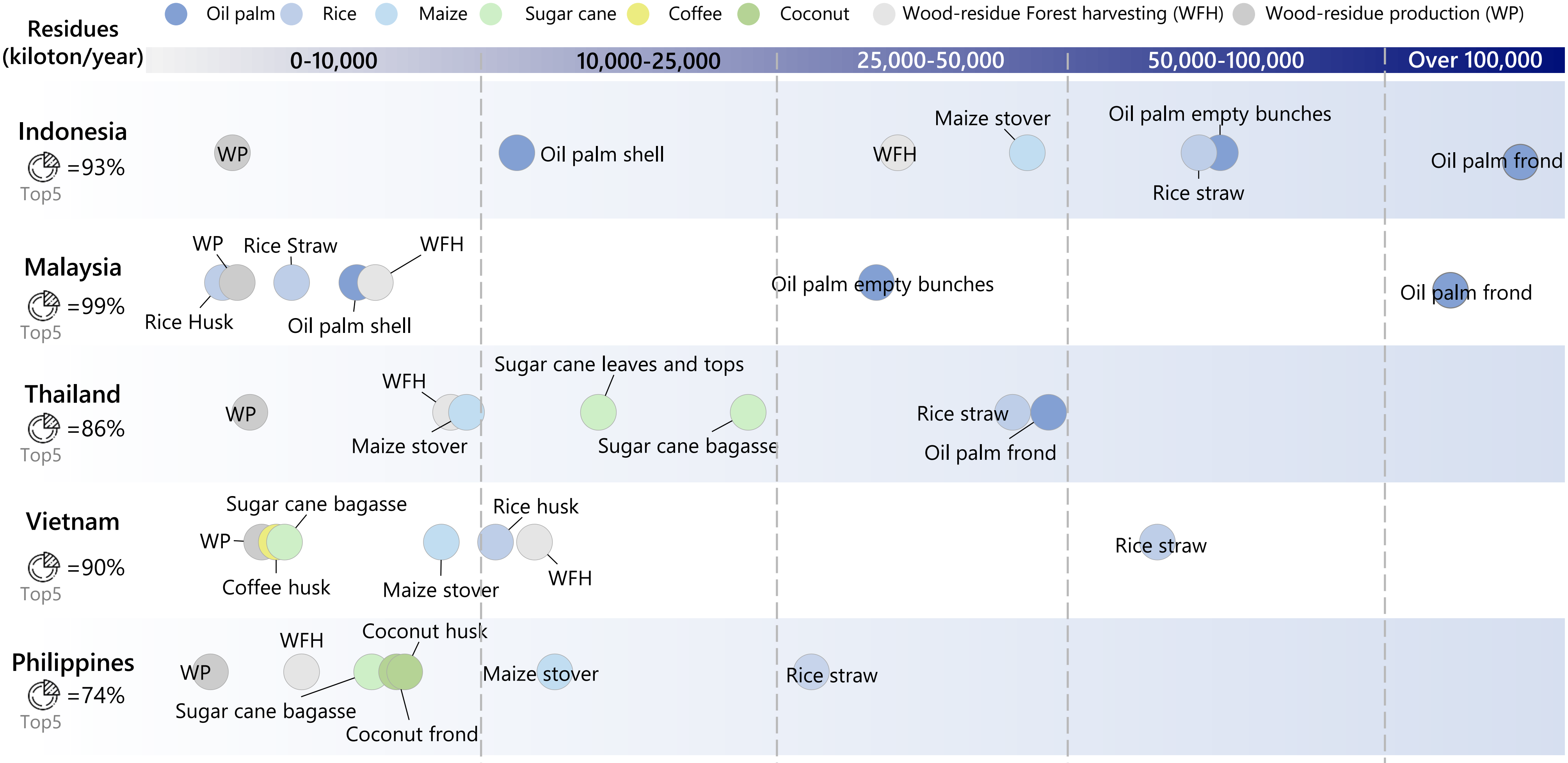
- The data of crop residues of year 2022 is obtained from Food and Agricultural Organization of the United Nations.
- The data of wood residues of year 2021 is obtained from Food and Agricultural Organization of the United Nations. It includes sawdust and slabs & chips from sawmill
- The data of animal manure of year 2021 is obtained from World Bank, What a waste global database. It includes urine and faeces of dairy cow, buffalo, swine and chicken
- The data of municipal solid waste is obtained from World Bank, What a waste global database. The year of data in each country is different as followed. Data in 2016 for Indonesia, 2014 for Malaysia, 2015 for Thailand, 2010 for Vietnam and 2016 for Philippines.

Source: Food and Agricultural Organization, World Bank-What a waste global database

Volume of Biomass Residues with High Volume in ASEAN | Crop Residue & Wood Residue

Within crop residues, oil palm, rice, maize and sugar cane are observed as a biomass residue with high volume across countries

Overview of Residues (Top 5 Crop-Residues and Wood-Residues)



Note: this chart shows the potential bioenergy availability from the top five crop residues and two types of wood residues

Source: Food and Agriculture Organization

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Promising biomass materials were selected based on residue volume, potential ease of use based on geographical location, and interest by Japanese companies

Results of Promising Biomass Material Selection for Each Country

Country	Biomass Residues					No. of residues per country
	Cassava	Maize	Palm	Bagasse	Wood	
Indonesia	Cassava pulp	Maize cob	*(Research conducted in different study*)*	Sugarcane bagasse	Woods residues	4
Malaysia			Oil palm empty bunches and shell		Woods residues	2
Thailand	Cassava pulp	Maize cob	Oil palm empty bunches and shell	Sugarcane bagasse	Woods residues	5
Vietnam	Cassava pulp				Woods residues	2
Philippines		Maize cob			Woods residues	2
No. of countries per material	3	3	2	2	5	

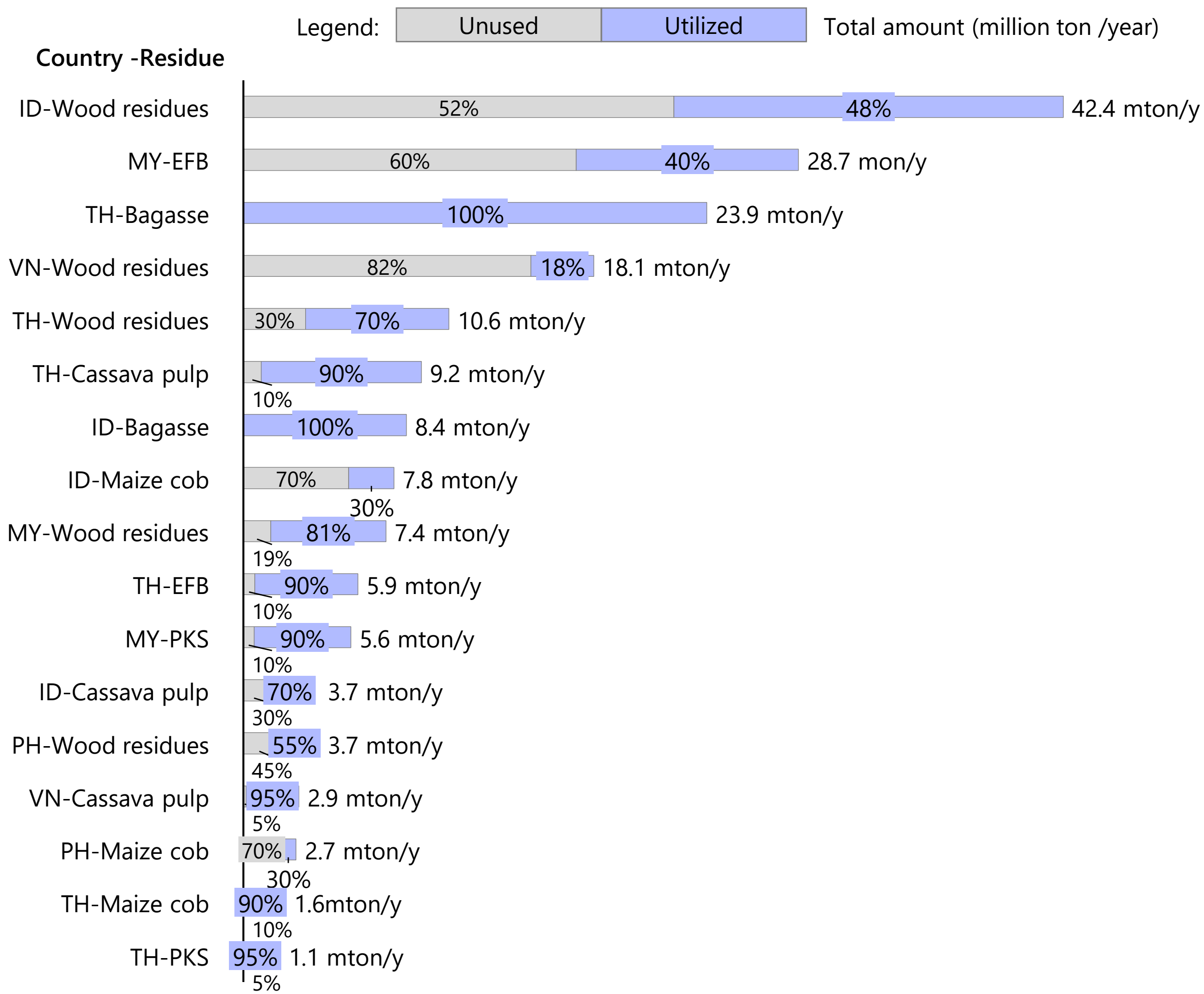
*Note: For palm in Indonesia, research was conducted in "Study on Policy Recommendation for Biofuel in Indonesia Phase 3," a project commissioned by NEDO and conducted by Deloitte, which provides research on usage of palm specifically for biofuel, such as the potential end-product, challenges for feedstock acquisition, geographical location, and supply chain map.

Source: Discussion with NEDO

Promising Biomass Materials | Summary of Estimated Utilization Proportion

Utilization rate and type of usage for each biomass residue differs across residue, in which electricity and non-energy usage are they key usage methods

Summary of Estimated Utilization Proportion and Utilization Type

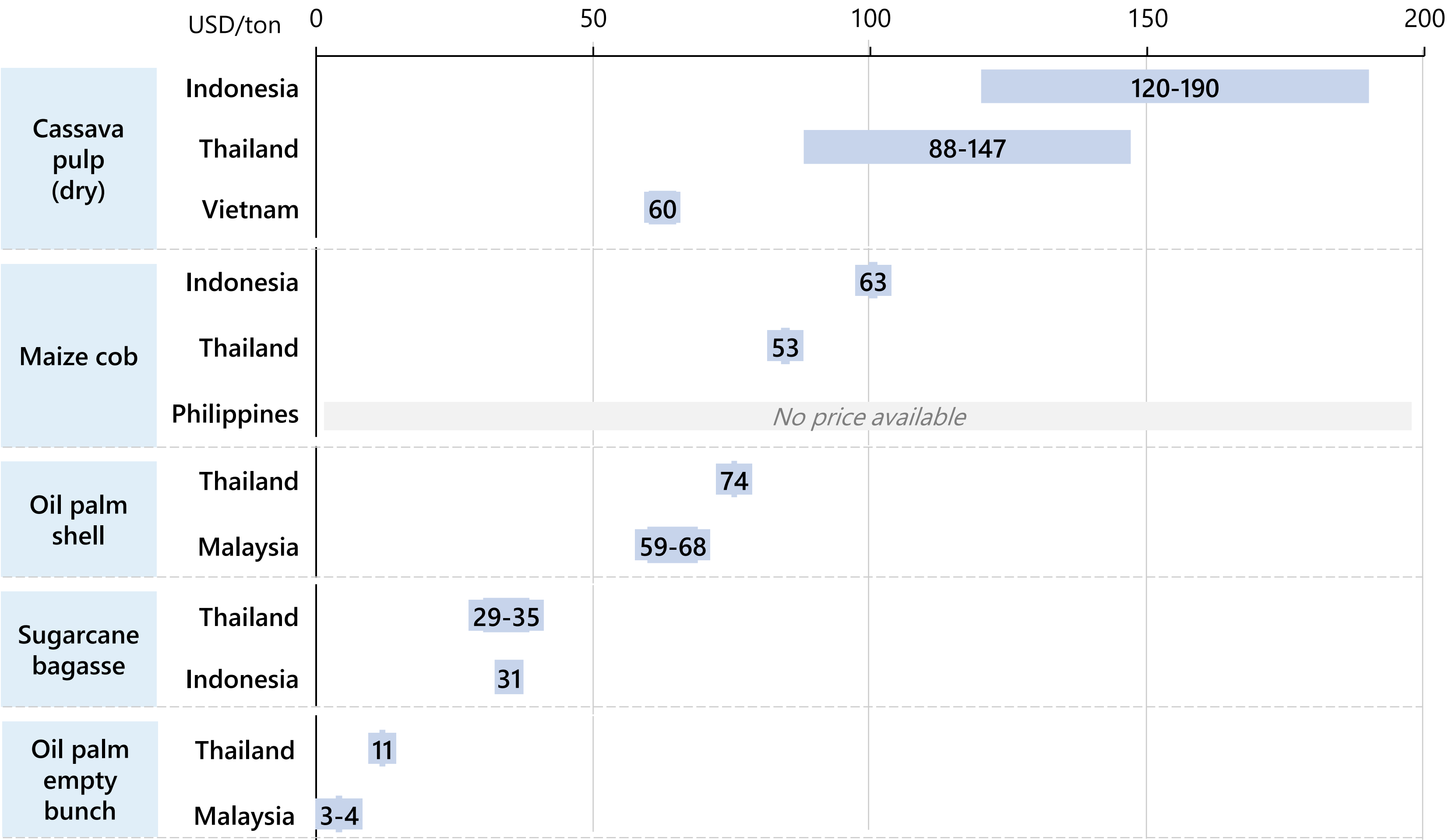


% Unused	% Utilized			
	Electricity	Transport	Heat	Others
52%	21%	0%	14%	13%
60%	20%	0%	5%	15%
0%	**90%**	0%	0%	10%
82%	0%	0%	10%	8%
30%	6.5%-7.8%	0%	7.7%-9.1%	**54%**
10%	10%	8%	15%	**57%**
0%	**80%**	0%	10%	10%
70%	20%	0%	partial	10%
19%	8%	0%	**36%**	**36%**
10%	**75%**	0%	5%	10%
10%	**80%**	0%	10%	0%
30%	10%	10%	10%	**40%**
45%	**54%**	0%	0%	0%
5%	5%	10%	20%	**60%**
70%	marginal	0%	0%	30%
10%	1%-22%	0%	23%-44%	**45%**
5%	**90%**	0%	5%	0%

Source: NRI estimation based on desktop study and interviews

Cassava pulp has the highest purchasing price whereas for sugarcane bagasse and oil palm empty bunch it is lower than the other residues

Purchasing Prices of Crop Residues



- The prices shown in this graph are the purchasing prices of agricultural residues, included transport fee
- PH-Maize cob: no price is available due to limited transactions between parties. Most maize cobs are used as fertilizer within plantations rather than being sold.

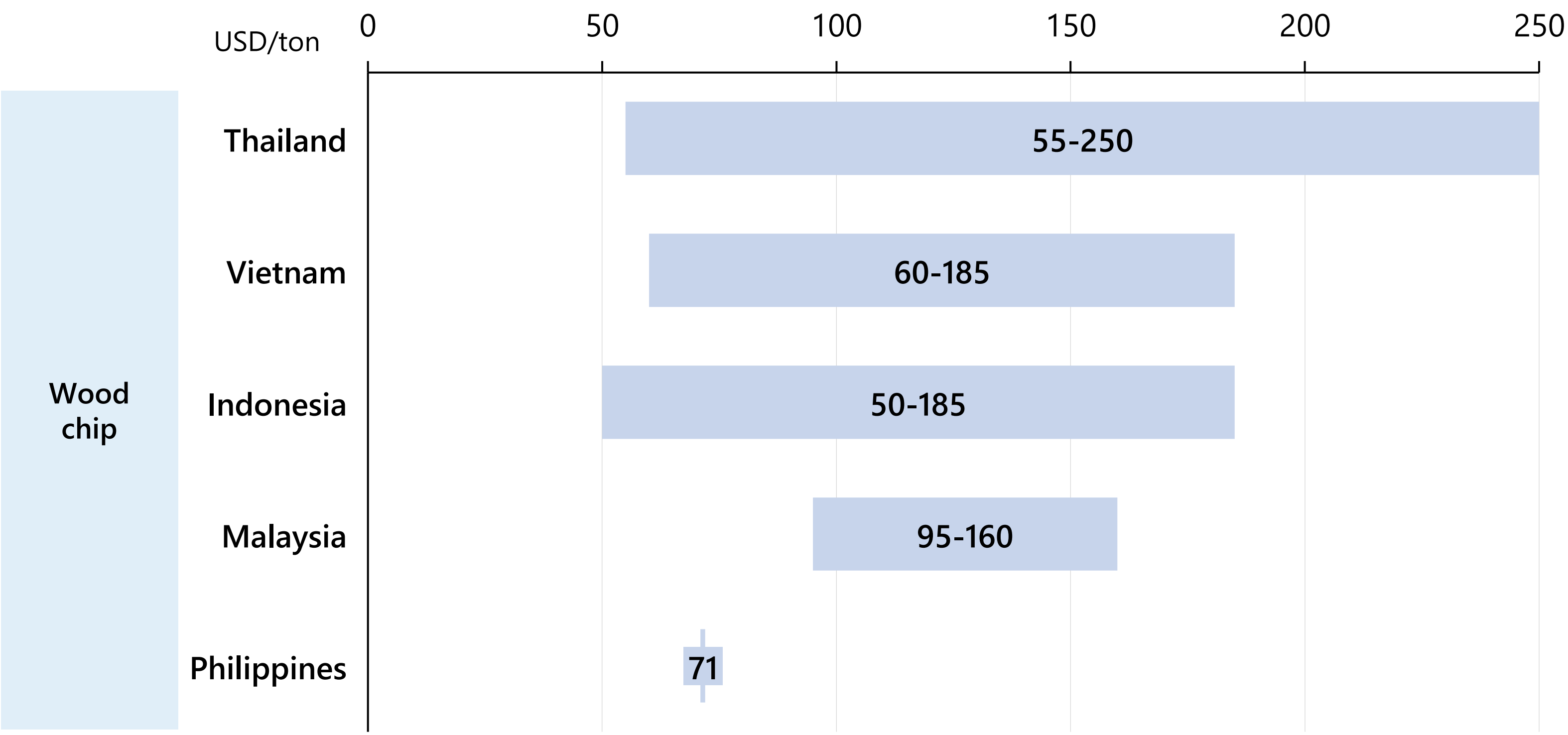
Exchange rate to 1 USD, as of 7 Nov 2024

IDR	15,565 IDR
MYR	4.40 MYR
THB	34 THB
PHP	58 PHP

Sources: Interview

Wood chips price is sold at around USD50-250, which is also a higher price range compared to sugarcane bagasse and oil palm empty bunch

Purchasing Prices of Wood Chip



- The prices shown in this graph are the general purchasing prices of wood chip, included transport fee, regardless types of tree or quality of wood chips. At some prices, the minimum order quantity is required.

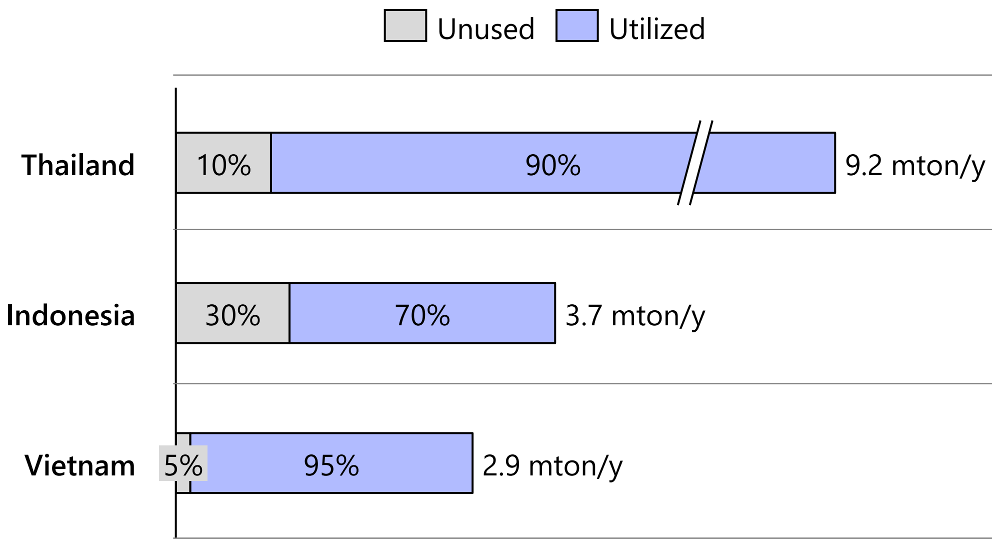
Exchange rate to 1 USD, as of 7 Nov 2024

IDR	15,565 IDR
MYR	4.40 MYR
THB	34 THB
PHP	58 PHP

Source: Interview, Tradekey, Paperindex

Thailand leads in cassava pulp utilization, while Vietnam and Indonesia have similar levels. However, limited supply in Indonesia and Vietnam could restrict large-scale investments and development

Estimated Utilization Proportion of Cassava Pulp



	% Unused & Amount	% Used & Amount	% Used & Amount by Application			
			Electricity	Transport	Heat	Others
Thailand	10% 0.9	90% 8.3	10% 0.9	8% 0.7	15% 1.4	**57%** **5.2**
Indonesia	30% 1.1	70% 2.6	10% 0.4	10% 0.4	10% 0.4	**40%** **1.5**
Vietnam	5% 0.1	95% 2.7	5% 0.1	10% 0.3	20% 0.6	**60%** **1.7**

Unit of amount is million tons/year

- In Thailand and Vietnam, cassava pulp utilization is nearly 100%, while Indonesia lags behind at around 70%.
- Thailand leads in total usage across all applications, whereas Vietnam and Indonesia show similar utilization levels. However, the limited supply in Indonesia and Vietnam constrains opportunities for large-scale investments, development, and broader application potential.

Source: NRI estimation based on desktop study and interviews

Cassava pulp is dispersed for both seasonality and geographical perspective, but has potential to be used for high-value usage such as biofuel

Supply Chain	Issues & Challenges		
Collection / Transportation/ Storage	Efficiency of processing		• Drying the cassava pulp improves the quality and allows higher selling price • However, drying in sun is manual labor and inefficient, but implementing dryers are costly
	Efficiency of transportation		• Transportation cost can be high due to the bulk and weight of the materials, as well as poor road conditions especially for rural areas
Utilization	Overall	Seasonality	• Dispersed seasonal availability of cassava pulp, leads to inconsistent supply and challenges for planning the collection and logistics
	By Type – Power Generation	Funding support	• Incentives for capital expenditure (e.g. power plant construction) and power generation (e.g. FIT) is limited
	By Type – Transpor-tation	Adoption of biofuel	• Adaption of bioethanol is still limited due to the lower efficiency compared to gasoline and biofuels not widely available at gas stations
	By Type – Others	Alternative utilization	• Lack of technology and innovation for utilization methods which may potentially have high value

Sources: Interview

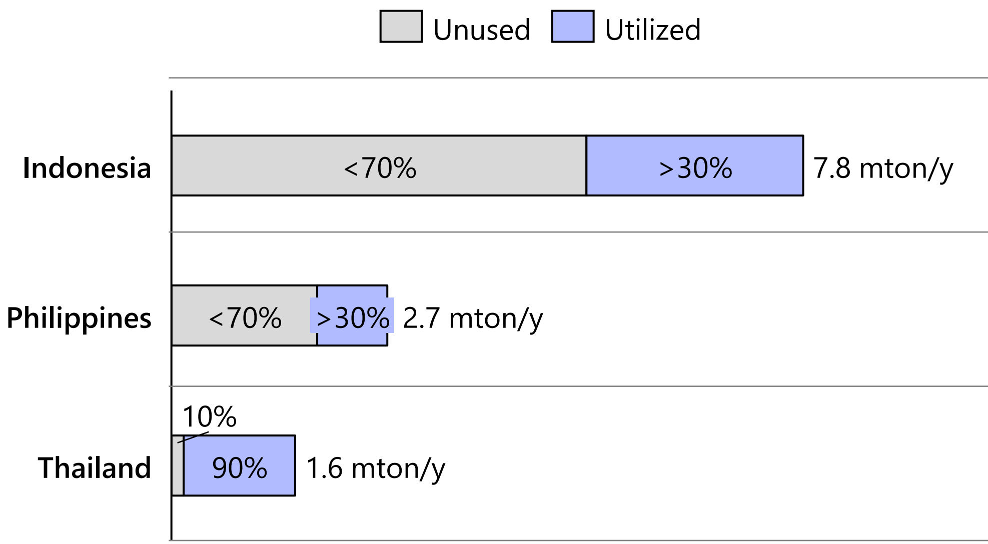
Adoption of new technology from Japanese companies can support the issues for seasonality and value-added products

Supply Chain	Issues & Challenges		Potential Solutions by Japanese Companies	
Collection / Transportation / Storage	Efficiency of pre-processing		Alternative Processing Methods	• Technology to dry the cassava pulp in a cost-efficient manner
	Efficiency of transportation		Supply chain optimization	• Supply chain optimization solutions (e.g. self-sustaining local biomass energy systems)
Utilization	Overall	Seasonality	Co-usage of other biomass	• Utilization method which other biomass material (e.g. bagasse) can be used as an alternative material during cassava's low season
	By Type: Power Generation	Funding support	Subsidies from Japanese gov.	• Pilot projects developed which includes Japanese government (e.g. METI, NEDO) subsidies
	By Type: Trans-portation	Adoption of biofuel	Next generation bio-fuel	• Technology transfer and development of factories for biofuel with high demand in future (e.g. SAF)
	By Type: Others	Alternative utilization	New technology	• Technology for application in high-value products (e.g. nano-cellulose and fiber production)

Sources: Interview, company webpage of Japanese companies

Maize cobs have minimal utilization in value-added applications due to challenges such as limited suitability as fuel, incompatible infrastructure, and high transportation costs

Estimated Utilization Proportion of Maize Cob



	% Unused & Amount	% Used & Amount	% Used & Amount by Application			
			Electricity	Transport	Heat	Others
Indonesia	**<70%**	>30%	20%	0%	Partial	10%
	<5.4	>2.3	1.6	0	Partial	0.8
Philippines	**<70%**	>30%	Partial	0%	0%	30%
	<1.9	>0.8	Partial	0	0	0.8
Thailand	10%	90%	~1%-22%	0%	~23%-44%	**45%**
	0.2	1.4	~0.02-0.36	0	~0.37-0.71	**0.7**

Unit of amount is million tons/year

- The utilized amount of maize cobs ranges from 0.8 to 2.3 million tons per year across these three countries. Indonesia and the Philippines have high unused proportions of maize cobs (70%), indicating a supply-demand imbalance, while Thailand demonstrates a more balanced situation with 90% utilization, since Thailand produce less maize cob.
- The high unused amount of maize cobs as biomass arises from several challenges. Maize cobs produce limited biogas, making them less suitable for energy production. Existing boiler technologies are not compatible with maize cob characteristics, requiring significant new investments. Furthermore, their bulkiness results in high transportation costs, further complicating utilization.

Source: NRI estimation based on desktop study and interview

Promising Biomass Material ② Maize Cob – Issues & Challenges

Efficiency of transportation is an issue for supply-side, whilst the limitations for power plant infrastructure a common issue for the demand-side

Supply Chain	Issues & Challenges			
Collection / Transp. / Storage	Efficiency of transportation			• In some countries (e.g. Thailand) the maize cob fields are mainly located in high hills. • Also, for some countries (e.g. Philippines, Indonesia) the location of corn field and biomass power plant are far, resulting in high transportation cost
Utilization	Overall		Seasonality	• Dispersed seasonal availability, which leads to inconsistent supply and challenges
	By Type	Power Generation	Funding support	• Adjusting the boiler of existing old biomass power plant to be able to handle new residues such as maize cob will cost a lot of investment, but there is limited government support
			Compatibility	• Each residue has different size, heat values, silica content and ash generated in the process etc. Therefore, the boiler can only handle residues with certain specifications
			Material procurement	• Selling price for bioenergy is not high in some countries (e.g. Indonesia) • This makes it challenging to secure the supply as farmer may choose to sell their cob for animal feed instead of for bio-energy
		Others	-	• -

Sources: Interview

 NRI

Promising Biomass Material ② Maize Cob – Potential Solutions from Japanese Companies

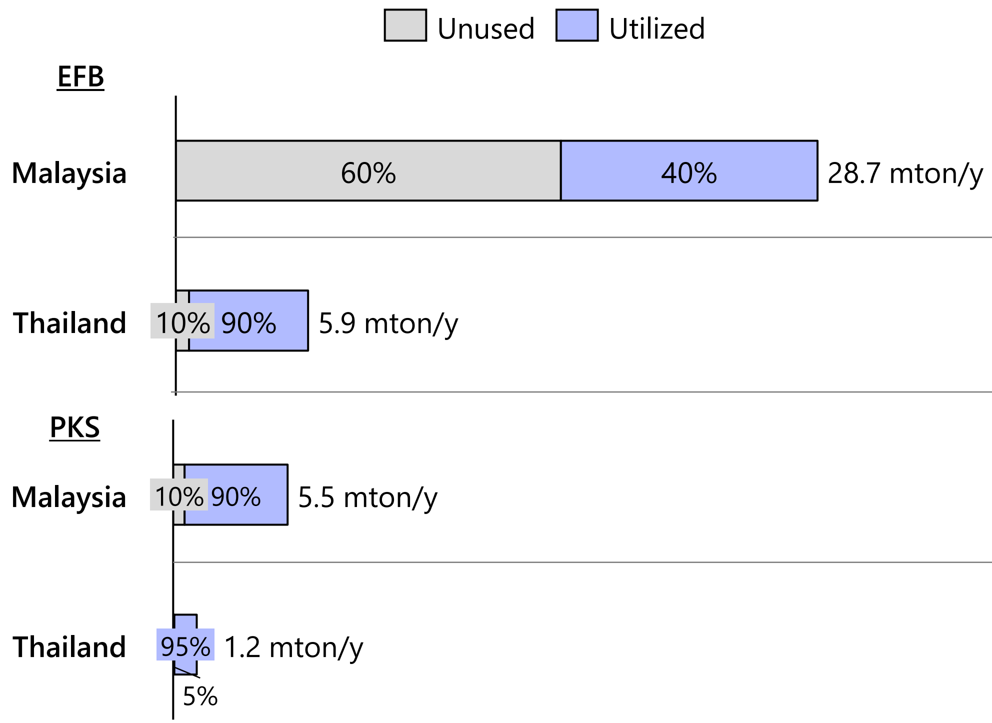
Advanced technology, equipment for material conversion, and supply chain optimization solutions can support the issues in the supply and demand

Issues & Challenges				Potential Solutions by Japanese Companies	
Collection / Transp. / Storage	Efficiency of transportation			Supply chain optimization	• Supply chain optimization solutions (e.g. self-sustaining local biomass energy systems)
				Equipment	• Equipment for easy conversion to biomass pellets, which is easier to transport at a higher price
Utilization	Overall		Seasonality	Co-usage of other biomass	• Provide new technology which various types of biomass material can be used, so that maize cob's low season will not cause issues to the supply
	By Type	Power Generation	Funding support	Subsidies from Japanese gov.	• Pilot projects developed which includes Japanese government (e.g. METI, NEDO) subsidies
			Compatibility	Flexible Boilers	• Boilers with compatibility for various types of biomass residues (e.g. CFB boilers) including both maize cobs and other residue types
			Material procurement		
		Others	-	-	• -

Sources: Interview, company webpage of Japanese companies

Despite the abundant supply of EFB in Malaysia, a portion remains unused. Enhancing technology can improve its utilization

Estimated Utilization Proportion of Oil Palm Residues



		% Unused & Amount	% Used & Amount	% Used & Amount by Application			
				Electricity	Transport	Heat	Others
EFB Malaysia	%	**60%**	40%	20%	0%	5%	15%
	Amount	**17.2**	11.5	5.7	0.0	1.4	4.3
EFB Thailand	%	10%	90%	**75%**	0%	5%	10%
	Amount	0.6	5.3	**4.4**	0.0	0.3	0.6
PKS Malaysia	%	10%	90%	**80%**	0%	10%	0%
	Amount	0.5	5.0	**4.4**	0.0	0.6	0.0
PKS Thailand	%	5%	95%	**90%**	0%	5%	0%
	Amount	0.1	1.1	**1.0**	0.0	0.1	0.0

Unit of amount is million tons/year

- Malaysia has a significantly larger supply of EFB, nearly five times more than Thailand. Despite Malaysia utilizing a greater quantity, a substantial portion remains unused. However, there are challenges in using EFB. Its bulky nature makes handling difficult and increases transportation costs. Additionally, its high moisture content requires specialized technology or machinery for pellet production, necessitating additional investment.
- Regarding PKS, the supply poses a challenge. The available volume of PKS could be insufficient if demand keeps growing in both countries.

Source: NRI estimation based on desktop study and interviews

EFB is difficult to pre-process and transport, but infrastructure in mills is not sufficient for processing and treating the EFB

Supply Chain	Issues & Challenges for EFB		
Collection / Transp. / Storage	Ease of pre-processing		• EFB need to be cut into smaller piece before utilization. Therefore, it is difficult and expensive to handle and transport
	Pellet production		• EFB high moisture content (over 50%), bulky, and also has a high content of "lignin" which can damage a normal pellet production machine (e.g. wood pellet machine). These characteristics make it challenging to process EFB into pellets efficiently.
Utilization	Power Generation	Limited infrastructure (electricity) for processing	• Many mills are located in a remote location near plantation area with limited electricity. In this case, many will have to use 100% of the electricity to produce the oil. Hence, many mills do not have enough power to process and treat EFB properly

Sources: Interview

Promising Biomass Material ③ Oil Palm Residues – Potential Solutions from Japanese Companies

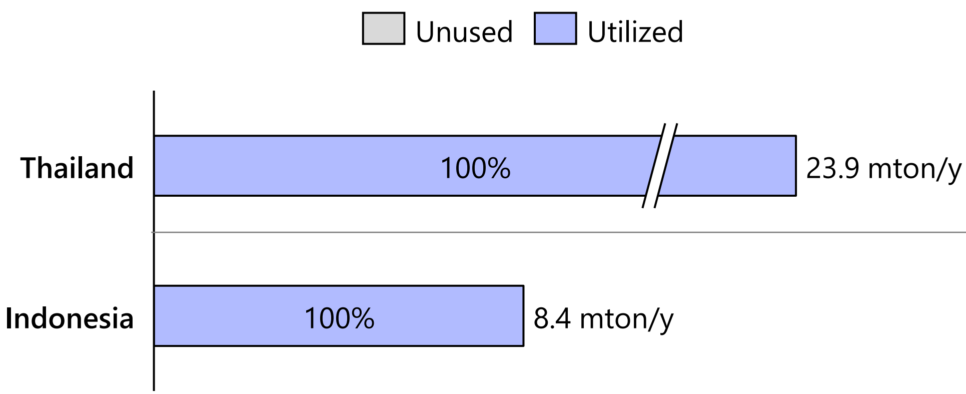
Japanese companies has equipment to support pre-processing and pellet production, and can support optimization of supply chain

Supply Chain	Issues & Challenges for EFB		Potential Solutions by Japanese Companies	
Collection / Transp. / Storage	Ease of pre-processing		Machinery for efficient pre-processing	• "Chipper machines" which can be used to cut the EFB into small pieces, which can also be used for other biomass materials as well (e.g. wood)
	Pellet production		Machinery and equipment for pellet production	• Equipment and machinery for easy conversion from biomass material to pellets
Utilization	Power Generation	Limited infrastructure (electricity) for processing	Supply chain development and optimization	• Development of processing plants to centralize and optimize the processing of EFB

Sources: Interview, company webpage of Japanese companies

Sugarcane bagasse is fully utilized in Thailand and Indonesia due to its easy collection and established technology and infrastructure

Estimated Utilization Proportion of Sugarcane Bagasse



	% Unused & Amount	% Used & Amount	% Used & Amount by Application: Electricity	Transport	Heat	Others
Thailand	0%	100%	**90%**	0%	0%	10%
	0	23.9	**21.5**	0	0	2.4
Indonesia	0%	100%	**80%**	0%	10%	10%
	0	8.4	**6.7**	0	0.8	0.8

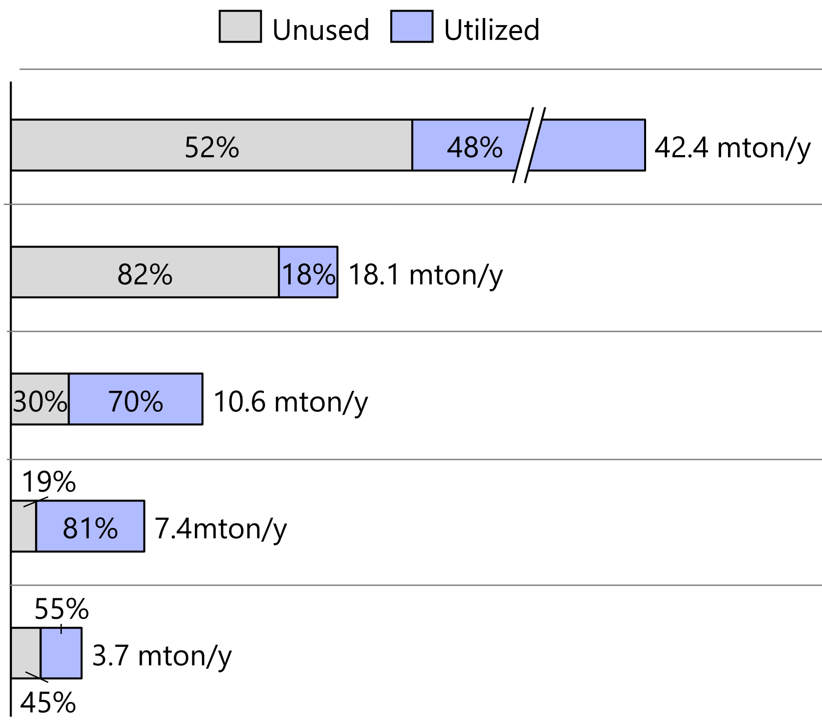
Unit of amount is million tons/year

- Sugarcane bagasse is fully utilized in Thailand and Indonesia, mainly for electricity generation, due to its on-site availability at sugar mills with no additional collection costs and well-developed technology and infrastructure. This makes it a cost-effective energy source.
- Additionally, other sugarcane residues, such as sugarcane leaves, are being considered for utilization to alleviate handling constraints and supplement the limited bagasse supply.

Source: NRI estimation based on desktop study and interview

The high utilization rates in Thailand and Malaysia are driven by the use of stumps and roots, which are typically left unused in other countries

Estimated Utilization Proportion of Wood Residues



	% Unused & Amount	% Used & Amount	% Used & Amount by Application			
			Electricity	Transport	Heat	Others
Indonesia	**52%**	48%	21%	0%	14%	13%
	22.3	20.1	8.8	0	5.7	5.6
Vietnam	**82%**	18%	0%	0%	10%	8%
	14.9	3.2	0	0	1.8	1.4
Thailand	30.2%	69.8%	~6.5%-7.8%	0%	~7.7%-9.1%	**54.3%**
	3.2	7.4	0.6-0.8	0	0.8-1.0	**5.8**
Malaysia	19%	81%	8%	0%	**36%**	**36%**
	1.4	6.0	0.6	0	**2.7**	**2.7**
Philippines	<45%	>54.0%	**>54.0%**	0%	0%	Partial
	<1.6	>2.0	**>2.0**	0	0	Partial

Unit of amount is million tons/year

- Indonesia shows the highest used amount around 20 million tons/year, followed by Thailand and Malaysia with the utilized amount around 6-8 million tone/year. Vietnam and the Philippines utilized wood resides only around 2-3 million tons/year.
- Thailand and Malaysia demonstrate higher utilization proportions, primarily driven by the use of stumps and roots. These materials are processed into woodchips for electricity generation and particleboard production, with both countries are exporters of particleboard. This application is economically viable, as the income generated outweighs the processing costs, making it a valuable investment.

Source: NRI estimation based on desktop study and interview

Promising Biomass Material ⑤ Wood Residues – Issues & Challenges

Technology for waste management and utilization enhancement is required, while financial support from the local government is limited

Supply Chain	Issues & Challenges		
Collection / Transportation / Storage	Efficiency of collection		• Mostly collected by manual labor and some parts of tree difficult to collect
	Efficiency of transportation		• Some plantations are located in remote or hard-to-reach areas (e.g., mountains), resulting in high transportation cost
	Farmer's custom and education		• Many farmers prefer burning rather than energy usage, utilization believing that it enriches soil with nutrients
Utilization	Power generation	Funding support	• Incentives for capital expenditure (e.g. power plant construction) and power generation (e.g. FIT) is limited
		Compatibility	• Technological challenges with wood residue compatibility of biomass residues with existing boilers
		Contamination	• Contamination of dust and soil can cause damages to the equipment such as boilers
		Ash generation	• Combustion of wood biomass can generate ash and emissions, which without proper management and pollution control, may result in maintenance issues
	Others	-	• -

Source: Interview

Japanese companies can provide a holistic approach, leveraging partnerships with Japanese government and advanced technologies for market development

Supply Chain	Issues & Challenges		Potential Solutions by Japanese Companies	
Collection / Transportation / Storage	Efficiency of collection		Equipment	• Machinery and equipment to make the collection process more efficient (e.g. portable wood chippers)
	Efficiency of transportation		Supply chain optimization	• Supply chain optimization solutions (e.g. self-sustaining local biomass energy systems)
	Farmer's custom and education		Education in the local community	• Educational programs, online community/platforms introducing economic benefit for energy usage
Utilization	Power generation	Funding support	Subsidies from Japanese gov.	• Pilot projects developed which includes Japanese government (e.g. METI, NEDO) financial support
		Compatibility	Flexible Boilers	• Boilers with compatibility for various types of wood residues (e.g. CFB boilers)
		Contamination	Equipment and O&M*	• Machinery (e.g. sorting) to prevent contamination, and O&M services to monitor manufacturing process
		Ash generation	Ash utilization	• Machinery and facilities to recuse ash efficiently (e.g. convert into fertilizer and construction materials such as cement)
	Others	-	-	• -

*Note: O&M: Operation and maintenance

Sources: Interview, company webpage of Japanese companies

Residues from rice, coconut, coffee, and maize are considered biomass materials which can potentially be utilized in the future

Country Name	Residue Name	Volume (Annual, Mn ton)	Current Utilization Status	Potential Application & Demand Observed by Local Government and Industry Players: Power generation	Transportation	Heat	Others
Indonesia	Sorghum husk	n/a	Not widely used				● (animal feed, fertilizer)
	Sorghum stem	n/a	Not widely used		● (bioethanol)		● (animal feed, fertilizer)
	Sorghum leaf	n/a	Not widely used				● (animal feed, fertilizer)
	Coffee husk	1.0	Not widely used	●			
Malaysia	Rice straws	3.1	Not widely used	●			
	Rice Fronds	0.6	Not widely used	●			
Thailand	Sugarcane leaves	9.8	50% used	●			
	Rice straws	45.6	Not widely used	●			● (biochar fertilizer)
Philippines	Rice straw	26.3	Not widely used	●			
	Coconut frond	7.0	Not widely used	●			
Vietnam	Rice straw	56.8	20% used	●			
	Rice husk	10.7	20% used	●			
	Coffee husk	2.6	25% used	●			
	Maize stover	8.7	30% used			●	

Source: Interview

The potential biomass materials are difficult to collect and transport, and the facilities in the utilization-side needs to be enhanced as well for further usage

Residue Name		Collection	Transportation	Utilization
Sorghum	Sorghum husk Sorghum stem Sorghum leaf	• -		• Technology to produce bioethanol from sorghum is not widely implemented
Sugarcane	Leaves	• Scattered in the field, and collection will require additional manpower	• Lightweight but requires significant storage space and results in multiple transportation required • (Sugarcane) piling in large quantities poses risk of explosion due to methane	• Most boilers can only accommodate limited amount of sugarcane leaves with bagasse
Rice	Straws Husks			• (Straw) Difficult to use as the straw is long and has a lot of fibers
Maize	Stover			• Limited knowledge and capacity for usage
Coconut	Fronds		• Bulky, large and difficult for transportation	• Hard to handle and pre-processing is tedious
Coffee	Husk	• -		• Limited knowledge and capacity for usage

Source: Interview

There are ongoing studies and demonstration projects to enhance the transportation and utilization, which Japanese companies can potentially support

Example of studies and demonstration projects in ASEAN region

Residue Name		Collection	Transportation	Utilization
Sorghum	Sorghum husk	-		Usage for power generation, transportation, and animal feed
	Sorghum stem			
	Sorghum leaf			
Sugarcane	Leaves	Scattered in the field, and collection will require additional manpower	Conversion to pellets/briquettes for easy transportation and higher sales value (Sugarcane) piling in large quantities poses risk of explosion due to methane	Most boilers can only accommodate limited amount of sugarcane leaves with bagasse
Rice	Straws			Usage in power generation; Usage for biochar
	Husks			
Maize	Stover			Limited knowledge and capacity for usage
Coconut	Fronds		Bulky, large and difficult for transportation	Hard to handle and pre-processing is tedious
Coffee	Husk	-		Utilization of ash from boiler

Source: Interview

Industry associations and ministries aim to introduce efficient ways to convert the biomass materials into easy-to-carry format such as pellets and briquettes

Residue Name		Collection	Transportation	Utilization
Sorghum	Sorghum husk			
	Sorghum stem			
	Sorghum leaf			
Sugarcane	Leaves			
Rice	Straws			
	Husks			
Maize	Stover			
Coconut	Fronds			
Coffee	Husk			

Thailand: Office of the Cane and Sugar Board
- Collaborating with engineer department of the university, KMUTNB to research about the briquette production machine. They are in the process of finalizing the price of machine and are nearly ready for commercialization.
- One of the key goals of this research is to improve pellet quality to meet international standards, such as those in Japan, and support exports.
- The organization is also open to collaboration with both public and private entities, particularly from Japan, to further enhance pellet quality.

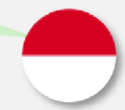
Thailand: Ministry of Energy, Department of Alternative Energy Development and Efficiency (DEDE)
- In 2025, DEDE plans to study effective technologies and strategies to improve the handling and utilization of rice straw, stubble, and similar biomass. This includes options like converting them into pellets or briquettes for easier transport and optimizing plantation planning, such as cultivating crops in plain areas or large fields to simplify machine-based collection of crops and residues.

Source: Interview

Overseas organizations are supporting the utilization of biomass in areas including power plant usage and conversion to biochar

Residue Name		Collection	Transportation	Utilization
Sorghum	Sorghum husk			
	Sorghum stem			
	Sorghum leaf			
Sugarcane	Leaves			
Rice	Straws			
	Husks			
Maize	Stover			
Coconut	Fronds			
Coffee	Husk			

Indonesia: National Research and Innovation Agency (BRIN)
- Conducting feasibility study for biomass utilization with 100-200 ha. of sorghum plantation, partnering with domestic private sector and farmers



Vietnam
- German Development Cooperation Agency (GIZ) supported Vietnam in implementing its "Rice is the New Green" (RING) project, evaluating technical and economic feasibility, to support usage of boilers with rice-husk to replace diesel

Thailand: National Science and Technology Development Agency (NSTDA)
- Conducting research/pilot project for conversion of rice straw to biochar

Philippines
- A British company has been doing a full research regarding the utilization of rice straw for biomass power plants

Source: Interview

Future Government Plans for Biomass Usage (Power Generation)

The ASEAN countries aim to continue expanding the utilization of biomass in the future, with quantitative targets announced in government policies

Government Plans for Biomass Usage (Power Generation)

Country	Policy	Issuers	Effective year	Key quantitative target
Indonesia	**Electricity Supply Business Plan (RUPTL) 2021-2030**	Minister of Energy and Mineral Resources	2021	• To increase the biomass proportion in co-firing from the current 5% to between 10% and 20% by 2025. • To accommodate maximumly 30% of biomass fuel in the new coal-fired power plants scheduled to operate after 2025. • To add new installed capacity of 590 megawatts of biomass and waste-based power generation during 2021-2030.
Malaysia	**Malaysia Renewable Energy Roadmap (MyRER)**	Sustainable Energy Development Authority (SEDA) Malaysia	2021	• To have 862 MW installed capacity by 2025 and 998 MW installed capacity by 2035 from biomass. As of 2020, the capacity was 496 MW. • To have 333 MW installed capacity by 2025 and 406 MW installed capacity by 2035 from biogas. As of 2020, the capacity was 173 MW.
Thailand	**Alternative Energy Development Plan (AEDP) 2024 (Draft)**	Ministry of Energy	Drafting	• To have 5,490 MW capacity of biomass for electricity sector by 2037, out of total renewable energy 73,286 MW (7%). The capacity in 2023 was 3,873 MW.
Vietnam	**Vietnam Renewable Energy Development Strategy (VREDS)**	Prime Minister	2016	• To have total biomass energy for electricity generation from 0.3 million tons of oil equivalent (TOE) in 2015 to 1.8 million TOE in 2020; approx. 9 million TOE in 2030 and 20 million TOE in 2050. • To have the share of biomass power in total electricity production from 1.0% in 2015 to 3.0% in 2020; approx. 6.3% in 2030 and 8.1% in 2050.
Philippines	**National Renewable Energy Program (NREP) 2020-2040**	Department of Energy	2021	• To have additional 277 MW of biomass power capacity by 2030.

Source: Government webpages

議題

調査結果のサマリー

Task 1: 賦存量および利用の容易性の把握

- **調査スコープおよび進め方**
- 調査結果の概要
- その他バイオマス資源の動向
- 調査対象のバイオマス資源の選定

Task 2: 有望なバイオマス資源の利用動向の把握

Task 3: 未利用資源の活用に向けた課題の整理

Task 4: 日系企業のバイオマス利用に向けた方向性の整理

Scope of Study

In this study, we will focus on crop residues and wood residues

Biomass Sources

	Focus scope of this report			
Type	**Crop-Residues**	**Wood-Residues**	**Animal Manure**	**Waste**
Definition	• The by-products that remain after the harvesting or processing of crops • The parts of the crops that are not consumed but are typically considered as waste during food processing	• The by-products or waste materials generated from the harvesting, processing, and manufacturing of wood	• The organic matter derived from the feces and urine of livestock	• The organic materials that are considered waste coming from agricultural, industrial, forestry, or household sources
Example of Materials	• Barley • Cassava • Oil palm • Rice • Sugar cane • Wheat	• Residues from forest harvesting e.g. stump, root, branch and tip • Wood residues from wood processing e.g. sawdust, slabs and chips	• Urine and feces of dairy cow • Urine and feces of buffalo • Urine and feces of swine	• Municipal waste

Source: Food and Agriculture Organization

In this study, the FAO database is used for reliable, consistent data on stable bioenergy materials across multiple countries and materials

Research Approach

Biomass Sources	Research Approach
Crop-Residues	• Desktop research on data Y2022 from FAOSTAT
Wood-Residues	• Desktop research on data Y2021 from FAOSTAT

Food and Agriculture Organization (FAO)

Organization Profile

Name	The Food and Agriculture Organization (FAO)
Year Founded	1945
Type	Intergovernmental organization, specialized agency
Parent organization	United Nations
No. of Member Nations	195 members, including 194 countries and the European Union

Organization Database

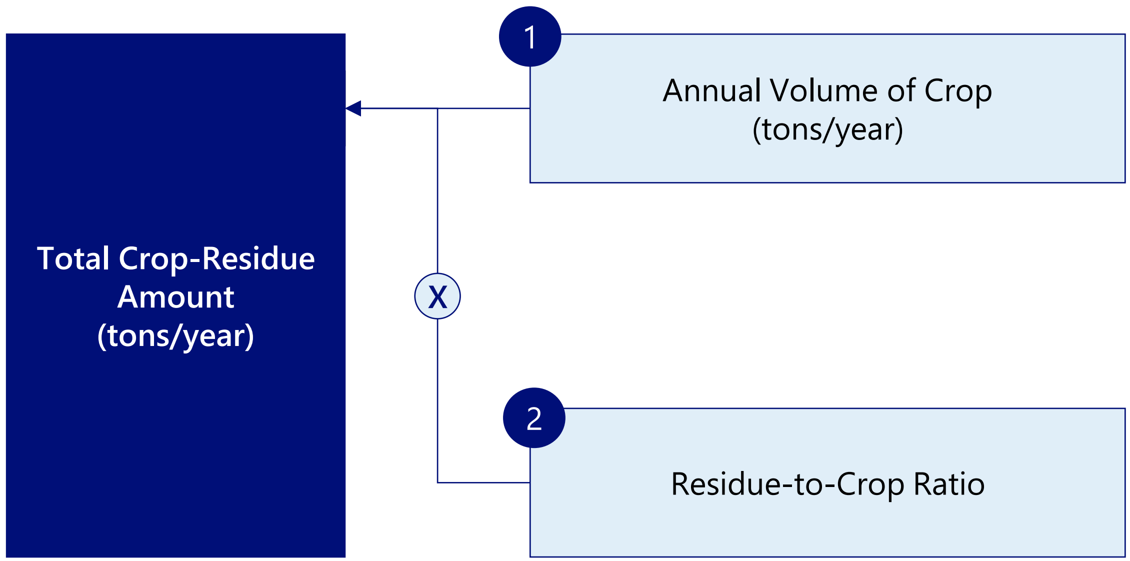
FAOSTAT	• A global database on the world agricultural statistics, managed by UN FAO
Examples of Available Topics	• Crops Productions • Forestry Production and Trade • World Census of Agriculture • Agrifood Systems Emissions
Advantages of FAOSTAT in this Study	• Internationally Reliable Source • Consistent Data Across Multiple Countries • Data on Commonly Used and Stable Materials for Bioenergy Production

Source: Food and Agriculture Organization

Research Approach: Crop-Residues

The amount to crop-residue is assessed based on the annual crop production and residue-to-crop ratio

Crop-Residues Estimation by FAO



Details of each factor # are explained in the next page

Source: Food and Agriculture Organization

Research Approach: Crop-Residues

Data of each factor derived from the country survey and literature research conducted by FAO

Definition and Data Collection Approach

Total Crop-Residue Amount (tons/year)

- Amount of the analyzed crop-residue type produced in one calendar

1 **Annual Volume of Crop (tons/year)**

- Amount of analyzed crop produced in one calendar year
- Data obtained by the survey of FAO Statistics Division

2 **Residue-to-Crop Ratio**

- Ratio of the amount of residue generated to the amount of the main product of the crop (e.g. ratio of straw and grain in the case of cereals).
- Data are derived from extensive literature research, conducted by FAO Statistics Division

Assumption and Limitation of Estimation

Assumption

- Crop-residue production is positively correlated with crop production, based on the residue-to-crop ratio.
- The residues used for other purposes should not be accounted as a potential resource for energy production, e.g., energy production should not compete with other residues uses.
- The number of harvests per year is assumed at one harvest per year

Limitation

- The residue-to-crop ratio are not country-specific but based on literature research of crop specie

Source: Food and Agriculture Organization

Research Approach: Crop-Residues

Crop-residues defined by FAO can be categorized into residues from the harvesting, residues from the processing, and from both process as following

Commonly Used and Stable Materials for Bioenergy Production by FAOSTAT

Residues from the harvesting

#	Crops	Crop-Residues	日本語
1	Barley	Barley straw	大麦わら
2	Cassava	Cassava stalk	キャッサバの茎
3	Coconut	Coconut frond	ココナッツ葉
4	Cotton	Cotton stalk	綿茎
5	Maize	Maize stover	トウモロコシの茎葉
6	Millet	Millet straw	キビわら
7	Oil palm	Oil palm frond	アブラヤシの葉 (OPF)
8	Rice	Rice Straw	稲わら
9	Rye	Rye straw	ライ麦わら
10	Sorghum	Sorghum straw/stalk	ソルガムわら/ソルガム茎
11	Soy bean	Soy bean straw	大豆わら
12	Sugar cane	Sugar cane leaves and tops	サトウキビ葉と先端
13	Wheat	Wheat straw	小麦わら

Residues from the processing

#	Crops	Crop-Residues	日本語
1	Coffee	Coffee husk	コーヒー殻
2	Cotton	Cotton hull	綿殻
3	Groundnut	Groundnut hulk	落花生殻
4	Maize	Maize cob	トウモロコシの芯
5	Maize	Maize husk	トウモロコシの殻
6	Oil palm	Oil palm shell	アブラヤシ殻 (PKS)
7	Oil palm	Oil palm empty bunches	パーム椰子空果房 (EFB)
8	Rice	Rice husk	もみ殻
9	Soy bean	Soy bean pods	大豆さや
10	Sugar cane	Sugar cane bagasse	サトウキビバガス

Residues from the harvesting/processing

#	Crops	Crop-Residues	日本語
1	Coconut	Coconut husk	ココナッツ殻
2	Coconut	Coconut shell	ココナッツシェル

Source: Food and Agriculture Organization

Research Approach: Wood Residues

Availability of wood-residues is assessed by the estimation of forest harvesting and wood processing residues

Definition and Data Collection Approach

Total Wood Residues

- Estimated amount of wood residues produced in one calendar year

1 Forest Harvesting Residues

- Estimated amount of parts of felled trees e.g. stump, root, branch and tip
- Data of stump and root estimated from FAOSTAT, assessed by FAO Statistics Division. Data from 2021
- Data of branch and tip obtained from FAOSTAT, assessed by FAO Statistics Division. Data from 2021

+

2 Wood Processing Residues

- Estimated amount of sawdust, slabs and chips generated during sawn wood production, which could be mobilized for bioenergy production, in one calendar year
- Data obtained from FAOSTAT, assessed by FAO Statistics Division. Data from 2021

Details of # are explained in the next page

Source: Food and Agriculture Organization

Research Approach: Wood Residues

Total wood residues are estimated as follow

Total wood Residues Calculation and Result

Total Wood Residues = Forest Harvesting Residues + Wood Processing Residues

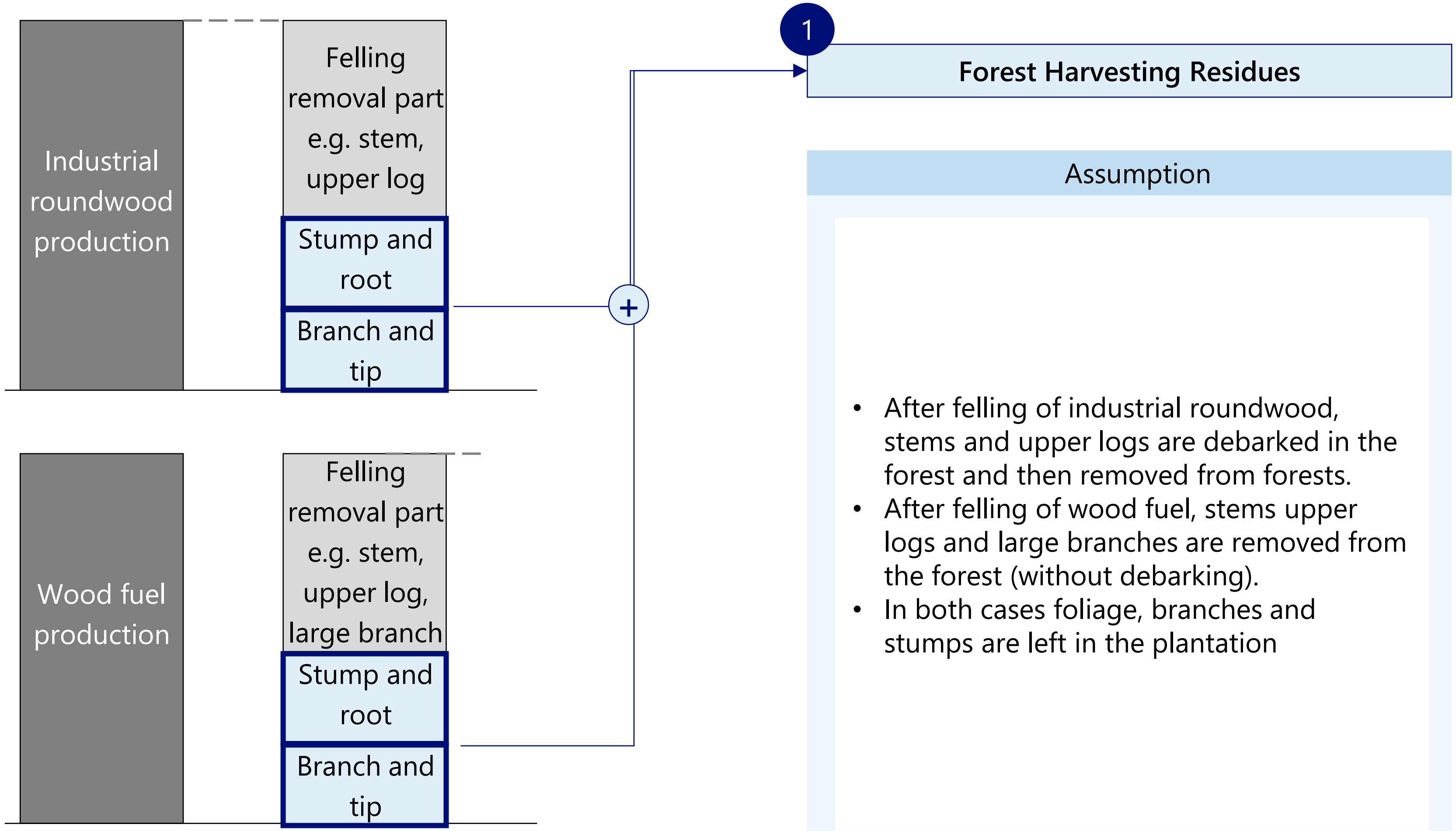
Item	Unit	Country				
		Indonesia	Malaysia	Thailand	Vietnam	The Philippines
Forest Harvesting Residues	ton/year	41,403,891	6,232,036	9,009,347	16,060,596	3,511,988
Wood Processing Residues	ton/year	960,440	1,137,445	1,602,725	2,039,190	149,090
Total Wood Residues	**ton/year**	**42,364,331**	**7,369,481**	**10,612,072**	**18,099,786**	**3,661,078**

Source: Food and Agriculture Organization

Research Approach: Wood Residues

Forest harvesting residues arises from amount of stump, root, branch and tip from industrial roundwood and wood fuel harvesting

Calculation Logic and Assumption for Wood Residues – Forest Harvesting Residues



Assumption

- After felling of industrial roundwood, stems and upper logs are debarked in the forest and then removed from forests.
- After felling of wood fuel, stems upper logs and large branches are removed from the forest (without debarking).
- In both cases foliage, branches and stumps are left in the plantation

Source: Food and Agriculture Organization

Research Approach: Wood Residues

Forest harvesting residues are estimated as follow

Forest Harvesting Residues Calculation and Result

Forest Harvesting Residues = Amount of stump and root + Amount of branch and tip

Item	Unit	Country				
		Indonesia	Malaysia	Thailand	Vietnam	The Philippines
Amount of stump and root	ton/year	13,741,791	1,877,236	3,602,327	4,091,736	1,645,238
Amount of branch and tip	ton/year	27,662,100	4,354,800	5,407,020	11,968,860	1,866,750
Forest Harvesting Residues	**ton/year**	**41,403,891**	**6,232,036**	**9,009,347**	**16,060,596**	**3,511,988**

Source: Food and Agriculture Organization, Wood Experts

Stump and root amount is estimated based on the composition of stump and root of the whole tree

Amount of Stump and Root Calculation and Result

Amount of stump and root = Roundwood production (m^3/year) X % Stump and root composition X Wood density (ton/m^3)

Item	Unit	Country				
		Indonesia	Malaysia	Thailand	Vietnam	The Philippines
Roundwood production	m^3/year	125,454,000	17,138,000	32,887,000	37,355,000	15,020,000
Stump and root composition	%	18.5%	18.5%	18.5%	18.5%	18.5%
Amount of stump and root	m^3/year	23,167,172	3,164,817	6,073,133	6,898,223	2,773,693
Wood density of stump and root	ton/m3	0.59	0.59	0.59	0.59	0.59
Amount of stump and root	**ton/year**	**13,741,791**	**1,877,236**	**3,602,327**	**4,091,736**	**1,645,238**

Note:
1. Data of roundwood production is obtained from FAO
2. Data of stump and root composition and density is obtained from 9 wood experts from SPEEDA. After collecting answers from wood experts, the average number is applied for the calculation as for tree in general.

Source: Food and Agriculture Organization, Wood Experts

Research Approach: Wood Residues

Amount of branch and tip is obtained from FAO Database

Amount of Branch and Tip Result

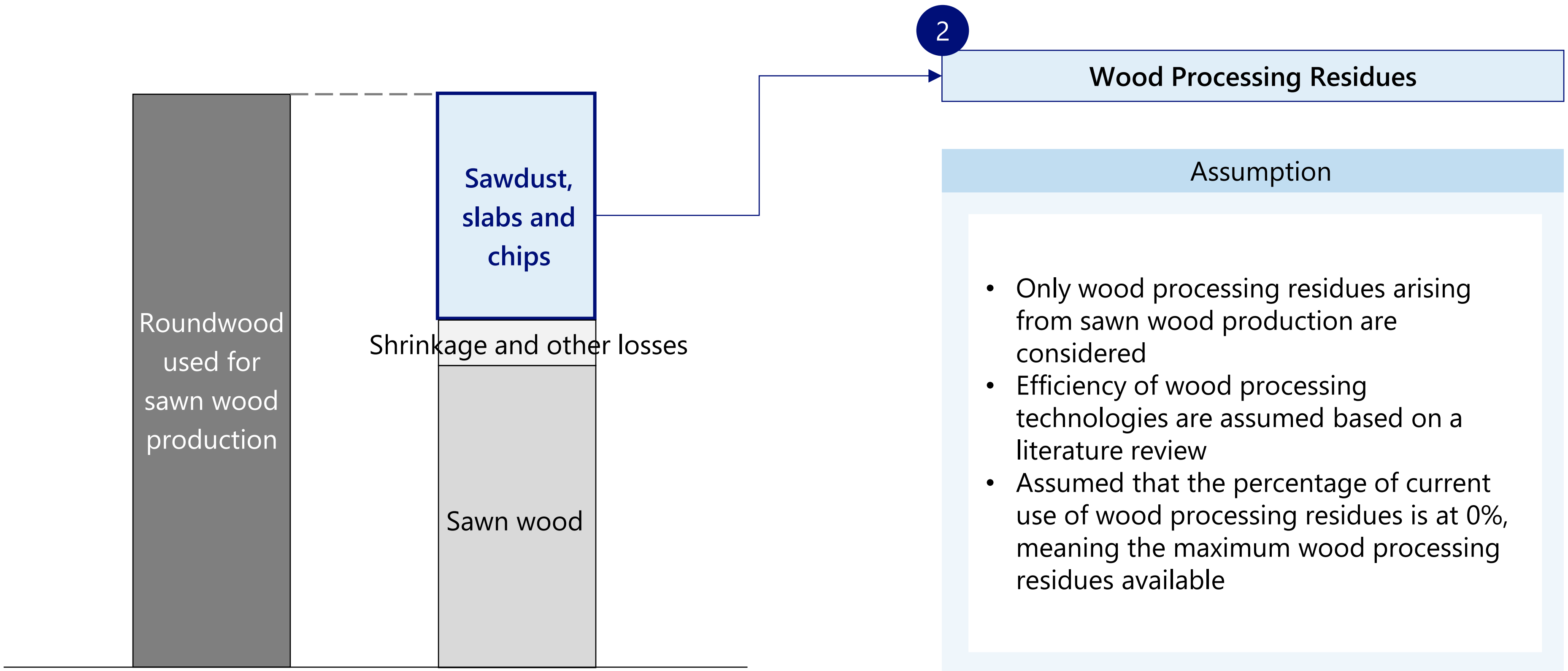
Item	Unit	Country				
		Indonesia	Malaysia	Thailand	Vietnam	The Philippines
Amount of branch and tip	ton/year	27,662,100	4,354,800	5,407,020	11,968,860	1,866,750

Source: Food and Agriculture Organization

Research Approach: Wood Residues

Wood processing residues are sawdust, slabs and chips produced during the sawn wood production in sawmills

Calculation Logic and Assumption for Wood Residues – Wood Processing Residues



Assumption

- Only wood processing residues arising from sawn wood production are considered
- Efficiency of wood processing technologies are assumed based on a literature review
- Assumed that the percentage of current use of wood processing residues is at 0%, meaning the maximum wood processing residues available

Source: Food and Agriculture Organization

Research Approach: Wood Residues

Amount of sawdust and slab, together as wood processing residues, is obtained from FAO Database

Amount of Branch and Tip Result

Wood Processing Residues = Amount of sawdust + Amount of slab and chip

Item	Unit	Country				
		Indonesia	Malaysia	Thailand	Vietnam	The Philippines
Amount of sawdust	ton/year	257,680	305,170	430,000	547,100	40,000
Amount of slab and chip	ton/year	702,760	832,275	1,172,725	1,492,090	109,090
Wood Processing Residues	**ton/year**	**960,440**	**1,137,445**	**1,602,725**	**2,039,190**	**149,090**

Source: Food and Agriculture Organization

議題

- 調査結果のサマリー
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Crop-residues from oil palm, rice, maize and sugar cane are available across countries. Top 5 residues take up to 70-99% of the total market in each countries

Oil palm | Rice | Maize | Sugar cane | Coffee | Coconut | Forest harvesting | Wood production

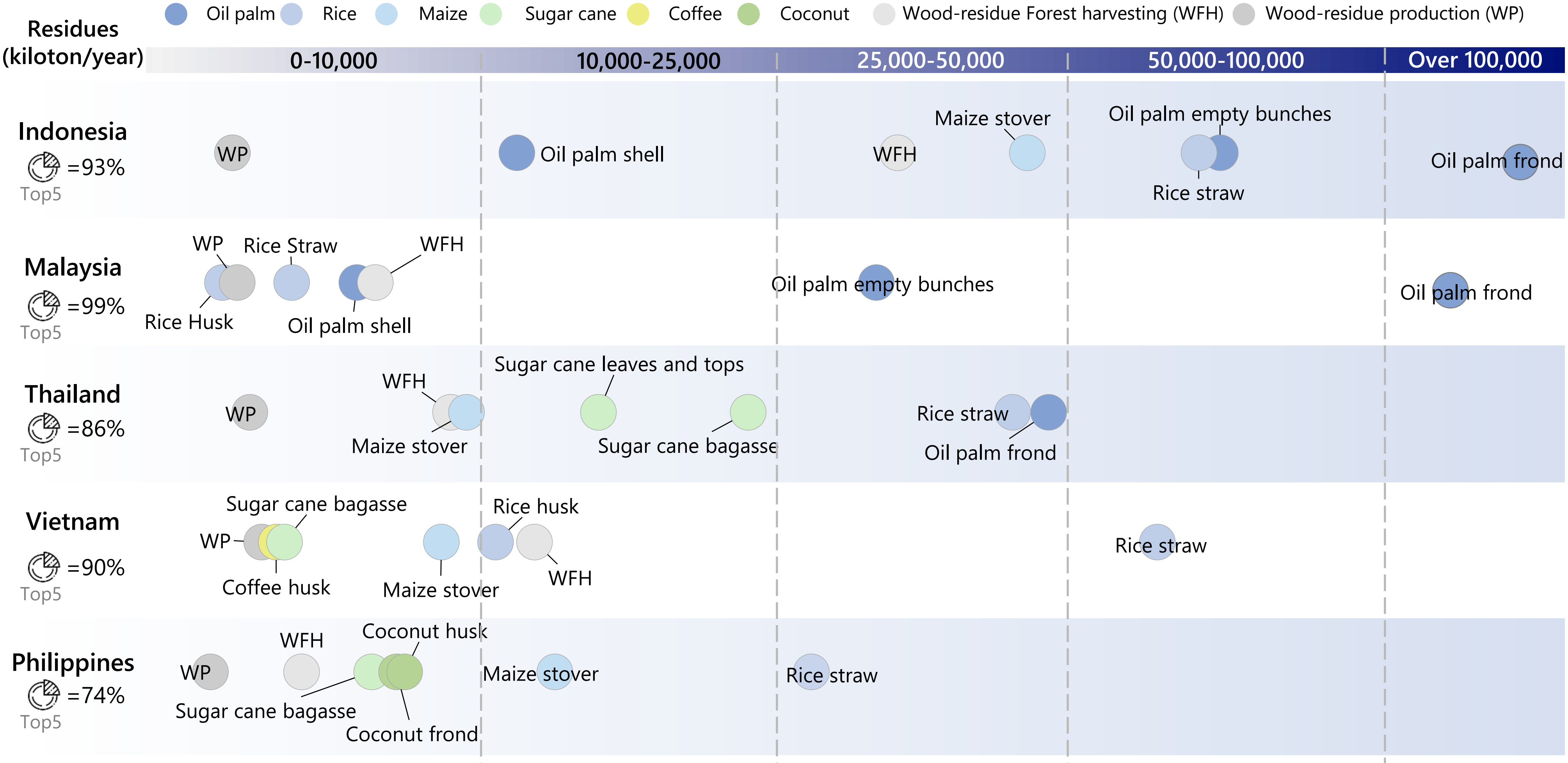
Overview Result of Residues

Country	Unit / Rank	Crop-Residues: Kiloton/year (% from total crop-residues) #1	#2	#3	#4	#5	% Total of top 5 residue	Wood-Residues: Kiloton/year (% from total wood-residues)	
Indonesia	Materials	Oil palm frond	Oil palm empty bunches	Rice straw	Maize stover	Oil palm shell	Top #1-5	Forest harvesting	Wood production
	Amount	667,757 (70.2%)	79,617 (8.4%)	72,816 (7.7%)	46,185 (4.9%)	15,410 (1.6%)	881,785 (92.7%)	41,404 (97.7%)	960 (2.3%)
Malaysia	Materials	Oil palm frond	Oil palm empty bunches	Oil palm shell	Rice Straw	Rice Husk	Top #1-5	Forest harvesting	Wood production
	Amount	240,500 (86.1%)	28,675 (10.3%)	5,550 (2%)	3,145 (1.1%)	591 (0.2%)	278,461 (99.6%)	6,232 (84.6%)	1,137 (15.4%)
Thailand	Materials	Oil palm frond	Rice straw	Sugar cane bagasse	Sugar cane leaves and tops	Maize stover	Top #1-5	Forest harvesting	Wood production
	Amount	49,560 (28.9%)	45,642 (26.9%)	23,945 (14%)	18,419 (10.8%)	9,596 (5.6%)	147,161 (85.9%)	9,009 (84.9%)	1,603 (15.1%)
Vietnam	Materials	Rice straw	Rice husk	Maize stover	Sugar cane bagasse	Coffee husk	Top #1-5	Forest harvesting	Wood production
	Amount	56,754 (62.7%)	10,668 (11.8%)	8,669 (9.6%)	2,882 (3.2%)	2,579 (2.8%)	81,553 (90.1%)	16,061 (88.7%)	2,039 (11.3%)
Philippines	Materials	Rice straw	Maize stover	Coconut husk	Coconut frond	Sugar cane bagasse	Top #1-5	Forest harvesting	Wood production
	Amount	26,276 (30.9%)	16,811 (19.1%)	7,316 (8.6%)	7,018 (8.3%)	6,098 (7.2%)	62,889 (74.1%)	3,512 (95.9%)	149 (4.1%)

Source: Food and Agriculture Organization

Here is the overview of top 5 cop-residues and wood-residues of 5 countries. Oil palm, rice, maize and sugar cane have the top residues across countries.

Overview of Residues (Top 5 Crop-Residues and Wood-Residues)



Note: this chart shows the potential bioenergy availability from the top five crop residues and two types of wood residues

Source: Food and Agriculture Organization

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Crop-Residues of Indonesia

In Indonesia, crop-residues from oil palm have the largest volume followed by rice and maize

Total Crop-Residues Amount (ton/year)

The potential availability of bioenergy from 21 types of crop residues has been calculated. The results are ranked from highest to lowest

#	Crop-Residue	Total Amount
1	Oil palm frond	667,756,780
2	Oil palm empty bunches	79,617,155
3	Rice straw	72,816,140
4	Maize stover	46,185,440
5	Oil palm shell	15,409,772
6	Rice husk	13,687,244
7	Sugar cane bagasse	8,424,000
8	Coconut husk	8,423,261
9	Coconut frond	8,079,454
10	Maize cob	7,776,120

#	Crop-Residue	Total Amount
11	Coconut shell	6,704,228
12	Sugar cane leaves and tops	6,480,000
13	Maize husk	5,184,080
14	Cassava stalk	1,764,620
15	Coffee husk	1,049,086
16	Cacao pod husk	1,000,944
17	Soy bean straw	460,530
18	Soy bean pods	328,090
19	Groundnut husk	178,130
20	Cotton stalk	303
21	Cotton hull	23

Source: NRI analysis, Food and Agriculture Organization

 NRI

Wood Residues of Indonesia

Wood residues in Indonesia is estimated at 42.3 million tons with 41.4 million tons as forest harvesting residue and 0.1 million tons as wood processing residues

Total Wood-Residues Amount (ton/year)

Biomass	Potential Availability	Unit
Wood Residues	**42,364,331**	**ton/year**
Forest Harvesting Residues	41,403,891	ton/year
Stump and root	13,741,791	ton/year
Branch and tip	27,662,100	ton/year
Wood Processing Residues	960,440	ton/year
Sawdust	257,680	ton/year
Slabs and Chips	702,760	ton/year

Source: Food and Agriculture Organization, Wood experts from Speeda

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Crop-Residues of Malaysia

In Malaysia, oil palm residues dominate as main potential material for bioenergy, being roughly 70 times more than those from rice, the 2nd largest residues

Total Crop-Residues Amount (ton/year)

The potential availability of bioenergy from 17 types of crop residues has been calculated. The results are ranked from highest to lowest

#	Crop-Residue	Total Amount
1	Oil palm frond	240,500,000
2	Oil palm empty bunches	28,675,000
3	Oil palm shell	5,550,000
4	Rice straw	3,144,722
5	Rice husk	591,113
6	Coconut husk	296,170
7	Coconut frond	284,081
8	Coconut shell	235,727
9	Maize stover	123,783
10	Maize cob	20,841

#	Crop-Residue	Total Amount
11	Maize husk	13,894
12	Sugar cane bagasse	6,508
13	Cassava stalk	5,529
14	Coffee husk	5,081
15	Sugar cane leaves and tops	5,006
16	Cacao pod husk	740
17	Groundnut husk	94

Source: NRI analysis, Food and Agriculture Organization

Wood Residues of Malaysia

Wood residues in Malaysia is estimated at 7.4 million tons with 6.2 million tons as forest harvesting residue and 1.2 million tons as wood processing residues

Total Wood-Residues Amount (ton/year)

Biomass	Potential Availability	Unit
Wood Residues	**7,369,481**	**ton/year**
Forest Harvesting Residues	6,232,036	ton/year
Stump and root	1,877,236	ton/year
Branch and tip	4,354,800	ton/year
Wood Processing Residues	1,137,445	ton/year
Sawdust	305,170	ton/year
Slabs and Chips	832,275	ton/year

Source: Food and Agriculture Organization, Wood experts from Speeda

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Crop-Residues of Thailand

In Thailand, crop-residues from oil palm and rice dominate as main potential materials for bioenergy with roughly 45-50 million ton per year

Total Crop-Residues Amount (ton/year)

The potential availability of bioenergy from 24 types of crop residues has been calculated. The results are ranked from highest to lowest

#	Crop-Residue	Total Amount
1	Oil palm frond	49,559,619
2	Rice straw	45,641,647
3	Sugar cane bagasse	23,944,904
4	Sugar cane leaves and tops	18,419,157
5	Maize stover	9,595,972
6	Rice husk	8,579,257
7	Oil palm empty bunches	5,909,032
8	Cassava stalk	4,428,841
9	Maize cob	1,615,648
10	Oil palm shell	1,143,684
11	Maize husk	1,077,099
12	Coconut husk	332,824

#	Crop-Residue	Total Amount
13	Coconut frond	319,239
14	Coconut shell	264,900
15	Barley straw	235,367
16	Sorghum straw/stalk	122,000
17	Soy bean straw	31,827
18	Coffee husk	24,669
19	Soy bean pods	22,674
20	Groundnut hulk	12,501
21	Cotton stalk	10,816
22	Wheat straw	1,691
23	Cotton hull	827
24	Cacao pod husk	186

Source: NRI analysis, Food and Agriculture Organization

Wood Residues of Thailand

Wood residues in Thailand is estimated at 10.6 million tons with 9 million tons as forest harvesting residue and 1.6 million tons as wood processing residues

Total Wood-Residues Amount (ton/year)

Biomass	Potential Availability	Unit
Wood Residues	**10,612,072**	**ton/year**
Forest Harvesting Residues	9,009,347	ton/year
Stump and root	3,602,327	ton/year
Branch and tip	5,407,020	ton/year
Wood Processing Residues	1,602,725	ton/year
Sawdust	430,000	ton/year
Slabs and Chips	1,172,725	ton/year

Source: Food and Agriculture Organization, Wood experts from Speeda

議題

- 調査結果のサマリー
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  - **調査結果の概要**
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    - マレーシア
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Crop-Residues of Vietnam

In Vietnam, crop-residues from rice account for the largest volume residue followed by those from maize

Total Crop-Residues Amount (ton/year)

The potential availability of bioenergy from 19 types of crop residues has been calculated. The results are ranked from highest to lowest

#	Crop-Residue	Total Amount
1	Rice straw	56,754,210
2	Rice husk	10,668,085
3	Maize stover	8,669,445
4	Sugar cane bagasse	2,881,584
5	Coffee husk	2,579,267
6	Sugar cane leaves and tops	2,216,603
7	Maize cob	1,459,651
8	Cassava stalk	1,381,492
9	Maize husk	973,101
10	Coconut husk	945,789

#	Crop-Residue	Toal Amount
11	Coconut frond	907,186
12	Coconut shell	752,771
13	Groundnut hulk	191,799
14	Soy bean straw	79,784
15	Soy bean pods	56,840
16	Millet straw	3,699
17	Cacao pod husk	2,250
18	Cotton stalk	116
19	Cotton hull	9

Source: NRI analysis, Food and Agriculture Organization

Wood Residues of Vietnam

Wood residues in Vietnam is estimated at 18.1 million tons with 16.1 million tons as forest harvesting residue and 2 million tons as wood processing residues

Total Wood-Residues Amount (ton/year)

Biomass	Potential Availability	Unit
Wood Residues	**18,099,786**	**ton/year**
Forest Harvesting Residues	16,060,596	ton/year
Stump and root	4,091,736	ton/year
Branch and tip	11,968,860	ton/year
Wood Processing Residues	2,039,190	ton/year
Sawdust	547,100	ton/year
Slabs and Chips	1,492,090	ton/year

Source: Food and Agriculture Organization, Wood experts from Speeda

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In Philippines, crop-residues from rice account for the largest volume residue followed by those from maize and coconut

Total Crop-Residues Amount (ton/year)

The potential availability of bioenergy from 22 types of crop residues has been calculated. The results are ranked from highest to lowest

#	Crop-Residue	Total Amount
1	Rice straw	26,276,002
2	Maize stover	16,180,995
3	Coconut husk	7,316,268
4	Coconut frond	7,017,644
5	Sugar cane bagasse	6,098,405
6	Coconut shell	5,823,152
7	Rice husk	4,939,098
8	Sugar cane leaves and tops	4,691,081
9	Maize cob	2,724,351
10	Maize husk	1,816,234
11	Oil palm frond	1,386,836

#	Crop-Residue	Total Amount
12	Cassava stalk	332,806
13	Oil palm empty bunches	165,354
14	Coffee husk	76,936
15	Oil palm shell	32,004
16	Cacao pod husk	15,669
17	Groundnut hulk	14,814
18	Sorghum straw/stalk	1,437
19	Soy bean straw	958
20	Soy bean pods	683
21	Cotton stalk	340
22	Cotton hull	26

Source: NRI analysis, Food and Agriculture Organization

Wood Residues of Philippines

Wood residues in the Philippines is estimated at 3.7 million tons with 3.5 million tons as forest harvesting residue and 0.2 million tons as wood processing residues

Total Wood-Residues Amount (ton/year)

Biomass	Potential Availability	Unit
Wood Residues	**3,661,078**	**ton/year**
Forest Harvesting Residues	3,511,988	ton/year
Stump and root	1,645,238	ton/year
Branch and tip	1,866,750	ton/year
Wood Processing Residues	149,090	ton/year
Sawdust	40,000	ton/year
Slabs and Chips	109,090	ton/year

Source: Food and Agriculture Organization, Wood experts from Speeda

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Amount of 4 additional residues is estimated by the same approach of other crop-residues, based on the annual crop production and residue-to-crop ratio

Additional Crop-Residues in Interest

- Sugarcane Bagasse
- Cassava Pulp
- Pineapple Peel
- Banana Peel

Crop-Residues Estimation

Total Crop-Residue Amount (tons/year)

Annual Volume of Crop (tons/year)

- Amount of analyzed crop produced in one calendar year
- Data obtained by the survey of FAO Statistics Division

X

Residue-to-Crop Ratio

- Ratio of the amount of residue generated to the amount of the main product of the crop
- Calculation is explained in the next page

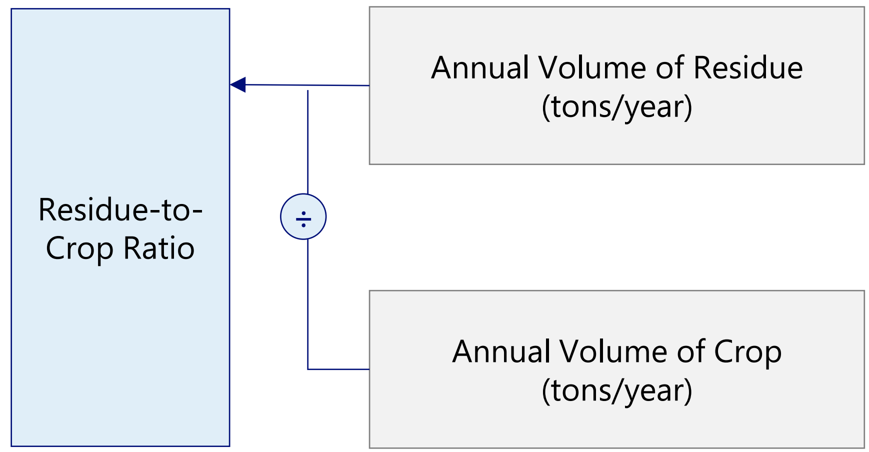
Source: Food and Agriculture Organization

Residue-to-crop ratios of bagasse and banana peel are available on desktop research while ratios of cassava pulp and pineapple peel are from calculation

Source of Data

Source of Residue-to-Crop Ratio	Crop-Residues
Desktop research	• Sugarcane Bagasse • Banana Peel
Calculation	• Cassava Pulp • Pineapple Peel

Residue-to-Crop Ratio Calculation



Note:
1. The residue-to-crop ratio is based on crop specie, not country-specific
2. The residue-to-crop ratio of sugarcane bagasse is obtained from FAO Statistics Division. The ratio is 0.26
3. The residue-to-crop ratio of banana peel is obtained from a research paper on Current Science Association. The ratio is 0.35
4. The residue-to-crop ratio of cassava pulp is calculated by dividing the annual cassava pulp of 9.5 million tons by the annual cassava volume of 35.1 million tons (Thailand, 2021). The ratio is 0.27
5. The residue-to-crop ratio of pineapple peel is calculated by dividing the annual pineapple peel of 154,693 tons by the annual pineapple volume of 369,089 tons (Malaysia, 2022). The ratio is 0.42

Source: Food and Agriculture Organization, Sustainable Environment Research, Ministry of Plantation and Commodities of Malaysia, Current Science Association

Among these 4 residues, top 2 of ID, TH and VN are bagasse and casava pulp. PH has bagasse and banana peel and MY has pineapple and banana peel

Crop-Residues Amount (tons/year)

	Sugarcane Bagasse	Cassava Pulp	Pineapple Peel	Banana Peel
Indonesia	1st 8,424,000	2nd 3,664,980	1,345,586	3,235,899
Malaysia	6,508	11,483	1st 154,693	2nd 115,350
Thailand	1st 23,944,904	2nd 9,198,361	719,969	450,909
Vietnam	1st 2,881,584	2nd 2,869,253	296,293	880,187
Philippines	1st 6,098,405	691,212	1,224,058	2nd 2,064,897

Source: Food and Agriculture Organization, Ministry of Plantation and Commodities of Malaysia

Overview Result of Residues (Additional Residues Added)

However, the additional residue amounts are smaller than the original top five crop residues (including bagasse), except for cassava pulp in Vietnam

Overview Result of Residues

		Top 5 Crop-Residues (Original List)					Additional Crop-Residues			
	Unit	Kiloton/year (% from total crop-residues)								
	Rank	#1	#2	#3	#4	#5				
Indonesia	Materials	Oil palm frond	Oil palm empty bunches	Rice straw	Maize stover	Oil palm shell	Sugarcane Bagasse	Cassava Pulp	Pineapple Peel	Banana Peel
	Amount	667,757	79,617	72,816	46,185	15,410	8,424	3,665	1,346	3,236
Malaysia	Materials	Oil palm frond	Oil palm empty bunches	Oil palm shell	Rice Straw	Rice Husk	Sugarcane Bagasse	Cassava Pulp	Pineapple Peel	Banana Peel
	Amount	240,500	28,675	5,550	3,145	591	7	11	155	115
Thailand	Materials	Oil palm frond	Rice straw	Sugar cane bagasse	Sugar cane leaves and tops	Maize stover		Cassava Pulp	Pineapple Peel	Banana Peel
	Amount	49,560	45,642	23,945	18,419	9,596		9,198	720	451
Vietnam	Materials	Rice straw	Rice husk	Maize stover	Sugar cane bagasse	Coffee husk		Cassava Pulp	Pineapple Peel	Banana Peel
	Amount	56,754	10,668	8,669	2,882	2,579		**2,869**	296	880
Philippines	Materials	Rice straw	Maize stover	Coconut husk	Coconut frond	Sugar cane bagasse		Cassava Pulp	Pineapple Peel	Banana Peel
	Amount	26,276	16,811	7,316	7,018	6,098		691	1,224	2,065

Source: Food and Agriculture Organization, Sustainable Environment Research, Ministry of Plantation and Commodities of Malaysia

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Promising biomass materials were selected based on residue volume, potential ease of use based on geographical location, and interest by Japanese companies

Results of Promising Biomass Material Selection for Each Country

Country	Biomass Residues					No. of residues per country
	Cassava	Maize	Palm	Bagasse	Wood	
Indonesia	Cassava pulp	Maize cob	*(Research conducted in different study*)*	Sugarcane bagasse	Woods residues	4
Malaysia			Oil palm empty bunches and shell		Woods residues	2
Thailand	Cassava pulp	Maize cob	Oil palm empty bunches and shell	Sugarcane bagasse	Woods residues	5
Vietnam	Cassava pulp				Woods residues	2
Philippines		Maize cob			Woods residues	2
No. of countries per material	3	3	2	2	5	

*Note: For palm in Indonesia, research was conducted in "Study on Policy Recommendation for Biofuel in Indonesia Phase 3," a project commissioned by NEDO and conducted by Deloitte, which provides research on usage of palm specifically for biofuel, such as the potential end-product, challenges for feedstock acquisition, geographical location, and supply chain map.

Source: Discussion with NEDO

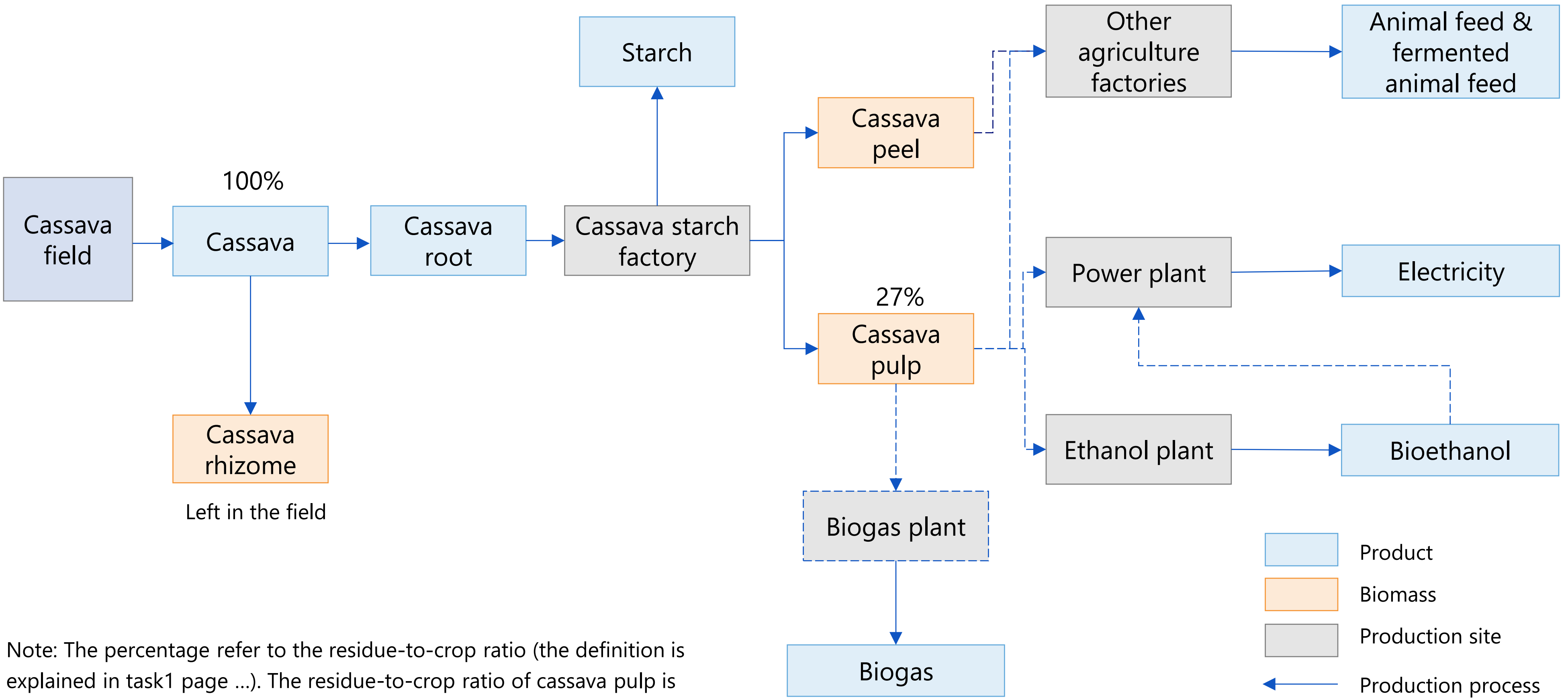
目次

Cassava pulp in Indonesia

Supply Chain

While Cassava rhizome is left in the field, fresh cassava root is sent to starch factories, where biomass products such as cassava pulp and peels are produced

Supply Chain



Note: The percentage refer to the residue-to-crop ratio (the definition is explained in task1 page …). The residue-to-crop ratio of cassava pulp is calculated by dividing the annual cassava pulp of 9.5 million tons by the annual cassava volume of 35.1 million tons (Thailand, 2021). The ratio is 0.27

Source: Interview

Current Acquisition Practice

Cassava pulp is transported to buyers using small trucks or container trucks. Measures are taken to manage odor and prevent spoilage. The price of cassava pulp ranges from 120 to 190 USD per ton

Current Acquisition Practice

Current Acquisition Practice	Collection	• Cassava pulp is collected in the starch factory during the starch production. There are no significant obstacles in collecting cassava pulp at the factory.
	Pre-Processing	• In general, the factory employs local workers to dry the cassava pulp using traditional methods, which is sun-dried, taking about 10 days to fully dry. • Once dried, the pulp is purchased and delivered to the factory.
	Storage	• Cassava pulp is typically stored in silos or warehouses with proper ventilation and moisture control to prevent degradation. • In some factories, they are kept in open areas for sun-drying with chemicals added to prevent spoilage.
	Transportation	• Cassava pulp is commonly transported in open-air trucks, with truck sizes varying based on the buyer's scale, from small vehicles to large containers. • However, the odor of cassava pulp is considered a concern that must be managed in accordance with the guidelines
Acquisition Cost		• Cassava pulp price: 120 – 190 USD (2-3 million IDR) per ton • Cassava root price: 30 – 60 USD (500,000 -900,000 IDR) per ton

IDR to USD conversion rate: 1 USD = 15,565 IDR (as of 7 November 2024)

Source: Interview

Utilized Portion

In Indonesia, cassava pulp is used for animal feed, electricity, bioethanol, and biogas, but demand is limited due to its higher cost than other residues

Utilized Portion

Utilized Portion	Application	• Animal feed • Heat and electricity generation • Bioethanol • Biogas

	Challenge in Utilization	• Dispersed locations
		  ○ Cassava pulp is often generated in dispersed locations making collection logistically challenging and costly. The Indonesian government is aware of this issue, in which BRIN previous conducted a project on cassava pulp utilization to use the waste locally to avoid high transportation costs.
		• Seasonal availability
		  ○ The availability cassava pulp is often seasonal, depending on the harvest periods. This can create storage and supply chain challenges.
		• Less supply compared to other residues
		  ○ The supply of cassava pulp is considered lower compared to other residues, such as palm and sugarcane bagasse, and may not meet the required portion needed for electricity generation.

Utilization Outlook		• The utilization of cassava pulp for bioethanol is anticipated to increase within the next 1–3 years, driven by the growing emphasis on green production and forthcoming government regulations that are yet to be enforced but expected to take effect in the near future. • The Indonesian government is interested in studying the usage cassava pulp as an alternative biomass material, and in early stages of promoting demonstration projects for this purpose.

Source: Interview

Utilization Proportion

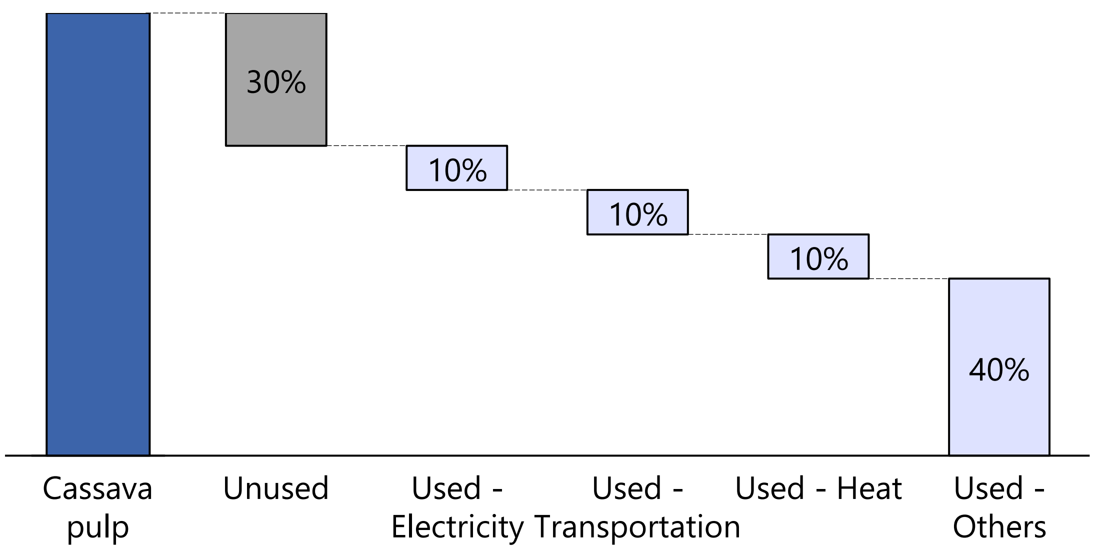
Currently, 30% of cassava pulp remains unutilized, with 40% being used for animal feed and 10% for electricity generation, transport and heat generation

Utilization Proportion

Unit: million tons/year

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
3.66	1.10	0.37	0.37	0.37	1.47

Utilization Proportion



Others:
- Animal feed

Note: total amount is estimated based on FAO's data while utilization proportion is obtained from interview with industry's experts.
The utilized amount is calculated from total amount x utilization proportion

Sources: Food and Agriculture Organization, Interview

Unutilized portion

The barriers to the utilization of cassava pulp are pricing compared to other biomass resources, lack of demand, and high competition with other resources

Unutilized Portion

Unutilized Portion	Current Management	• Discard at factory ○ Approximately 50% of cassava pulp is unused, as it cannot be dried during the rainy season and is simply discarded at the factory.

	Barriers to Utilization	• For general utilization:
		  ○ The supply of cassava pulp is more limited compared to other biomass resources, resulting in less interest in utilizing it
		• For utilizing as animal feed and food:
		  ○ Cassava pulp is less competitive in price, compared to other materials for animal feed and food
		• For bioenergy:
		  ○ Pricing: using casava pulp for biogas or bioethanol product is still costly. The cost should compete with other cheaper fuels, such as liquid palm oil waste.
		  ○ Limited market demand: there is a lack of large-scale demand for cassava pulp as biofuel due to a limited number of biogas and ethanol plants.
		  ○ Substitution: there are also other biomass residues that can be used for biofuel production. For example, the palm oil industry often uses the waste from its own factory for biogas production and this reduce the demand for cassava pulp.

Source: Interview

Unutilized portion

Utilization for bioethanol and bio-CNG is considered as a potential application, in which gov. programs are being enforced for infrastructure development

Unutilized Portion

Potential Use for Unutilized Portion	Potential Applications	• Heat generation
		• Replacing LPG for cooking
		• Blend with gasoline
		    ○ Usage for bioethanol and bio-CNG
		    ○ The government has initiated a plan to produce a 20% blend for gasoline, using alcohol, biogas/bio-CNG, and solid biomass fuel mixed with other biomass resources.

	Required support	• New biogas and bioethanol plants are needed as part of Indonesia's energy transition programs. • To support the utilization of biogas for broader applications (not limited to cassava pulp), there are several government programs supporting the development of biogas infrastructure, such as producing bio-CNG for transportation vehicles.

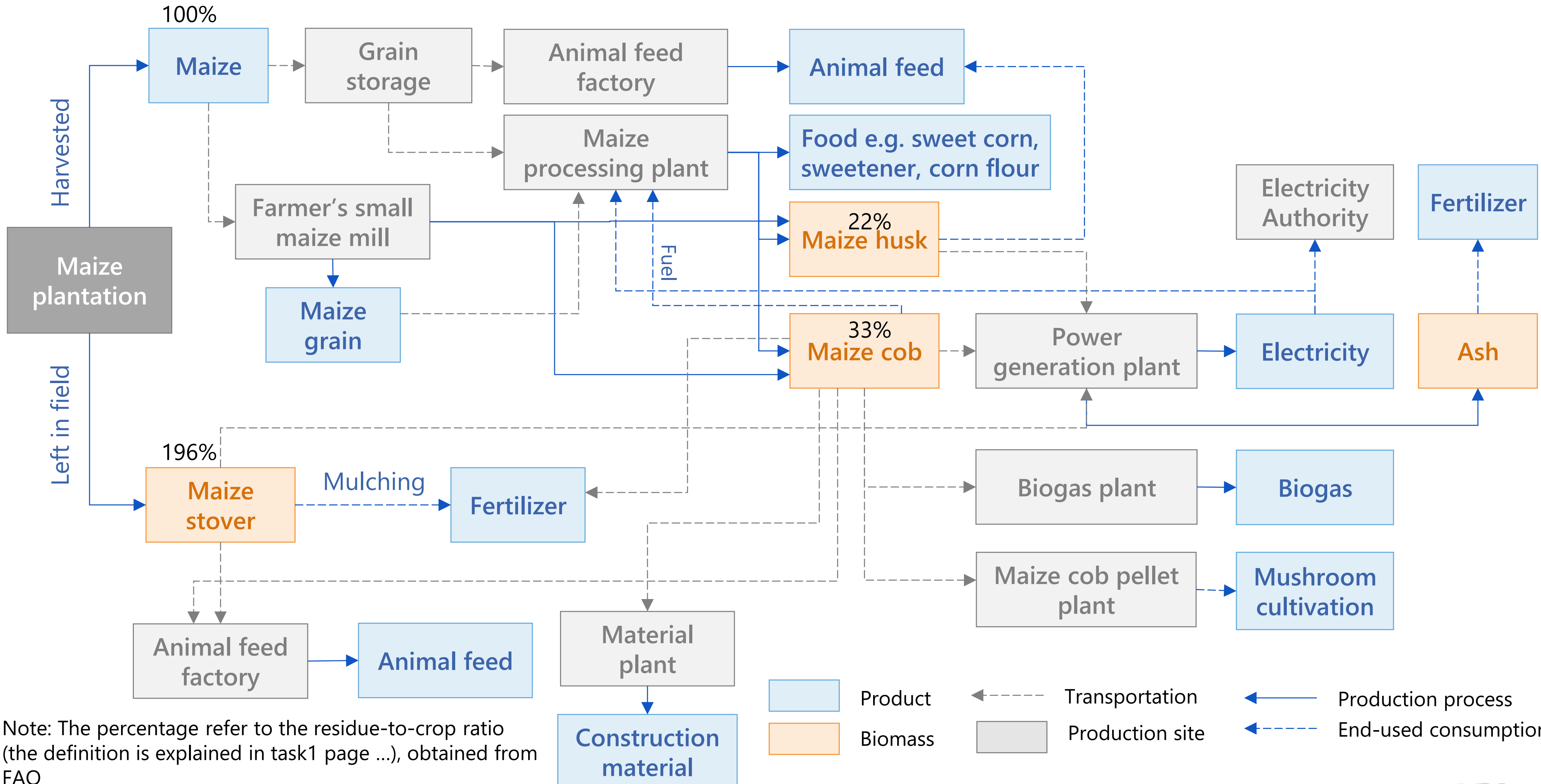
Source: Interview

Maize cob in Indonesia

Supply Chain

Maize stover is found in plantations, while maize husks and cobs are byproducts of maize processing plants.

Supply Chain



Note: The percentage refer to the residue-to-crop ratio (the definition is explained in task1 page …), obtained from FAO

Source: Interview

Current Acquisition Practice

Maize cobs are easy to collect, and the pre-processing methods vary depending on their application. For power plants, the price of cobs is fixed at 1.2 times the price of coal.

Current Acquisition Practice

Current Acquisition Practice	Collection	• Maize cobs can be collected in 2 locations:
		  ○ In the plantations area, from farmers' small maize mills or grain separating machine
		  ○ In the maize processing factories
		• Even though maize cob can be collected easily at the maize mill, each mill is scattered from each other. Therefore, collecting maize cob from many mills can be a challenge

	Pre-Processing	• For mushroom cultivation utilization
		  ○ High-quality maize cobs, selected based on buyers' criteria (e.g., Korean companies), are cleaned and are dried for moisture level less than 10% before delivery.
		• For power generation utilization
		  ○ Low-quality cobs are chopped into smaller pieces before being sent to co-firing plants or power plants

	Storage	• There is no specific method for storing maize cobs; farmers typically leave them in the field.
	Transportation	• Maize cobs are transported by trucks. • It is expensive to handle and transport the raw maize cob. Therefore, most companies choose to have their own maize cob pellet factories, producing pellet for mushroom cultivation.

Acquisition Cost		• Purchasing price for mushroom cultivation
		  ○ 63 USD (1,000,000 IDR) per ton
		• Purchasing price for co-firing plant or biomass power plant
		  ○ Cobs are sold at a government-fixed price, set at 1.2 times the price of coal.

IDR to USD conversion rate: 1 USD = 15,830 IDR (as of 7 November 2024)
Source: Interview

Utilized Portion

Maize cobs are utilized for power generation, mushroom cultivation, animal feed, roof material and soil fertilizer.

Utilized Portion

<table>
<tr><td rowspan="2">Utilized Portion</td><td>Application</td><td>• Fuel for electricity generation
• Fuel in maize processing plant
    ○ Maize processing plant can also use cob which is their own waste as a fuel for the grain drying process
• Pellet for mushroom cultivation
    ○ This application is primarily found in Java, where large Korean companies purchase maize cobs for export to Korea for mushroom cultivation.
• Animal feed
• Construction material
• Soil fertilizer (mulching)</td></tr>
<tr><td>Challenge in Utilization</td><td>• Difficulty in collection and transportation
    • Even though maize cob can be collected easily at the maize mill, each mill is scattered from each other causing difficulties for collection and high transportation cost
• High cost for power plant
    • The acquisition cost is too high for power plant to use as feedstock for electricity generation comparing to other residues
• Seasonality
    • Seasonality makes the volume of maize cob in each time of the year swing
• For mushroom cultivation
    • There are high standards for sourcing maize cobs for mushroom cultivation, which the suppliers need to take into consideration</td></tr>
<tr><td colspan="2">Utilization Outlook</td><td>• The utilization of maize cobs in power plants and co-firing may not increase, partly because the price of maize cobs as fuel for co-firing is not attractive. As a result, farmers may choose to sell the cobs for other uses instead
• The utilization of maize cobs in mushroom cultivation may keep increasing and reducing the unused portion.</td></tr>
</table>

Source: Interview

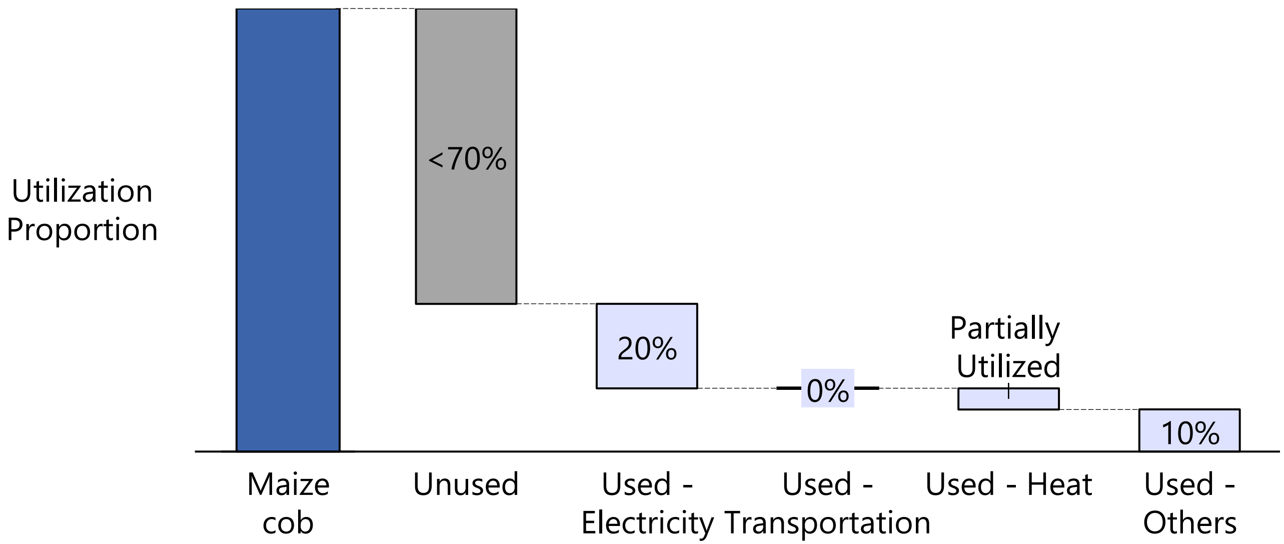
Utilization Proportion

Estimated that up to 70% of maize cob is left unused. For the used part, 20% is utilized for electricity generation and 10% for other usages e.g. mushroom cultivation and partially utilized for heat generation

Utilization Proportion

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
7.78	<5.44	1.56	0	Partially Utilized	0.78

Unit: million tons/year



Others:
- Animal feed
- Construction materials (e.g. material for roof)
- Mushroom cultivation
- Soil fertilizer (mulching)

Note: total amount is estimated based on FAO's data while utilization proportion is obtained from interview with industry's expert. The utilized amount is calculated from total amount x utilization proportion

Sources: Food and Agriculture Organization, Interview

Unutilized portion

The unutilized maize cobs are usually burnt in the field. The lack of nearby power plants increases logistical expenses, which undermines the cost-effectiveness of the supply chain

Unutilized Portion

Unutilized Portion	**Current Management**	• Burnt in the field

	Barriers to Utilization	• For electricity generation utilization:
		  ○ Outside of Java, there are few power plants near maize fields where transportation costs are reasonable. Supplying maize cobs to distant power plants would incur high transportation costs, making it economically inefficient
		• For usage of bio-CNG
		  • Currently, the government is still in the process of feasibility study. However, if the demand from commercial sector which is the potential main user of bio-CNG is not high enough, the usage of cob will be low
		  • If the price of bio-CNG is not attractive enough, people will keep using maize cob for cattle feed which have a good price and high demand

Potential Use for Unutilized Portion	**Potential Applications**	• Ethanol production ○ Ethanol production has not yet been commercialized in Indonesia and is currently still in the research phase.
	Required supports	• A strong logistics plan is essential for maize cob pellet exportation ○ Maize cob plantations and pellet manufacturers should be located near seaports to streamline transportation and reduce costs. • More power plants in the area of maize cob plantations or processing plants to drive the demand of maize cob for power generation

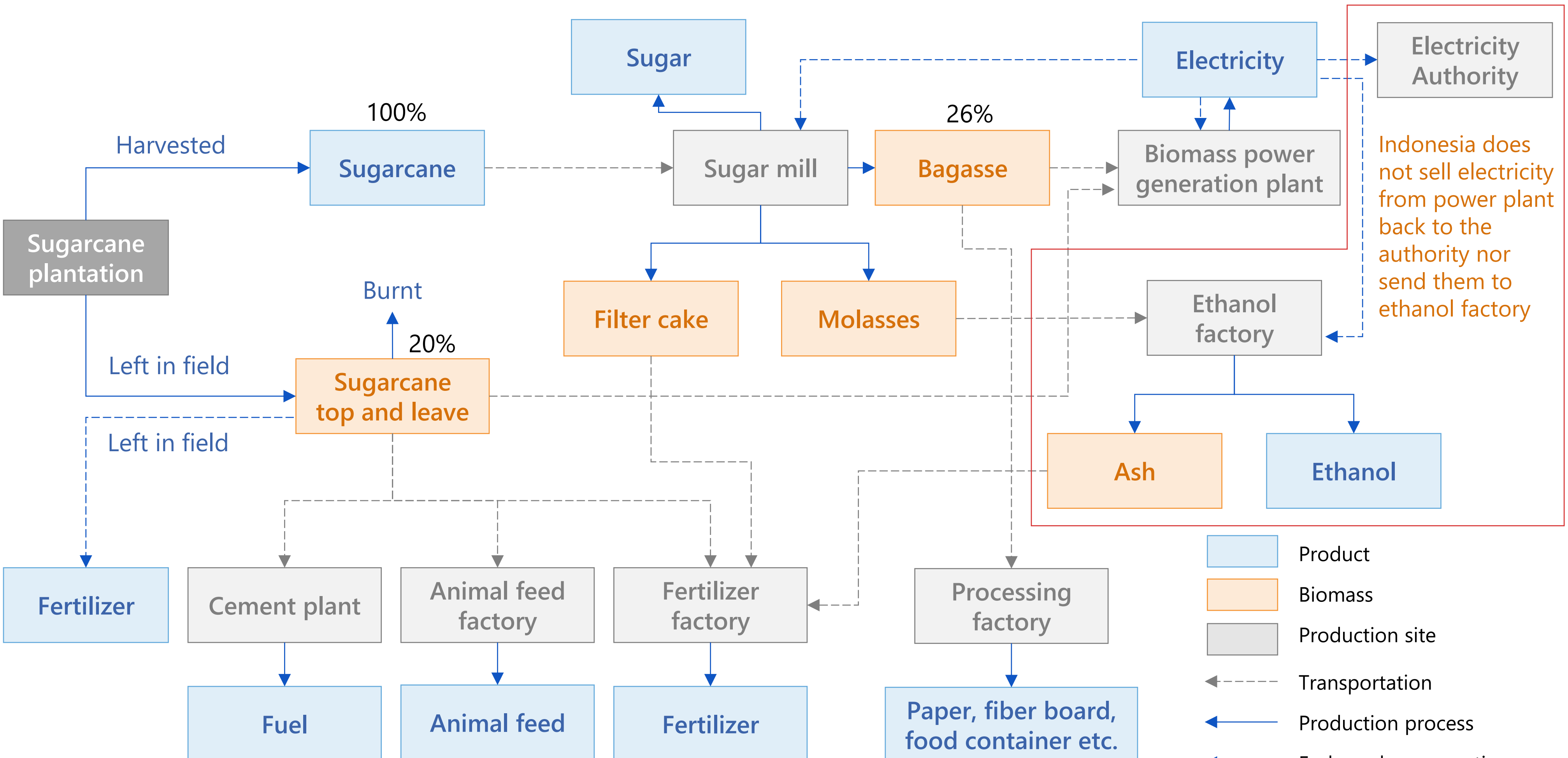
Source: Interview

Sugarcane bagasse in Indonesia

Supply Chain

Top and leave are left in the field while bagasse, molasse and filter cake are by-products in sugar mills.

Supply Chain



Source: Interview

Note: The percentage refer to the residue-to-crop ratio (the definition is explained in task1 page ...), obtained from FAO

Current Acquisition Practice

There are no major challenges in acquiring bagasse. It undergoes drying and chopping before being used as fuel. The purchasing price of bagasse is USD 31 per ton

Current Acquisition Practice

Current Acquisition Practice	Collection	• *No details on collection method* • There are no significant obstacles in collecting bagasse at the factory.

	Pre-Processing	• For electricity and heat generation
		  ○ Drying: the bagasse is often dried to reduce moisture content, making it more efficient as a fuel source.
		  ○ Size reduction: the bagasse may be shredded or chopped into smaller pieces to facilitate better combustion in the boiler.

	Storage	• *No details on storing method* • In general, sugar mills do not store excess bagasse due to the large space required for storage. Instead, they sell the surplus bagasse to other facilities, which may include other sugar mills. ○ If bagasse needs to be stored, it is compressed into a smaller volume.
	Transportation	• Bagasse is transported by truck with minimal challenges. Buyers will organize the transportation to collect bagasse. ○ However, bagasse transportation to outside factories is not frequent.
Acquisition Cost		• Purchasing price for sugar mills ○ Bagasse can be sold for 31 USD (500,000 IDR) per ton

Source: Desktop research, Interview

Utilized Portion

The primary use of bagasse is for electricity generation in sugar mills, but the supply is insufficient. Implementing new technologies for bagasse conversion could help enhance output or reducing required amount of bagasse.

Utilized Portion

Utilized Portion	Application	• Fuel for electricity generation in sugar mills (main application) ○ 90% of sugar mills use their own waste, including bagasse, for their power generation plants. The remaining 10% of sugar mills, which do not have power plants, sell surplus bagasse to other facilities that require additional fuel. • Fuel for boiler in sugar mills • Paper production

	Challenge in Utilization	• Insufficient bagasse supply
		  ○ There is insufficient bagasse to meet the demand of sugar mills, primarily due to the once-a-year harvesting period (July to December) and the resulting limited supply.
		  ○ Currently, if sugar mills face a shortage of bagasse for heat or electricity production, they purchase other biomass residues, such as woodchips, for heat generation and buy electricity directly from the local authority.
		• Technology in electricity generation
		  ○ Modern, high-efficiency facilities and boilers can convert a large amount of bagasse into electricity, enabling the full utilization (100% utilized) of available bagasse. However, sugar mills outside Java often operate with older facilities or boilers that cannot fully process all bagasse residues generated. As a result, up to 30% of the bagasse may remain unutilized.
		• Electricity selling price is not attractive
		  ○ Currently no one sell the surplus electricity to electricity authority as the electricity selling price is not attractive

Utilization Outlook		• Currently, there are limited research for new application • Even if in the future the volume of bagasse increase, it is likely that the above mentioned 3 usages will continue to be the primary utilization method

Source: Interview

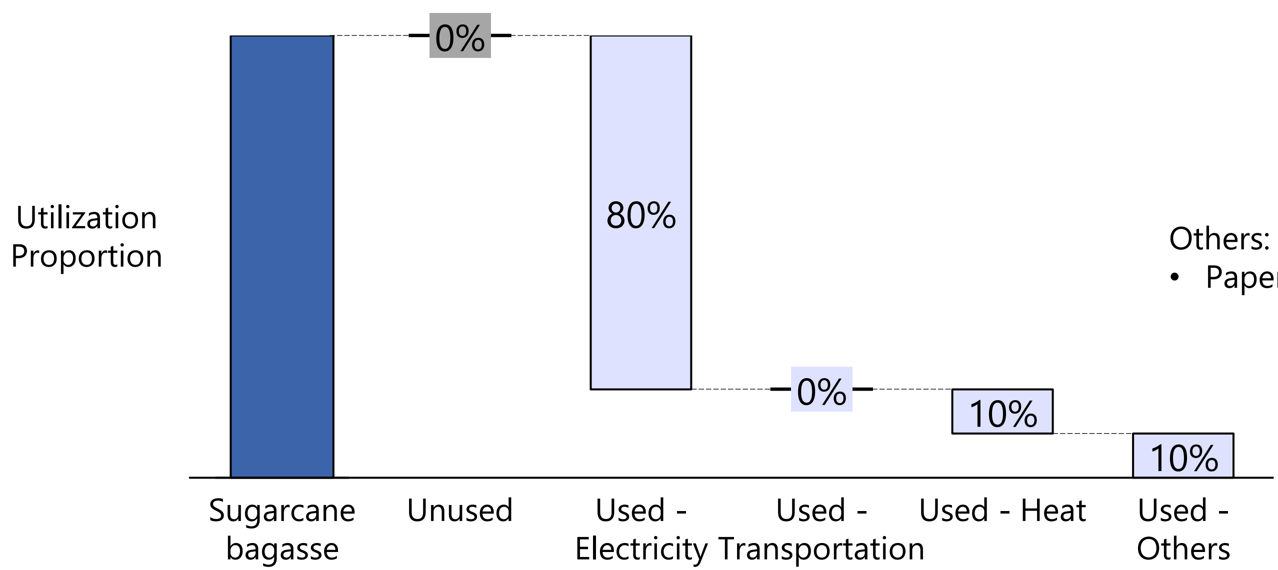
Utilization Proportion

Sugarcane bagasse is completely utilized. 80% is utilized as resource for electricity generation and small portion for heat and other productions such as paper

Utilization Proportion

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
8.42	0	6.74	0	0.84	0.84

Unit: million tons/year



Others:
- Paper production

Note: total amount is estimated based on FAO's data while utilization proportion is obtained from interview with industry's expert.
The utilized amount is calculated from total amount x utilization proportion
Sources: Food and Agriculture Organization, Interview

Wood Residues in Indonesia

Wood Types

Rubber trees, Eucalyptus and Acacia are example of the key tree types observed in Indonesia plantation

Wood Types and Usages

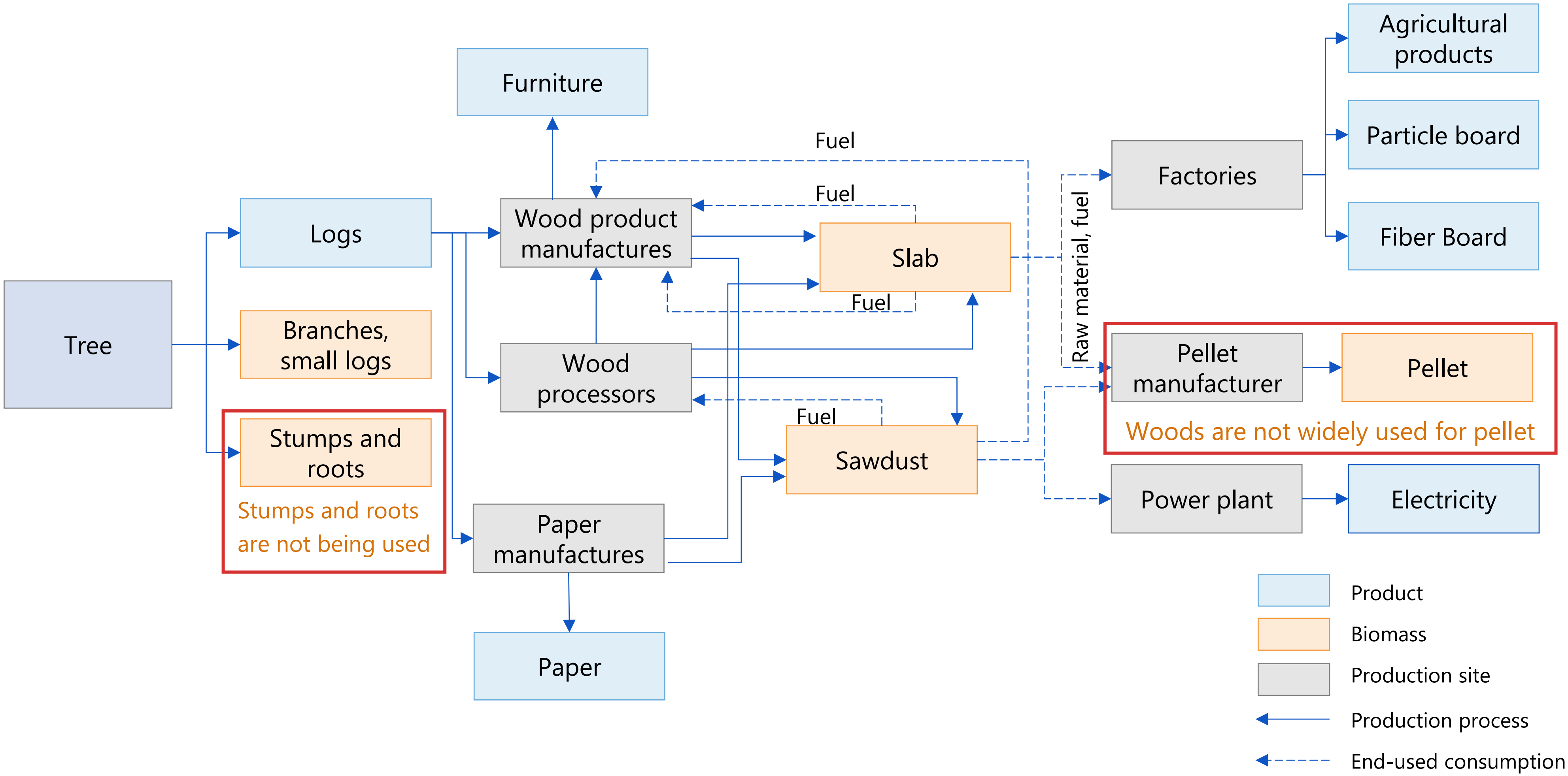
Wood Type	Plantation Type	• *No information regarding proportion of public and private plantation*
	Tree Type	Key types of trees in Indonesia include; • Rubber trees • Eucalyptus, mainly found in Papua • Acacia, mainly found in Kalimantan and Sumatra • Caliandra • Calothyrsus • Gliricidia • Sepium

Source: Interview

Supply Chain

Wood residues typically come from waste produced by the wood industry, which often has its own plantations and sawmills that produce and use the waste themselves

Supply Chain



Sources: Department of Alternative Energy Development and Energy Conservation, Caraga State University, NRI experts, Interview

Current Acquisition Practice

The main challenge in using wood residues is the high transportation cost, resulting in some residues to be left in the field

Current Acquisition Practice

Current Acquisition Practice	Collection	Branch: *no information* • Stump and root: left in the plantation • Slab: collected from manufacture • Sawdust: collected from manufacture
	Pre-Processing	• *No information*
	Storage	• Sawdust and slabs: stored in regular storage to protect them from the rain
	Transportation	• Small trucks are used to transport the wood residues. • One major challenge in transporting wood residues is the high transportation cost. ○ The distance from the sawmill to the pellet factory is typically less than 100 km. • With high transportation costs, some residues, such as small logs, stumps, and roots, are left in the field due to inefficiency in cost.
Acquisition Cost		• Final cost of wood residues is 58-77 USD (900,000-1.2 million IDR) per ton • The selling price differs based on whether it is dry or wet, in which dry sawdust can be 2-3 times higher in price compared to wet sawdust with 60-70% moisture

IDR to USD conversion rate: 1 USD = 15,565 IDR (as of 7 November 2024)

Source: Interview

Utilized Portion

Applications for slab and sawdust include usage for power generation and heat

Utilized Portion

Utilized Portion	**Application**	• Slab: ○ Used for electricity generation (co-firing) ○ Used for heat generation in factories ○ Processed into briquettes, which are then carbonized to produce charcoal ○ Used for wood pellet production ▪ The wood pellet industry produces a maximum of 1,500 tons per month. ○ Used for particle board production ○ Used in soy products • Sawdust: ○ Used for electricity generation (co-firing) ○ Used for heat generation in factories ○ Processed into briquettes, which are then carbonized to produce charcoal ○ Used for particle board production

Source: Interview

Utilized Portion

Compatibility and transportation cost is an issue, in which technological advancement may support the improvement in the compatibility

Utilized Portion

Utilized Portion	Challenge in Utilization	• Compatibility
		  ○ Boilers in many power plants are not compatible with rubber tree residues as feedstock, which affects the combustion process when generating electricity with the existing boilers.
		  ○ Especially for co-firing biomass residues with coal is more complex because it may require specific types of trees. Testing the biomass is essential to avoid potential damage to the boiler. If the test results are favorable, the biomass residues can be used for co-firing.
		  ○ Technological advancements may address this challenge by allowing biomass residues to be integrated into the boiler without compromising performance or safety.
		• Transportation costs are also high, causing limitations to the usage

Utilization Outlook		• If the price of wood materials used for producing charcoal, briquettes, and pellets increases, the demand for these materials is expected to grow correspondingly.

Source: Interview

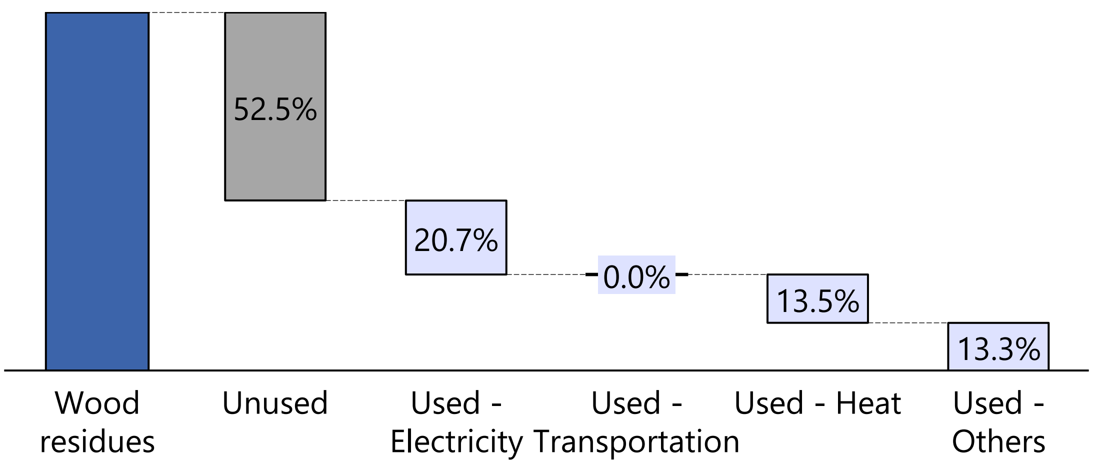
Utilization Proportion

In overall, half of wood residues, mainly stump and root, is still unutilized. Around 20% is used for electricity generation and 14% for heat generation.

Utilization Proportion

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
42.36	22.25	8.77	0	5.71	5.63

Unit: million tons/year



Others:
- Particleboard production
- Charcoal production

Note:
1. this total amount of wood residues is the sum of amount of each wood residue (stump & root, branch & tip, slab and sawdust)
2. the utilized amount of wood residues for each application is the sum of the utilized amount of each wood residue (stump & root, branch & tip, slab and sawdust) for each application
3. Then, the percentage of each application is calculated based on the result of step 1 and 2

Sources: Food and Agriculture Organization, Interview

Unutilized portion

Major challenges in utilizing wood residues is the high transportation cost.

Unutilized Portion

Unutilized Portion	Current Management	• Branches and tips are left in the plantation because of a tax imposed on removing materials from the site.
	Barriers to Utilization	• Major challenges in utilizing wood residues is the high transportation cost. Some residues, with low value are not cost-effectively used.
Potential Use for Unutilized Portion	Potential Applications	• *No information*
	Required support	• *No information* • *No information*

Source: Interview

Government Policies in Indonesia

Government policy

Indonesian government set target to reach 31% of RE in total energy supply by 2050. In order to achieve that target, more usage of biomass is encouraged

Government Policies

	Policy	Description	Issuers	Effective year
Government Policies	Government Regulation No. 79/2014 National Energy Policy (KEN)	• The plan sets goals of reaching a 23% share of RE in total energy supply by 2025 and 31% by 2050 • The use of renewable energy from biomass is stated to be directed to electricity and transportation	Government of Indonesia	2014
	President Regulation No. 22/2017 National Energy Plan (RUEN)	• The plan aims to achieve the objectives of the KEN and national goals for economic growth, energy independence and energy security, and serves as a guideline for energy planning until 2050 • It calls for 45.2 GW of RE capacity to be installed by 2025 to meet the 23% RE share of total energy supply stipulated in the KEN • By this regulation, business entities providing electricity are required to purchase electricity from biomass power stations • Additionally, this regulation encourages the construction of at least 1 biomass power station unit in each province outside Java	Minister of Energy and Mineral Resources	2017
	Ministerial Regulation (PERMEN ESDM) No. 27/2014	• This regulation was issued specifically to incentivize biomass/biogas power plant project development. It introduced higher base tariffs and uplift factors than the previous version of regulation • The base tariffs are now defined separately for biomass power plants and biogas power plants. In general, the tariff for a biomass power plant is higher, around 1.15-1.50Rp/kWh • The regulation also outlines a more transparent procedure for project development	Minister of Energy and Mineral Resources	2014

Source: Minister of Energy and Mineral Resources, News, IEA, AGEP

Government policy

Several policies and regulations were launched in order to encourage the biomass usage especially as feedstock for co-firing

Government Policies

	Policy	Description	Issuers	Effective year
Government Policies	**Electricity Supply Business Plan (RUPTL) 2021-2030**	• The plan outlines the state electricity company or PLN's plan to increase renewable energy capacity and mix coal with biomass for coal fired power plants • The RUPTL identifies 18,895 MW capacity of coal-fired power plants located in 52 locations that have the potential for co-firing. This would generate 2.7 GW of electricity from renewable energy and require up to 14 million tons of biomass fuel per annum. • To achieve the target for 23% renewable energy by 2025, co-firing is planned by mixing coal with 10% - 20% biomass fuel (currently at 5%), and the design of new coal-fired power plants that are planned to operate after 2025 must enable them to use a minimum of 30% biomass fuel • The RUPTL also provides annual roadmap for the development and new installed capacity of biomass from 2021 to 2030 with total capacity of 590MW.	Minister of Energy and Mineral Resources	2021
	Presidential Regulation No. 112/2022	• This regulation guarantees that electricity purchases from biomass power station will use the highest standard price. • This regulation also introduces a moratorium on new coal-fired power plants and sets a phase-out plan for unabated coal power generation by 2050, promoting biomass as a substitute during this transition.	Minister of Energy and Mineral Resources	2022

Source: Minister of Energy and Mineral Resources, News, IEA

Government policy

Apart from high pricing for biomass in co-firing, incentives are provided to private and state companies involved in the RE business

Government Policy and Incentive

	Policy/ Incentive	Description	Issuers	Effective year
Government Policies	Energy and Mineral Resources Minister Regulation No. 12/2023	• This regulation outlines the utilization of biomass as a fuel mixture for co-firing in coal-fired power plants owned by state-owned electricity company (PLN), aiming to enhance the use of renewable energy sources during Indonesia's energy transition. Examples of target biomass are wood dust, wood chips, palm shell and rice husk. • Biomass users shall purchase biomass from a provider based on the highest benchmark price calculated with the coal price. The pricing is set at 1.2 times the coal price (CIF price)	Minister of Energy and Mineral Resources	2023

Government Incentive	Energy Law No. 30/2007	• The law includes incentives for private and state companies involved in the distribution and utilization of renewable energies, including biofuels
		• The law authorizes the government to provide facilities and incentives to companies and individuals for renewable energy supply. This follows various laws on taxes and duties, which allow for tax facilities for strategic activities with respect to income tax, value-added tax (VAT), and import taxes and duties. Examples of the incentives are as following
		    • An investment tax deduction equivalent to 30% of fixed capital investment, applied as 5% over 6 years
		    • Exemption from import tax on machines and equipment, excluding spare parts; depending on the imported good, this can be as much as 7.5% of the declared value
			Government of Indonesia	2007

Source: Minister of Energy and Mineral Resources, News, IEA, ADB

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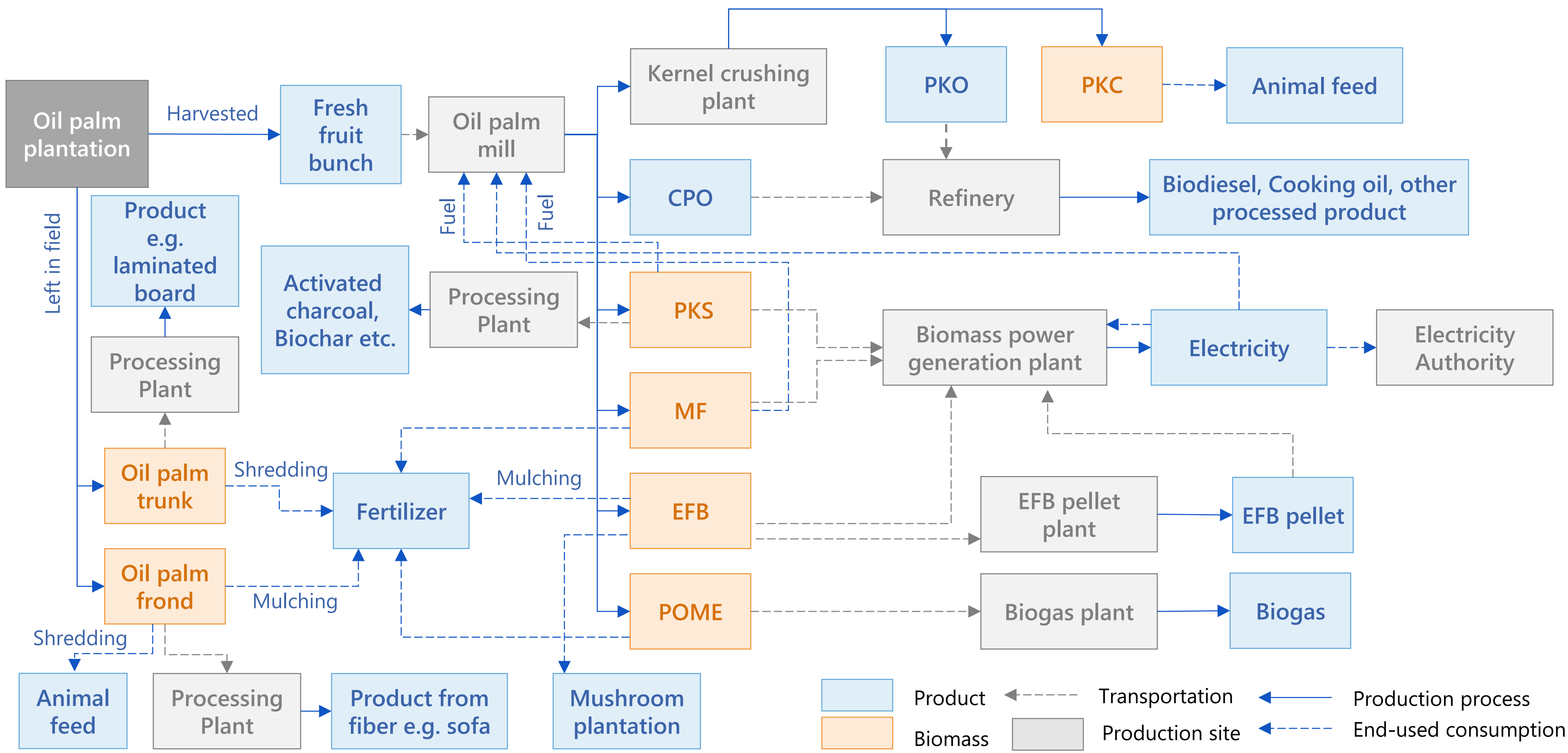
Oil Palm in Malaysia

Supply Chain

Trunk and frond are found in plantation while PKS, MF, EFB, POME and PKC are residues from oil palm processing.

Supply Chain



Note: CPO=Crude Palm Oil, PKS=Palm Kernel Shell, MF=Mesocarp Fiber, EFB=Empty Fruit Bunch, POME=Palm Oil Mill Effluent, PKO=Palm Kernel Oil, and PKC=Palm Kernel Cake

Source: Interview

Current Acquisition Practice

EFB requires more preprocessing than PKS. The residues aimed for export also require more proper storage method to meet criteria of target buyers

Current Acquisition Practice

		Empty bunch (EFB)	Shell (PKS)
Current Acquisition Practice	Collection	• Empty bunches can be collected at the conveyer belt area right next to the mills	• Palm shell can be collected in the Kernal crushing plant after the production of Palm Kernal Oil (PKO)
	Pre-Processing	• EFB requires pressing and cutting before usage. These pre-processing will able to reduce moisture content from roughly 75% to around 50-60%	• No need as the shell is already being processed in the production of PKO

	Storage	• For local or internal usage
		  • Oil palm residues will be stored in open air space on normal ground
		• For export
		  • Oil palm residues will be stored in a tower storage with cement flooring to control the moisture content. Residues for export must pass certain criteria such as having contamination less than 2,000 PPM*. Storing them on a normal ground will risk contaminating up to 16,000 PPM, therefore a proper storage is preferred
		  • The residues will be stored at the stock park which located near the port for better logistics	

	Transportation	• Lorry or truck are mainly used for the transportation • Transportation distance is very short for mulching application as the mills and the plantation are usually located near each other (e.g. in a range of 0.2-10km.)	• Lorry or truck are mainly used for the transportation
Acquisition Cost		• Purchasing price: 0.45 – 2.72 USD (2-12 MYR) per ton • Purchasing price of EFB pellet for local usage: 90.9 – 102.2 USD (400-450 MYR) per ton	• Purchasing price for local usage: 59-68.1 USD (260-300 MYR) per ton

Note: Parts per million (PPM) is a unit used to measure the concentration of contaminants in water, soil, and other substances
MYR to USD conversion rate: 1 USD = 4.40 MYR (as of 7 November 2024)
Source: Interview

Utilized Portion

Both empty bunch and shell can be used for electricity generation. However, usage of the shell will differ based on the capacity of oil palm mills

Utilized Portion

		Empty bunch (EFB)	Shell (PKS)

Utilized Portion	Application	• Used for electricity generation
		• Used for EFB pellet production
		  ○ 85-90% of EFB pellet is exported to Japan and Korea
		• Use for mulching
		• Used for mushroom cultivation
			• Used for electricity generation
			  • Large mills, roughly 50% of the total 450 mills, with excess PKS from internal usage usually sell the residue to other parties, which is mainly for electricity generation. Almost 20% of total PKS is exported and majority is sold to Japan
			• Used as fuel for boiler in palm mills
			  ○ Small mills on the other hand will usually use all available PKS as fuel to start heating up the boilers
			• Biochar and activated charcoal
			  ○ There are usage of PKS for biochar but it is not widely used as the biochar from coconut shell is better in quality. Therefore, PKS biochar is seen as a second grade, and only used in small amounts
			• Slow-release fertilizer
			• Cement replacement material

Source: Interview

Utilized Portion

PKS has minimal challenge, while the empty bunch has difficulties from bulkiness and lack of required technology

Utilized Portion

		Empty bunch (EFB)	Shell (PKS)

Utilized Portion	Challenge in Utilization	• Bulkiness
		  • EFB need to be cut into smaller piece before utilization. Hence it is difficult and expensive to handle and transport
		• Some mills are lack of power supply
		  • Many mills are located in a remote location near plantation area with limited electricity. In this case, many will have to use 100% of the electricity to produce the oil. Hence, many mills do not have enough power to process and treat EFB properly
		• Lack of investment in technology and machine
		  • Higher content of "Lignin" in EFB compared to many hardwood can damage the normal wood pellet making machine. Therefore, EFB should not use the same machine as the wood pellet and require additional investment. So, it is a challenge for low budget farmer to acquire such machine
			• There are no challenges in utilizing PKS; however, the supply poses a challenge. The available volume of PKS is insufficient to meet the growing demand.

Utilization Outlook		• Increase in bioenergy usage
		  • The expert anticipate that in the future, more of both EFB and PKS will be used for bioenergy usage such as electricity generation
		  • The background is that, in 2026, more data centers are planned to be built in Malaysia. Data centers require a large volume of electricity to operate, and the Malaysian government has established regulations to promote the use of bioenergy in order to achieve 31% renewable energy capacity by 2025.
		  • It is expected that bioenergy from biomass will be prioritized, hence the demand for biomass in general should increase in a near future	

Source: Interview

Utilization Proportion

60% of EFB is unutilized while only 10% of PKS left unused. Main application of PKS is electricity generation.

Utilization Proportion

Empty bunch

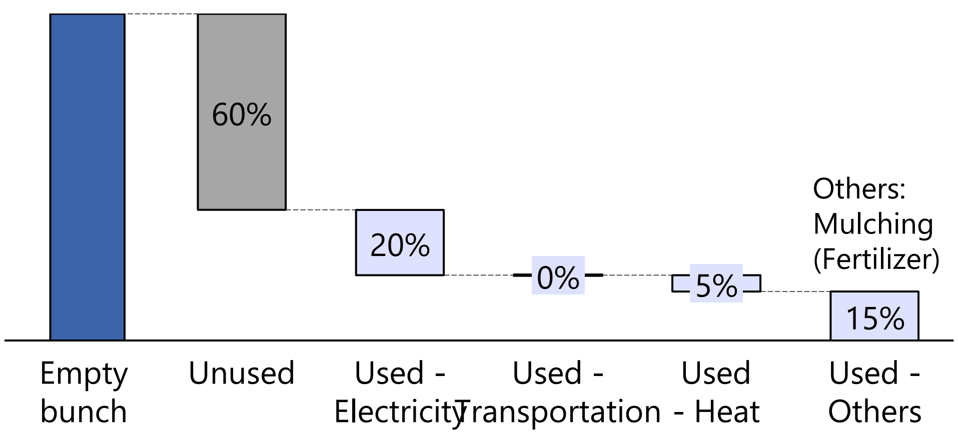
Unit: million tons/year

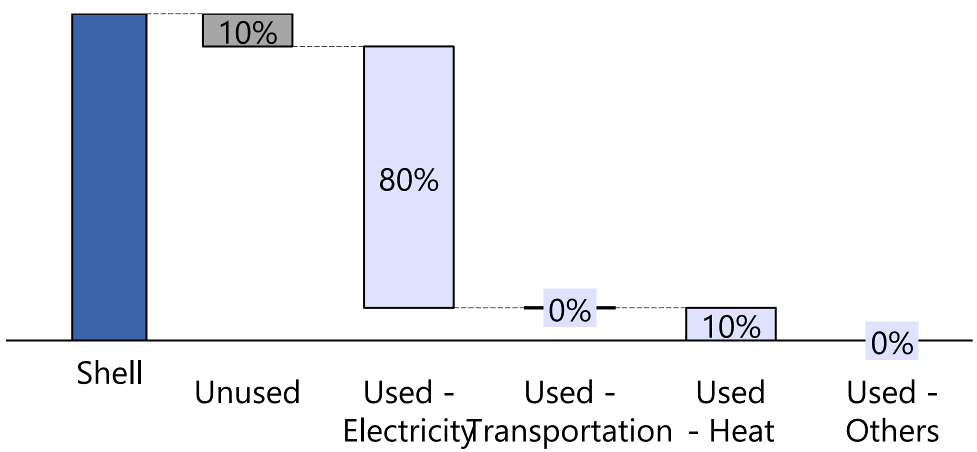
Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
28.68	17.21	5.74	0	1.43	4.30

Shell

Unit: million tons/year

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
5.55	0.56	4.44	0	0.56	0





Note: total amount is estimated based on FAO's data while utilization proportion is obtained from interview with Industrial's experts
The utilized amount is calculated from total amount x utilization proportion.

Sources: Food and Agriculture Organization, Interview

Unutilized portion

Transportation, limited resources and machine are the main difficulty that leads to non-utilization of EFB

Unutilized Portion

Unutilized Portion	Current Management	• Despite having standards like MSPO and RSPO prohibiting farmers from dispose EFB, in practice majority of EFB is disposed secretly in the landfill
	Barriers to Utilization	• As many mills are located in a remote location with limited electricity, facilities, and processing machine with limited budget, unused EFB is thrown away rather than to be processed or transported
Potential Use for Unutilized Portion	Potential Applications	• Electricity generation • Fertilizer • Mushroom cultivation
	Required support	• New technology to do the value added to the EFB in an accessible price such as pellet making machine that suitable for EFB which is does not require too much additional investment for farmers

Source: Interview

Wood Residues in Malaysia

Wood Types

The main sources of wood residues in Malaysia are rubber trees, Acacia mangium, Eucalyptus, teak, Sentang, and others

Wood Types and Usages

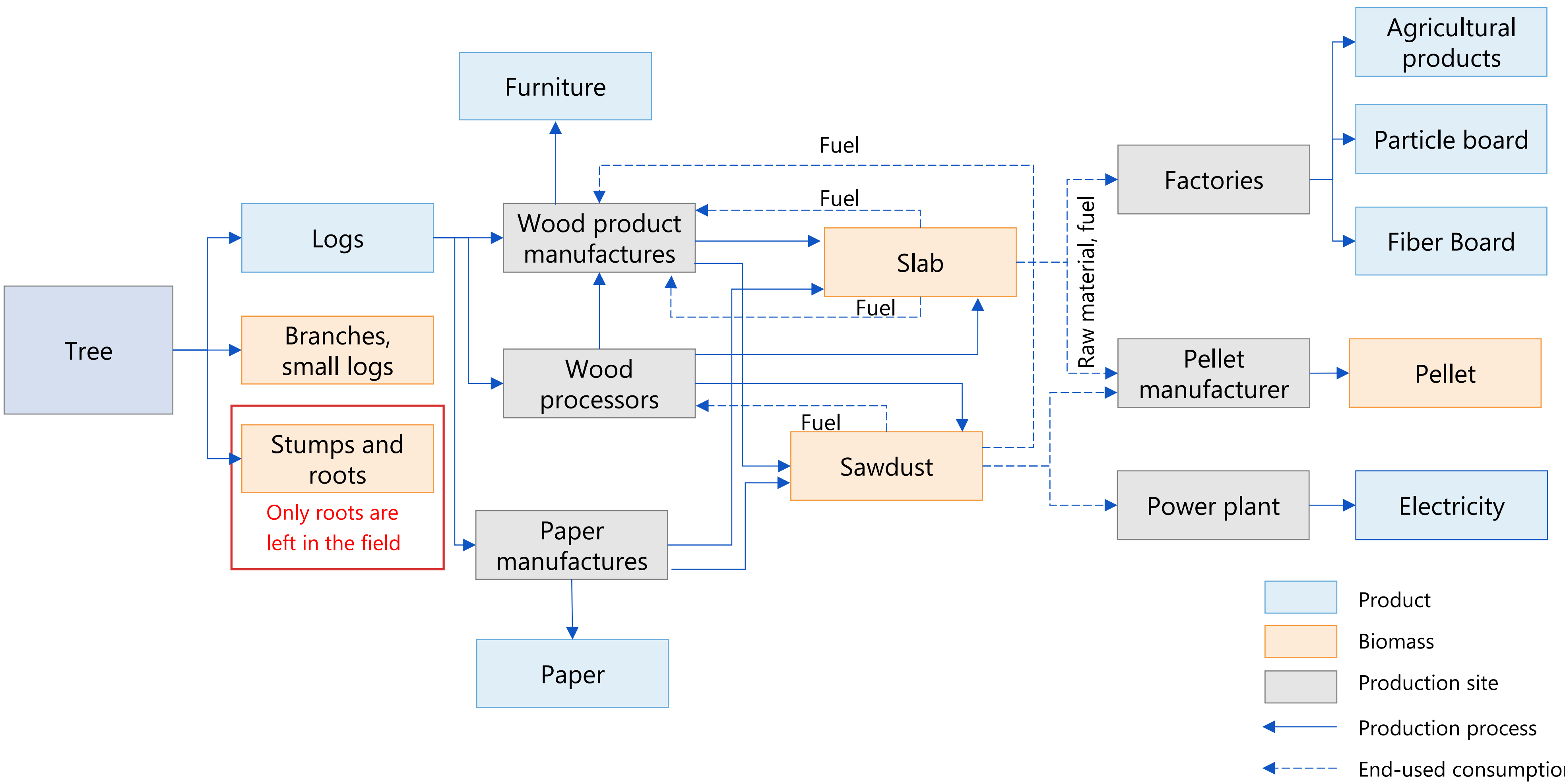
Wood Type	Plantation Type	• *No information*	
	Tree Type	• Rubber (getah) • Acacia mangium • Eucalyptus • Teak • Sentang • Karas	• Kapur • Mahagony • Paraserianthes, • Merawan • Pine • others

Source: Ministry of Plantation and Commodities, Universiti Teknologi PETRONAS

Supply Chain

Logs, branches, stumps, and roots are sourced from the plantation, with only the roots left unused, while slabs and sawdust are produced by wood processors

Supply Chain



Sources: Department of Alternative Energy Development and Energy Conservation, Caraga State University, NRI experts, Interview

Current Acquisition Practice

Wood residues are typically allocated to regular customers or through contracts, transported using lorries, with costs influenced by logistical distance and certifications

Current Acquisition Practice

Current Acquisition Practice	Collection	• Wood residues, such as slab and sawdust, are produced and collected from sawmills and other timber processing factories, including plywood, veneer, and molding facilities. • Wood residues are typically allocated to regular customers or through contracts, but new buyers often drive-up prices due to competition for large-scale purchases.
	Pre-Processing	• Wood residues needs to go though the shredding process, which cut wood into small pieces.
	Storage	• Wood residues are stored in silo or open spaces within the factories.
	Transportation	• Transportation is done using lorries to transport the material from the plantation to the factory. • The transport frequency depends on the availability of lorries. However, with a limited number of lorries, collection may not occur daily. If there are not enough lorries, the expert may contact other factories to borrow one.
Acquisition Cost		• The FOB price of the woodchip: 160 USD per metric ton. • The FOB price of the wood pellet: 130 USD per metric ton. • On average, the raw material cost for wood residues ranges from 130 to 150 Malaysian Ringgit, approximately 29 to 30 USD per ton. This price applies to residues sourced from both forestry and other factories, such as sawmills. • The cost is influenced by logistical factors, including transportation, which can add about 40 USD for each 50-kilometer distance required to deliver the material to the factory. • The price can also be affected by certifications, such as PEFC (Program for the Endorsement of Forest Certification), FSC (Forest Stewardship Council), and GGI (Global Green Certification Initiative), which are required for certain exports. These certifications can limit the types of wood residues that can be used and complicate the procurement process.

Source: Ministry of Plantation and Commodities, Universiti Utara Malaysia, Rhenus Logistics, interview

Utilized Portion

Wood residues are used for electricity and heat generation, as well as for raw materials in wood pellets, biocomposites, MDF, and more

Utilized Portion

Utilized Portion	Application	• The utilization of wood residues in Malaysia is primarily divided into three categories: electricity generation, heat production, and raw materials for manufacturing.
		  • Electricity generation: Less than 10% of the wood residues are currently used for electricity generation within the factories. This is mainly due to recent initiatives, with power plants starting to use wood residues as a coal replacement three years ago.
		    • One notable example is the Tanjung Bin power plant, which has started using 1.5% wood residues mixed with coal and aims to increase this usage to 15% in 10 years.
		  • Heat generation: The use of wood residues for heat within the factories depends on the price of oil, which is relatively cheap in Malaysia compared to other Southeast Asian countries. When oil prices are high, more wood residues are used for heating purposes, with a typical breakdown of 45% for heat production.
		  • Raw materials: The remaining 45% of wood residues are used as raw materials for products such as wood pellets, chipboard, and particle boards. The demand for wood residues as raw materials can fluctuate depending on market prices and the demand from local industries.
		
		• Utilization of wood by types of residues:
		  • Barks, stumps, tips, branches, and small logs: The forestry department encourages using residues such as barks, stumps, tips, branches, and small logs for mulching. However, this practice is now less emphasized, and these residues can be repurposed for other uses.
		  • Sawdust: Commonly utilized for wood pellet and biocomposite production, primarily targeting export markets. Other uses, such as animal bedding and mushroom farming, exist but have lower demand, with rice husks being more commonly preferred in the northern and central regions.
		  • Offcuts, including slabs, sawdust, and wood chips: Primarily used for medium-density fiberboard (MDF), particleboard, and chipboard production, as well as eco-friendly fuel for biomass boilers in industries like glove manufacturing, steel production, and cement plants.

Source: Ministry of Plantation and Commodities, Interview

Utilized Portion

Challenges such as declining wood biomass availability, limited R&D, and financial constraints hinder wood residue utilization; however, their use in electricity generation is expected to grow significantly in Malaysia by 2035

Utilized Portion

Utilized Portion	Challenge in Utilization	• Decreasing demand for wood-based products:
		  • The demand for wood-based products, such as furniture and timber, has significantly decreased, primarily due to the global economic downturn following COVID-19.
		  • As a result, many wood-based factories are now operating at less than 50% capacity, with some even facing potential closure. Consequently, the available biomass has also declined, with biomass availability in 2024 dropping to only half of the 3.9 million reported in 2021.
		• Limited Research and Development (R&D):
		  • Biomass R&D is heavily focused on oil palm due to its abundance, while R&D in wood biomass energy production is minimal.
		  • Rubberwood industry-related agencies prioritize natural rubber and latex over biomass utilization.
		  • Biomass energy production is often limited to large mills due to high capital costs, with small and medium enterprises (SMEs) unable to enter the market.
		• Financial constraints:
		  • Biomass energy projects require substantial capital investments, and financial institutions are hesitant to fund these due to perceived high risks and infancy of the sector.
		  • Issues such as low investor confidence, lack of experience, and absence of suitable financing models hinder project development.

Utilization Outlook		• The utilization of wood residues in Malaysia is likely to increase in the future, particularly in electricity generation, as demand grows from factories switching from coal to woody biomass/EFB pellets. The share of wood biomass used for electricity generation could potentially rise to around 30% by 2035

Source: NC State University, Interview

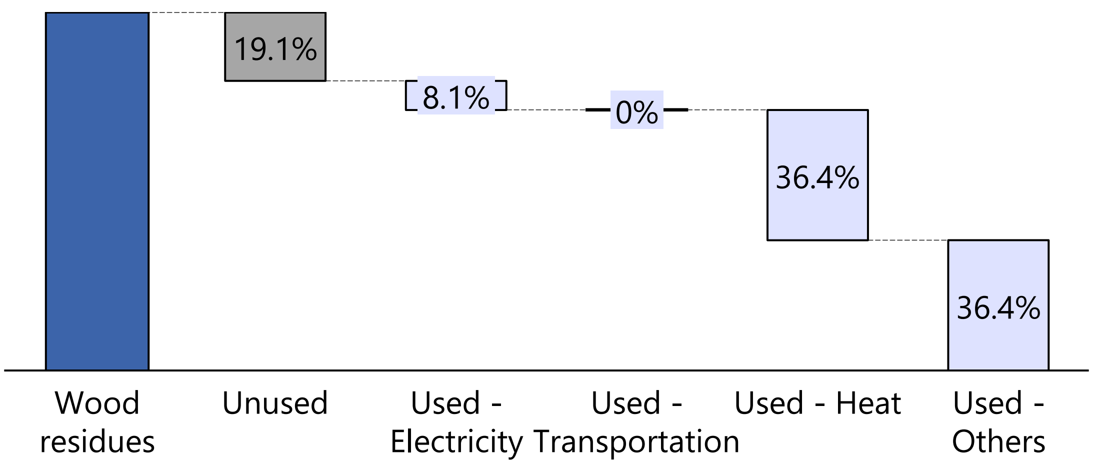
Utilization Proportion

Wood residues in Malaysia are mostly used for heat generation and non-energy use such as fiberboard and particle board production. 8% is for electricity generation. Around 19% is unutilized, which is the root part

Utilization Proportion

Unit: million tons/year

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
7.37	1.41	0.60	0	2.68	2.68



Others:

- Medium-density fiberboard (MDF), particleboard, and chipboard production

Note:

1. this total amount of wood residues is the sum of amount of each wood residue (stump & root, branch & tip, slab and sawdust)
2. the utilized amount of wood residues for each application is the sum of the utilized amount of each wood residue (stump & root, branch & tip, slab and sawdust) for each application
3. Then, the percentage of each application is calculated based on the result of step 1 and 2

Sources: Food and Agriculture Organization, Interview

Unutilized portion

Roots face challenges in utilization due to extraction costs and technological limitations but have potential for conversion into biochar and activated carbon

Unutilized Portion

Current Practice for Unused Portion	Current Management	• Roots are typically left discarded in the plantation after logging, without being burned. • Occasionally, roots are used for specific purposes, such as burning material for dryers in the factory, but they are not commonly utilized.
	Barriers to Utilization	• Lack of technology and machinery to efficiently extract roots from the ground. • The wood residues primarily come from hardwood trees, which are harder to process than softer woods, making them more difficult to grind and break down into smaller particles. • High costs are associated with removing roots for further utilization, as operators are taxed based on the weight of the material transported by lorries, and roots are typically quite heavy.
Potential Use for Unused Portion	Potential Applications	• The potential use of tree roots lies in their conversion into biochar and activated carbon, which can be used in industrial applications like steel mills as a replacement for cokes (a carbon-rich material derived from coal). This is especially relevant in countries like Japan, Korea, and Europe, where steel mills are actively seeking sustainable alternatives to coal and cokes. • The demand for biochar is significant, with Japan's steel industry requiring around 500,000 metric tons annually, equivalent to the total wood pellet production in Malaysia. This indicates a strong export potential for Malaysia if production capacity for biochar is increased.

	Required Resources and Infrastructure	• Technological development:
		  • Continuous production technology: Currently, biochar production is done in batches due to the difficulty in maintaining consistent temperature and pressure. There is a need for technological advancements to enable continuous production, which would improve efficiency and capacity.
		  • Improved processing equipment: Specialized equipment is needed to efficiently extract roots from plantations and process them into biochar or activated carbon. This would require investment in research and development to create better machinery.

Source: Interview

Government Policies in Malaysia

Government policy

MyRER outlines strategic initiatives to achieve 31% renewable energy by 2025 and 40% by 2035, focusing on solar, bioenergy, hydro, and new solutions

Government Policy

	Policy	Description	Issuers	Effective year

Government Policy	Malaysia Renewable Energy Roadmap (MyRER)	MyRER is designed to support the national goals of achieving 31% renewable energy (RE) capacity by 2025 and 40% by 2035, under the guidance of the Ministry of Energy and Natural Resources.
		• Key objectives of MyRER:
		  • Increase RE capacity: Achieve an increase of 4,466 megawatts (MW) in renewable energy (RE) capacity, reaching 12,916 MW by 2025, up from 8,450 MW in 2020. By 2035, the capacity is expected to further rise to 17,996 MW.
		  • Reduce carbon emissions: Reduce the carbon emissions intensity in the electricity supply sector by 45% by 2030 compared to 2005 levels, and by 60% by 2035.
		• MyRER's strategic framework is built upon four pillars:
		  1. Solar: Aim for 4,706 MW of installed capacity by 2025 through rooftop photovoltaic deployment and large-scale solar projects.
		  2. Bioenergy: Expand biomass, biogas, and waste-to-energy capacity under FiT with new business models (e.g., auctions), targeting 862 MW from biomass and 333 MW from biogas by 2025, while exploring opportunities in bio-CNG and biomass co-firing.
		  3. Hydro: Achieve 5,862 MW from large hydro and 1,153 MW from small hydro by 2025 through FiT auctions and hydro-geological studies.
		  4. New Solutions and Resources (post-2025): Explore new renewable energy technologies and assess energy storage systems for grid stability beyond 2025.
			The Energy and Natural Resources Ministry (KeTSA)
			
			Sustainable Energy Development Authority (SEDA)
				2021

Source: SEDA, MIDA, articles

Government policy

The National Biomass Action Plan 2023–2030 by KPK aims to unlock Malaysia's biomass potential for sustainable development, green wealth creation, and net-zero emissions through various strategies

Government Policy

	Policy	Description	Issuers	Effective year

Government Policy	National Biomass Action Plan (NBAP) (2023–2030):	The National Biomass Action Plan (NBAP) 2023–2030 is Malaysia’s strategic framework to maximize the potential of its abundant biomass resources from plantations, forests, agriculture, livestock, and fisheries through sustainable development, economic growth, and environmental sustainability.
		• Strategies of the NBAP include:
		  • Accessing biomass feedstock through diverse strategies, including joint ventures with feedstock owners.
		  • Exploring and assessing the feasibility of the biomass hub concept.
		  • Encouraging private sector participation in biomass research and development (R&D). Focusing on high technology readiness levels (TRL) with quick-win commercialization opportunities.
		  • Bridging knowledge gaps on soft loans and grants to facilitate innovation.
		  • Developing and implementing technology-driven business models.
		  • Reviewing and adopting constructive findings from international best practices related to biomass policies.
		• The plan aims to drive sustainable development, create green wealth, achieve net-zero emissions, generate RM 17 billion by 2030, and advance biomass innovations such as biofertilizers, fuel pellets, and bio-based carbon products.
			The Ministry of Plantation and Commodities (KPK)	2023

Source: Interview, The Ministry of Plantation and Commodities

Government policy

DAKN 2030 provides a strategic framework to drive sustainability, productivity, and market growth across Malaysia's agricommodity sector

Government Policy

	Policy	Description	Issuers	Effective year
Government Policy	**National Agri-commodity Policy 2021-2030 (DAKN 2030)**	The National Agricommodity Policy 2021-2030 (DAKN 2030) is Malaysia's strategic framework designed to guide the development of its agricommodity sector over the next decade. It sets clear directions and targets across five policy thrusts: sustainability, productivity, value creation, market development, and inclusiveness. Strategies will be implemented across eight commodities, including: • Palm Oil: Leveraging smart partnerships for technological adoption in the palm oil industry. • Rubber: Synergizing the transformation of the rubber industry value chain. • Timber: Modernizing the timber industry to increase resilience. • Cocoa: Driving the development of the cocoa industry. • Pepper: Fostering the growth of the pepper industry. • Plant-Based Fibers: Revitalizing the plant-based fibers industry. • Biomass: Scaling up the circular economy through agricommodity biomass. • Biofuels: Promoting biofuels as a source of clean energy.	Ministry of Plantation Industries and Commodities (MPIC)	2022

Source: Interview, Ministry of Plantation Industries and Commodities, news

Government policy

The MSPO Certification Scheme promotes sustainable and legal palm oil practices in Malaysia, aiming to become a globally recognized standard

Government Policy

	Policy	Description	Issuers	Effective year

Government Policy	**The Malaysian Sustainable Palm Oil (MSPO) Certification Scheme**	The MSPO Certification Scheme is a national initiative designed to ensure the sustainability, legality, and competitiveness of the palm oil industry. It aims to promote sustainable production practices, adherence to environmental, economic, and social standards, and compliance with legal requirements.
		• The government supports the scheme with incentives for industry players who complied before 2020 and provides free certification for smallholders.
		• Non-compliance after 2020 is penalized under Malaysian Palm Oil Board (MPOB) regulations.
		• In the palm oil industry, there are four main certification standards:
		    • MSPO (Malaysian Sustainable Palm Oil) – Issued by the Malaysian government.
		    • ISPO (Indonesia Sustainable Palm Oil) – Issued by the Indonesian government.
		    • RSPO (Roundtable on Sustainable Palm Oil) – Established by the European business sector.
		    • ISCC (International Sustainability and Carbon Certification) – Developed in Germany.
		• MSPO has gained international recognition, including acceptance by Japan (METI), enabling certified exports.
		• With Malaysia being a top palm oil producer, the government aims to position MSPO as a leading global standard, potentially rivaling the longer-established RSPO.
			The Malaysian government	Introduced in 2013, became mandatory from 2020

Source: Interview, MSPO, EFECA report

Government policy

The government supports the utilization of biomass through incentives, such as the Investment Tax Allowance, Green Investment Tax Allowance, and others

Government Incentives

	Incentives	Description	Issuers	Effective year
Government Incentives	**Investment Tax Allowance (ITA)**	Companies using oil palm biomass to produce value-added products like particleboard, MDF, plywood, pulp, and paper are eligible for a 100% investment tax allowance on qualifying capital expenditure over 5 years. This allowance can offset 100% of statutory income each year, with any unutilized amount carried forward until fully used.	Malaysian Investment Development Authority (MIDA)	*No information*
	Green Investment Tax Allowance (GITA)	GITA provides a 100% tax allowance on qualifying capital expenditures for renewable energy projects, including biomass, which can be offset against 70% of statutory income for a period of 5 years.	Malaysian Investment Development Authority (MIDA)	2014 - 2026
	Green Technology Financing Scheme 4.0 (GTFS 4.0)	The GTFS is a financing scheme offered to investors or projects, including biomass and biogas power plants, supported by the government with a 1.5% rebate on the interest or profit rate for loans of up to 7 years and a 60% to 80% government guarantee on the green component cost for financial institutions.	Malaysian Green Technology and Climate Change Corporation	2010
	Feed-in Tariff (FiT)	The FiT mechanism allows renewable energy projects to sell green electricity to companies holding licenses to distribute electricity (e.g., TNB). The FiT rate varies depending on the type of renewable resource and installed capacity. The FiT for biogas ranges from 0.06 to 0.07 USD (0.2786 to 0.3184 MYR) per kWh. For biomass, the FiT is 0.09 USD (0.38 MYR) per kWh.	Sustainable Energy Development Authority (SEDA)	2011

MYR to USD conversion rate: 1 USD = 4.40 MYR (as of 7 November 2024)

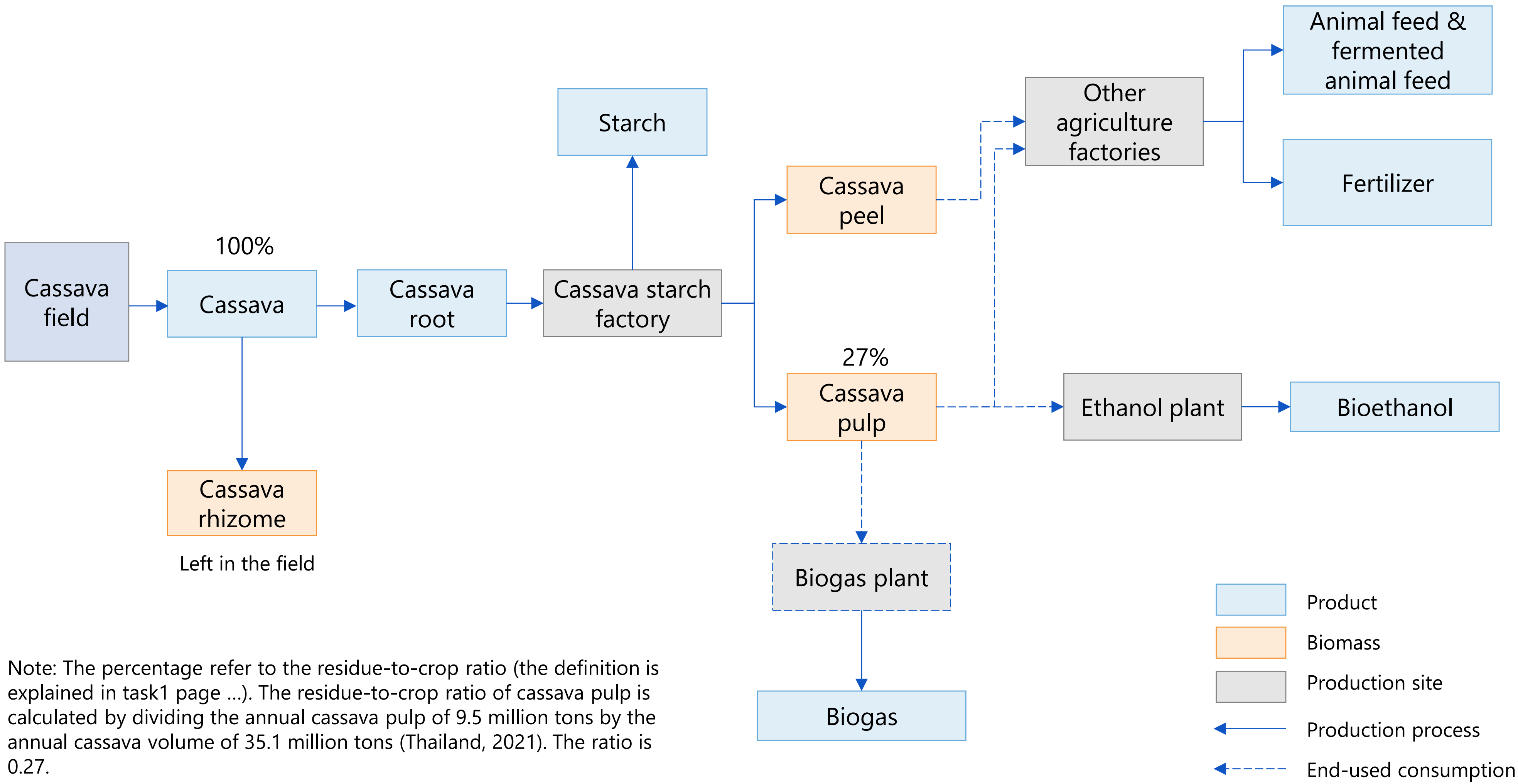
Source: News, Malaysian Green Technology and Climate Change Corporation, MIDA, SEDA

目次

Cassava pulp in Thailand

Supply Chain

Fresh cassava roots are sent to starch factories, where biomass products such as cassava pulp and peels are produced and further utilized as animal feed and biogas



Note: The percentage refer to the residue-to-crop ratio (the definition is explained in task1 page …). The residue-to-crop ratio of cassava pulp is calculated by dividing the annual cassava pulp of 9.5 million tons by the annual cassava volume of 35.1 million tons (Thailand, 2021). The ratio is 0.27.

Source: Department of Alternative Energy Development and Energy Conservation, Waste Management & Research article, Food and Agricultural Organization, Interview

Current Acquisition Practice

Cassava pulp can be processed using either sun-drying or mechanical dryers, with each method having distinct benefits and challenges, particularly regarding cost, labor, and quality improvement potential.

Current Acquisition Practice

<table>
<tr><td rowspan="2">Current Acquisition Practice</td><td>Collection</td><td>• Cassava pulp is a byproduct of the starch extraction process from cassava roots.
  o After the roots are grated and water is added to separate starch granules, mechanical systems like belt presses are sometimes used to enhance starch recovery. The resulting pulp, rich in lignocellulose and residual starch, is then collected.
  o A starch production facility generates approximately 800 to 900 tons of cassava pulp daily as a byproduct of its operations. The production process operates with a conversion ratio in which 1 ton of starch production results in 2.5 tons of cassava pulp.</td></tr>
<tr><td>Pre-Processing</td><td>• Cassava pulp can be dried either by the sun-drying method or by a dryer.
• Sun-drying method:
  o A truck lifts the pulp and spreads it on the yard, ensuring it doesn't overlap by more than 5 cm.
  o The pulp is turned every few hours and dried for 2-3 days until the humidity reaches 14%. Which is an accepted standard of humidity of cassava pulp
  o Challenge:
    ▪ Even though the sun-drying is cost-effective, it can be more labor-intensive, using man-power to handle the drying process.
    ▪ Expansive area is required for sun-drying process.
    ▪ The sun-drying method is limited by weather.
• Dryer:
  o Using a conveyor belt system to transfer the pulp directly from the silo to the dryer then dry wet cassava pulp with heat. This process does not require to spread cassava pulp on the floor. After dying, the dried pulp is packed and is sold as animal feed.
  o Around 20 factories are using dryers to dry the cassava pulp as it improves the quality of cassava pulp and allow for a higher selling price.
  o Challenge:
    ▪ Using dryer requires additional investment. Factories are reluctant to make this investment as it may be an unviable investment due to the limited demand for cassava pulp.</td></tr>
</table>

Source: Interview

Current Acquisition Practice

No significant challenges in the storage and transportation of cassava pulp. The price of dried cassava pulp ranges from 88 to 147 USD per ton, while the wet cassava pulp is approximately 15 USD per ton.

Current Acquisition Practice

Current Acquisition Practice	Storage	• The pile of cassava pulp is stored in the central courtyard. • Dry pulp can be stored for a long time without developing odor, unlike the wet one.
	Transportation	• For animal feed utilization, trucks are used to scoop the cassava pulp out of the pile and deliver it to the animal feed factories. • For biogas production, cassava pulp is directly conveyed via a conveyor belt into a fermentation tank for biogas production in a biogas plant in a factory
Acquisition Cost		• The price of dry cassava pulp is 88-147 USD (3,000 to 5,000 THB) per ton. • The price of wet cassava pulp is at 15 USD (500 THB) per ton.

THB to USD conversion rate: 1 USD = 34 THB (as of 7 November 2024)

Source: Thai Tapioca Association, Interview

Utilized Portion

Cassava pulp is mainly used as animal feed, with additional uses in bioethanol, biogas production, and soil conditioning, influenced by economic considerations.

Utilized Portion

Utilized Portion	Application	Details

Utilized Portion	Application	• Dry cassava pulp:
		  ○ Used as animal feed (e.g., fish food) – main application
		  ○ Used as a material for growing plants
		  ○ Used as cat litter exported to China
		• Wet cassava pulp (containing 80-85% water and 15-20% solids):
		  ○ Used as animal feed (mix with animal feed to increase protein content for animal feed) – main application
		  ○ Used for bioethanol production
		    ▪ Bioethanol is produced for fuel grade alcohol for energy purpose and industrial grade alcohol which is used for food and beverage, cosmetic, and medical industries. Currently, bioethanol is starting to be used in other industries, such as Bio-Polyethylene (bio-PE) and bioplastics.
		    ▪ In 2023, 2.72 million tons of cassava is utilized for ethanol production
		  ○ Used for biogas production,
		    ▪ Biogas is utilized in starch factories primarily for heat generation. Additionally, some facilities have the capability to produce electricity from biogas, which is used to power their operations and, in some cases, sold to the electrical grid.
		    ▪ The primary reason starch factories do not predominantly use cassava pulp for biogas production is that they prefer to sell it as animal feed to generate income.
		  ○ Soil conditioner (separated remaining pulp from the wastewater)
		    ▪ Some factories utilize the cassava pulp as a soil amendment, while others provide it to farmers delivering cassava to the factory for use as a soil conditioner. However, some farmers refuse the offer due to the additional transportation required to return the pulp to their farms.

Source: Krungsri research, Ubon Bioethanol, Interview

Utilized Portion

To enhance the utilization of cassava pulp in biogas, bioethanol, and biochemical production, advanced technologies are needed to increase its value and ensure it can be sold at a competitive price.

Utilized Portion

Utilized Portion	Challenge in Utilization	• Most starch factories have their own biogas plants for waste management, such as wastewater, but do not utilize cassava pulp because cassava pulp can be sold with a good price for animal feed. • Although the technology is available, companies remain hesitant to invest due to the high costs and uncertain profitability, especially given the current demand levels for using pulp in new applications, such as cassava pulp for nano-cellulose production. • Technology for utilizing cassava pulp for biogas, bioethanol and biochemicals product could be more developed for better efficiency.
Utilization Outlook		• Increasing in biogas production o It is anticipated that many companies have already begun investing in biogas systems. As a result, biogas utilization is expected to increase in the future, particularly if electricity prices rise. • Increasing in bioethanol and biochemicals production o Some factories are exploring the processing of cassava pulp into bioethanol and other biochemicals. However, this process has not yet been widely commercialized.

Source: Interview

Utilization Proportion

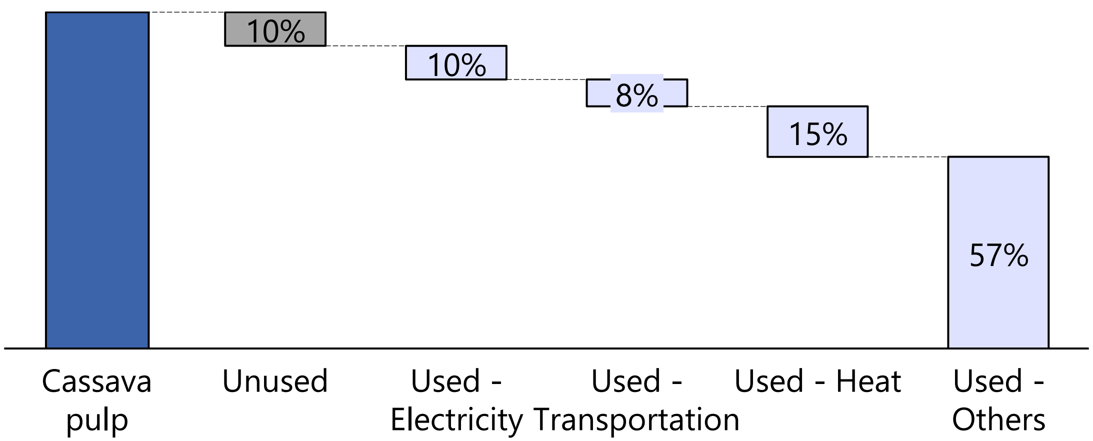
Estimated that 90% of cassava pulp is utilized, around 57% for animal feed, 15% for heat generation, 10% for electricity and 8% for transport.

Utilization Proportion

Unit: million tons/year

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
9.20	0.92	0.92	0.74	1.38	5.24

Utilization Proportion



Others:
- Animal feed (main application)
- Material for growing plants
- Soil conditioner

Note:
1. total amount is estimated based on FAO's data while utilized amount is estimated based on information from ASEAN Cassava Centre, DEDE, industry experts and desktop research.
2. The utilization proportion is calculated based on the estimated utilized amount from step 1.

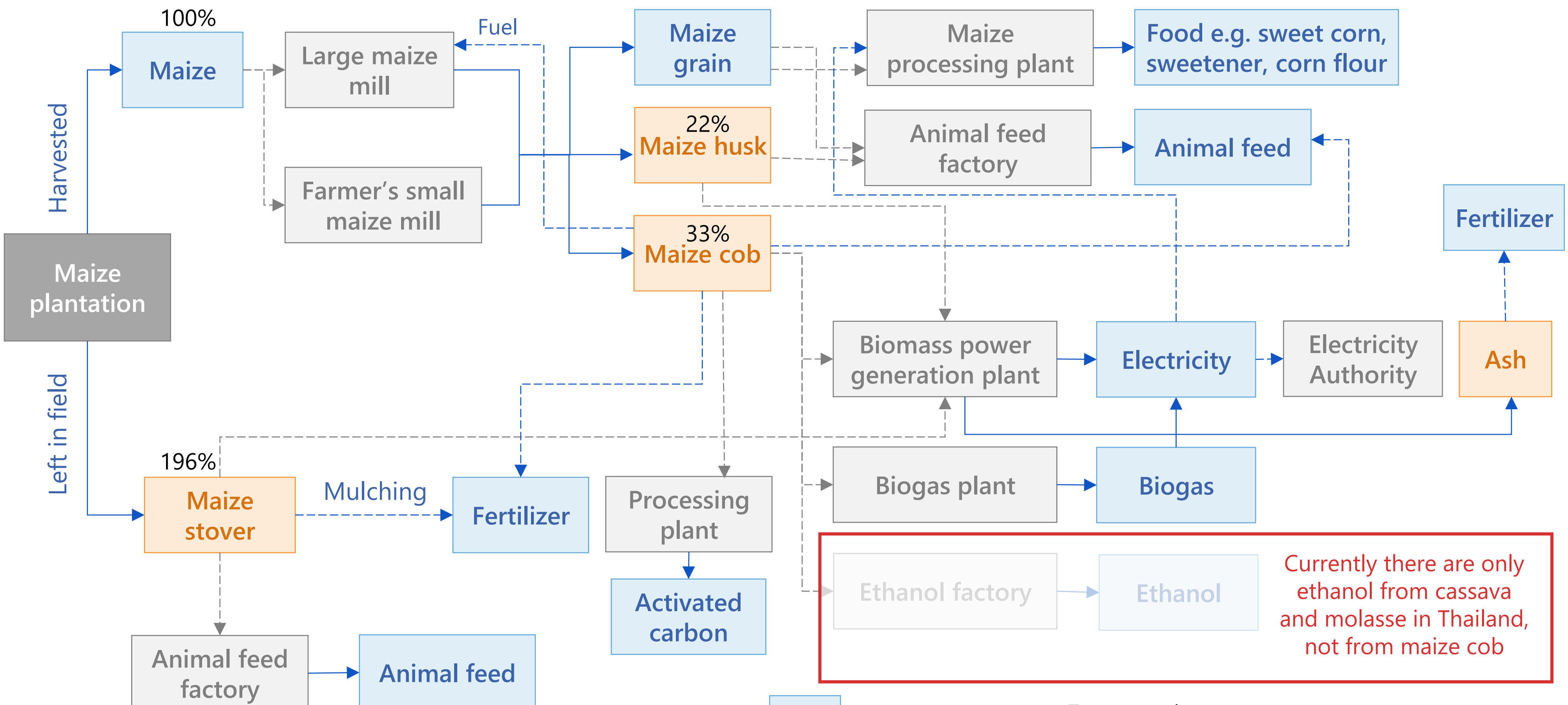
Sources: Food and Agriculture Organization, Krungsri research, ASEAN Cassava Centre, DEDE, Q&A with experts

Maize Cob in Thailand

Supply Chain

Maize stover is a field residue, whereas maize husk and maize cob are residues generated from maize milling.

Supply Chain



Note: The percentage refer to the residue-to-crop ratio (the definition is explained in task1 page ...), obtained from FAO

Source: DEDE, ERC, Office of Industrial Economics

Current Acquisition Practice

The challenge in acquisition is in transportation process as farmers' mills are located in hard-to-reach areas, leading to high transportation costs. Cob's price is around 53 USD/ton

Current Acquisition Practice

Current Acquisition Practice	Collection	• Maize cob can be collected during maize harvesting period between September and October from maize processing plants/maize mill facilities which often located near the plantation areas. • The maize cob is collected naturally after the seed separating process, ready to be transported with minimal challenge.
	Pre-Processing	• Maize cobs can be processed by crushing them into smaller pieces and then drying them to reduce their moisture content.
	Storage	• They are piled up in an open space or garage.
	Transportation	• In general maize cob will be transported to biomass power generation plant by truck and other road transport • Some maize processing plants have their own power generation plants. In this case, the transportation will be minimal. • Challenge in transportation can be mostly found in the northern region where half of Thailand's corn is grown. Many fields are difficult to access due to their location on steep, rocky mountain slopes. As a result, economically transporting maize cobs to biomass power generation plants poses a challenge for farmers.
Acquisition Cost		Purchasing price of maize cob is around 52.9 USD (1,800 THB) per ton

THB to USD conversion rate: 1 USD = 34 THB (as of 7 November 2024)

Source: Office of Agricultural Economics,
Energy Research and Development of Institute of Nakornping, Interview

Utilized Portion

Maize cob is mainly utilized for animal feed. Some portion is used to produce biogas for electricity generation.

Utilized Portion

Utilized Portion	**Application**	• Used for animal feed – main application
		• Used for electricity generation
		• Used for mills internal heat generation
		• Used for biogas generation (for electricity and heat generation)
		    • Maize cobs will only serve as a supplementary feedstock for biogas production, not the primary source.
		    • There are a few companies that are doing biogas from maize with its primary use being electricity generation; however, this presents only in a small portion.
		• Used as fertilizer
		• Used for activated carbon production
		    • This portion is significantly small

Source: Interview

Utilized Portion

Limited biogas yield and technology constraints, such as equipment compatibility in power plants, hinder maize cob utilization for biogas and energy. The primary use remains in animal feed

Utilized Portion

Utilized Portion	Challenge in Utilization	• Technology readiness in power plant
		  ○ The use of maize cobs in power plants can present challenges due to the specifications of boilers and feeders. Different types of equipment are designed to handle specific types, sizes, heat values, and volumes of biomass residues. If maize cobs do not match the existing equipment in a power plant, the plant cannot switch to utilizing them, even if they are readily available. Adapting the equipment would require significant additional investment to replace or modify boilers and feeders.
		• Limited biogas yield of maize cobs.
		  ○ On their own, maize cobs cannot produce a significant amount of biogas. To achieve a large volume of biogas, the entire maize plant, not just the cob, must be utilized. Additionally, the maize used for biogas production needs to be less than 70 days old to ensure optimal biogas output, unlike maize grown for animal feed, which is typically harvested at 120 days.

Utilization Outlook		• The primary use of maize cobs is still predominantly for animal feed. However, with advancements in transportation technology, the use of maize cobs for energy production and fertilizers is expected to grow. • Ethanol production from maize cobs is unlikely to occur now or in the future, as the current supply is insufficient to meet existing demands, particularly for animal feed.

Source: Interview

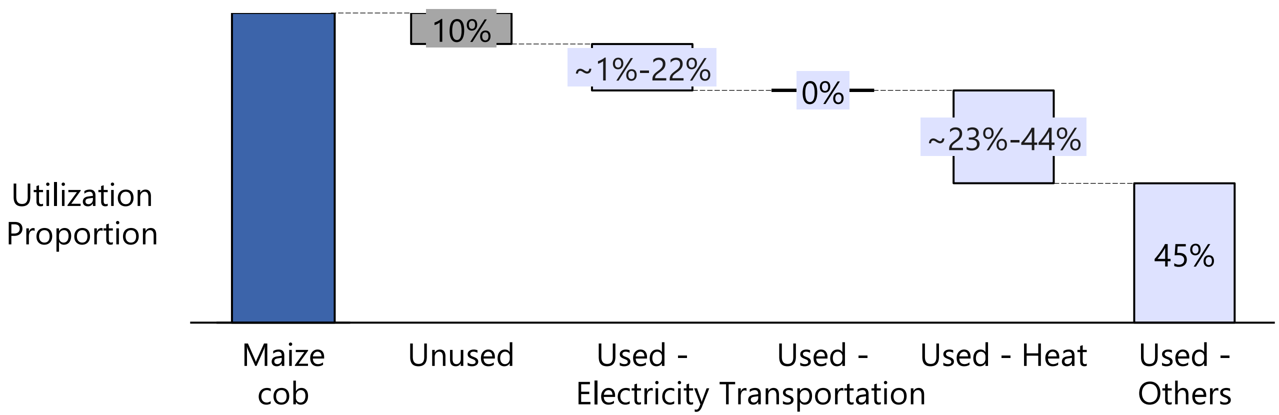
Utilization Proportion

Out of 1.62 million tons of maize cobs, approximately 0.73 million tons are used for animal feed, 0.37-0.71 million tons for heat generation, 0.02-0.36 million tons for electricity generation, and 0.16 million tons remain unused

Utilization Proportion

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
1.62	0.16	~0.02-0.36	0	~0.37-0.71	0.73

Unit: million tons/year



Others:
- Animal feed (main application)
- Fertilizer
- Activate carbon production

Note: total amount is estimated based on FAO's data while utilization proportion is obtained from interview with DEDE.
The utilized amount is calculated from total amount x utilization proportion.
Within 45% of electricity and heat generation, it is assumed that major portion (23%-44%) is for heat generation and minor portion (1%-22%) is for electricity generation.

Sources: Food and Agriculture Organization, Interview

Unutilized portion

Unused maize cobs are typically burned in the fields. The lack of efficiency transportation solutions hinders utilization, especially in remote and mountainous regions

Unutilized Portion

Unutilized Portion	Current Management	• Currently, open burning is a common practice for disposing of maize cobs and husks after harvesting to prepare the land for the next planting season. This method is favored over alternatives like landfill due to its convenience and low cost.
	Barriers to Utilization	• No solutions or technologies to facilitate the transportation at a reasonable price. ○ Transporting maize cobs to other facilities in the northern region is difficult due to the steep mountain geography and the long distance from plantation to processing factory. Moreover, maize cob is bulky and lightweight contributing more to high transportation cost.

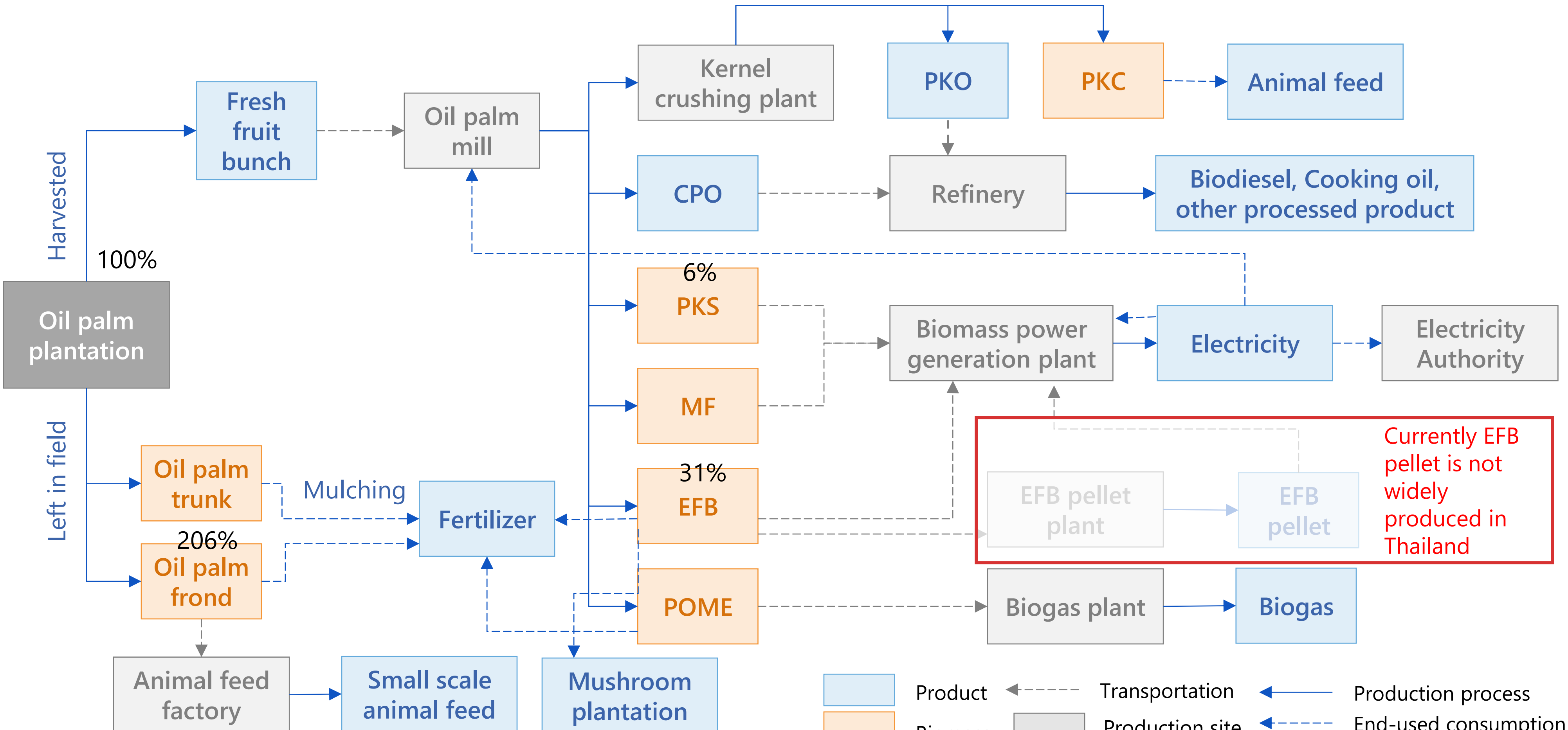
Source: Interview

Oil Palm Residues in Thailand

Supply Chain

Oil palm generates several biomass residues utilized as material for electricity generation, fertilizer, and animal feed

Supply Chain



Note: CPO=Crude Palm Oil, PKS=Palm Kernel Shell, MF=Mesocarp Fiber, EFB=Empty Fruit Bunch, POME=Palm Oil Mill Effluent, PKO=Palm Kernel Oil, and PKC=Palm Kernel Cake

Source: Interview Note: The percentage refer to the residue-to-crop ratio (the definition is explained in task1 page ...), obtained from FAO

Current Acquisition Practice

No significant challenges in current acquisition process. The cost of EFB ranges from 2 to 15 USD per ton, while PKS is priced higher at 62 to 73 USD per ton.

Current Acquisition Practice

		Empty bunch (EFB)	Shell (PKS)
Current Acquisition Practice	Collection	• EFB is easy to collect with no difficulty during the production in oil palm mills.	• Palm shell is also easy to collect during the production process in the oil palm mills.
	Pre-Processing	• Due to its bulkiness and moisture content, EFB needs to be crushed and dried before they can be used in power plants.	• Palm shell requires no additional pre-processing
	Storage	• It will be piled up in an open space. No specific storage specifically for empty bunch. However, EFB should not be stored for a long time because its heat value may decrease and it can lead to beetles to come in and lay eggs, destroying palm oil further	• Palm shell is also piled up in an open space • There is no need to build a storage since the demand is high and it will be sold or transported almost immediately.
	Transportation	• Empty bunch is generally daily transported by truck	• In general palm shell is easily transported by trucks as they are in small pieces
Acquisition Cost		• Cost of purchasing oil palm empty bunch varies based on season and volume of supply in each period ○ Price range 2 – 15 USD (50-500 THB) per ton. Surveyed price by DEDE is at 11.7 USD (400 THB) per ton ○ Price for empty bunch that has been squeezed all of the oil out will be higher than those that still have a little bit of oil left inside. The dryer the bunch, the better it is for power generation	• Like empty bunch, cost of purchasing oil shell also varies based on season and volume of supply in each period • Price range 62 – 73 USD (2,100-2,500 THB) per ton. Surveyed price by DEDE is at 73 USD (2,500 THB) per ton

THB to USD conversion rate: 1 USD = 34 THB (as of 7 November 2024)
Source: Interview

Utilized Portion

EFB and PKS are primarily used for electricity generation.

Utilized Portion

		Empty bunch (EFB)	Shell (PKS)

Utilized Portion	Application	• Used for electricity generation (main application)
		  ○ Currently 90% of the empty bunch is used for electricity generation
		  ○ However, less than 10% of palm mill have their own small power plant and can utilize empty bunch Therefore, majority of the empty bunch from conventional palm mills with no power plant will be sold to those that can utilize the bunch or to the biomass power plant close by
		• Used for mushroom cultivation
		• Used as organic fertilizer
		• Used for EFB pellet production
		  ○ Currently EFB pellet is not widely produced in Thailand
			• Used for electricity generation (main application)
			  ○ Currently 100% of oil palm shell is used for power generation since it has high heat value, and is easy to collect and transport
			  ○ Some portion is exported to South Korea and Japan
			• Used for activated carbon production
			  ○ Activated carbon can be sold for a high price. Therefore, this application gains popularity

Source: Interview

Utilized Portion

EFB faces challenges in utilization due to high moisture content, low heat value, and fouling issues, while PKS offers future potential for activated carbon production due to its high market value.

Utilized Portion

		Empty bunch (EFB)	Shell (PKS)
Utilized Portion	Challenge in Utilization	• Current utilizing EFB process for power generation faces issues of inefficient energy output, lower combustion efficiency, higher costs of pre-treatment, and ash content and fouling because EFB has lower heat value, comparing to other oil palm residues. • Challenge is also found is EFB pellet production. The production has to deal with EFB high moisture content, which exceeds 50%, and its bulky nature. These characteristics make it challenging to process EFB into pellets efficiently.	• N/A
Utilization Outlook		• Using PKS for activated carbon could increase in the future because it can be sold for a high price.	

Source: Interview

Utilization Proportion

Both oil palm empty bunch and shell are mostly utilized. The primary application for both residues is electricity generation.

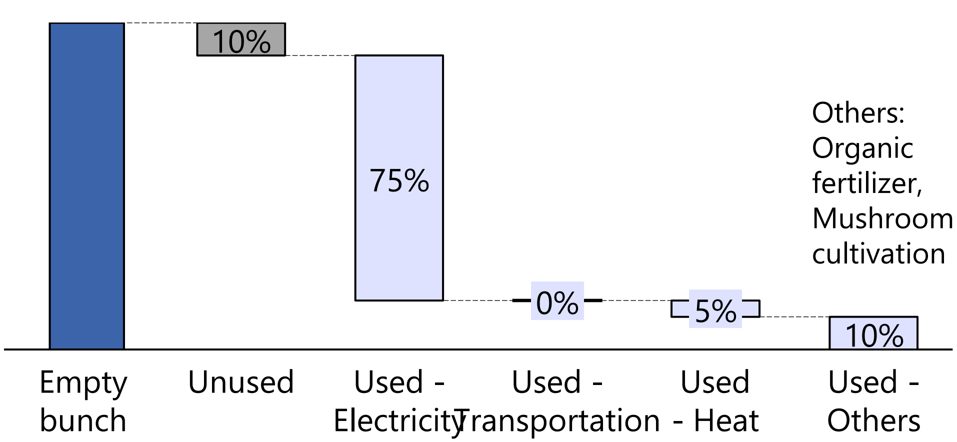
Utilization Proportion

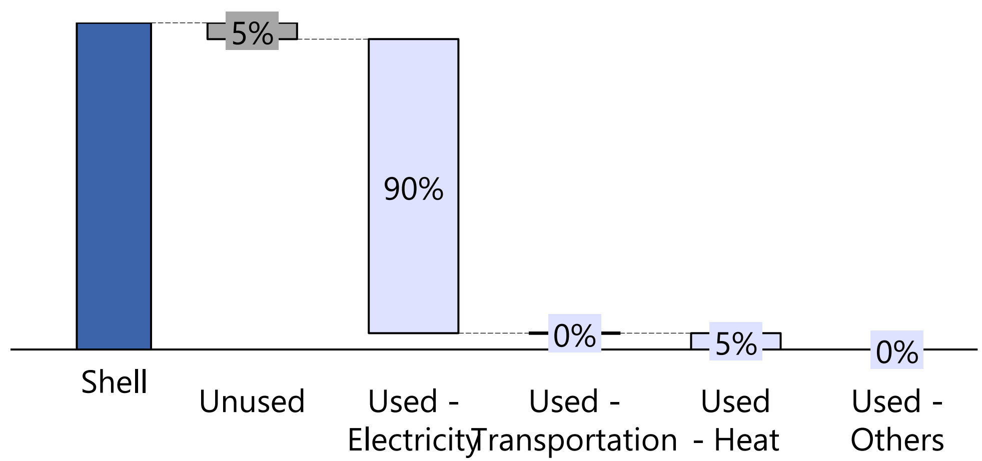
Empty bunch Unit: million tons/year

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
5.91	0.59	4.43	0	0.30	0.59

Shell Unit: million tons/year

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
1.14	0.06	1.03	0	0.06	0





Note: Total amount is estimated based on FAO's data while utilization proportion is obtained from interview.
The utilized amount is calculated from total amount x utilization proportion.

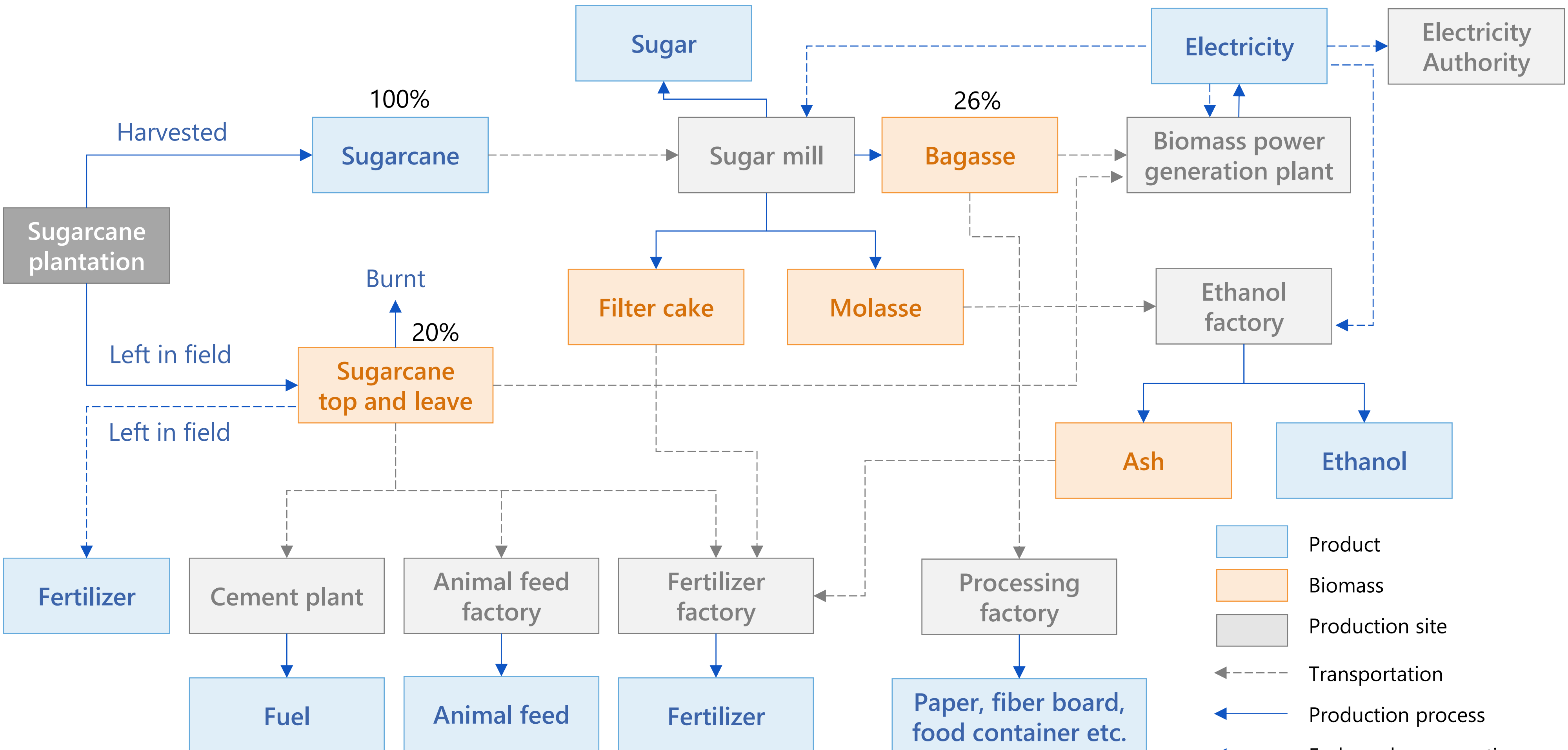
Sources: Food and Agriculture Organization, Interview

Sugarcane Bagasse in Thailand

Supply Chain

Sugarcane tops and leaves are residues from the plantation, while bagasse, molasses and filter cake are byproducts of the sugar mill

Supply Chain



Note: The percentage refer to the residue-to-crop ratio (the definition is explained in task1 page …), obtained from FAO
Source: Interview

Current Acquisition Practice

Bagasse is collected during cane juice extraction at sugar mills, cut into smaller pieces, stored in closed facilities, and transported by truck to power plants. Its price ranges from 29 to 35 USD/ton.

Current Acquisition Practice

Current Acquisition Practice	Collection	• Bagasse can be collected with minimum difficulty from sugar mill plants during the cane juice extraction. • The prime collecting period is from November to April when the sugarcane is most harvested. Having one collection period can lead to insufficient supply for all year round.
	Pre-Processing	• Bagasse must be cut into smaller piece before storing
	Storage	• After cutting into smaller piece, bagasse is stored in warehouses or closed facilities to prevent humidity
	Transportation	• Bagasse is transported by trackers or trucks from the sugar mill to the biomass power generation plants • Majority of sugar companies have their own sugar mill and biomass power generation plants. In many cases they will be located in the same area and the transportation distance will be minimal.
Acquisition Cost		• Purchasing price of bagasse from sugar mills: 29 – 35 USD (1,000-1,200 THB) per ton

THB to USD conversion rate: 1 USD = 34 THB (as of 7 November 2024)

Source: Office of Agricultural Economics, Wangkanai Sugar, Interview

Utilized Portion

Sugarcane bagasse is 90% utilized as resource for electricity generation used within internal production, and the surplus electricity is sold to the grid.

Utilized Portion

Utilized Portion	**Application**	• Used for electricity generation (main application) ○ Currently, most of the available bagasse is utilized for power generation in biomass power plants. Sugar companies primarily use it to produce electricity for their own operations, reducing sugar production costs. Any surplus electricity generated is sold back to the grid. ○ Out of 57 sugar factories, there are only 1-2 factories that do not have their own power plant • Used for paper production, fiberboard and food containers (small portion of utilization)
	Challenge in Utilization	• The insufficient supply of bagasse: ○ A single collection period may result in an insufficient supply for year-round power generation. Each sugar factory must plan and estimate the required amount of bagasse in advance. ○ If the supply is anticipated to be inadequate, factories will need to purchase bagasse from other plantations or alternative biomass sources, such as sugarcane leaves, wood residues, or oil palm empty fruit bunches. Notably, oil palm empty bunches are a preferred choice, as the sugar production period coincides with the palm oil low season, allowing for their purchase at a lower price.

Source: Interview

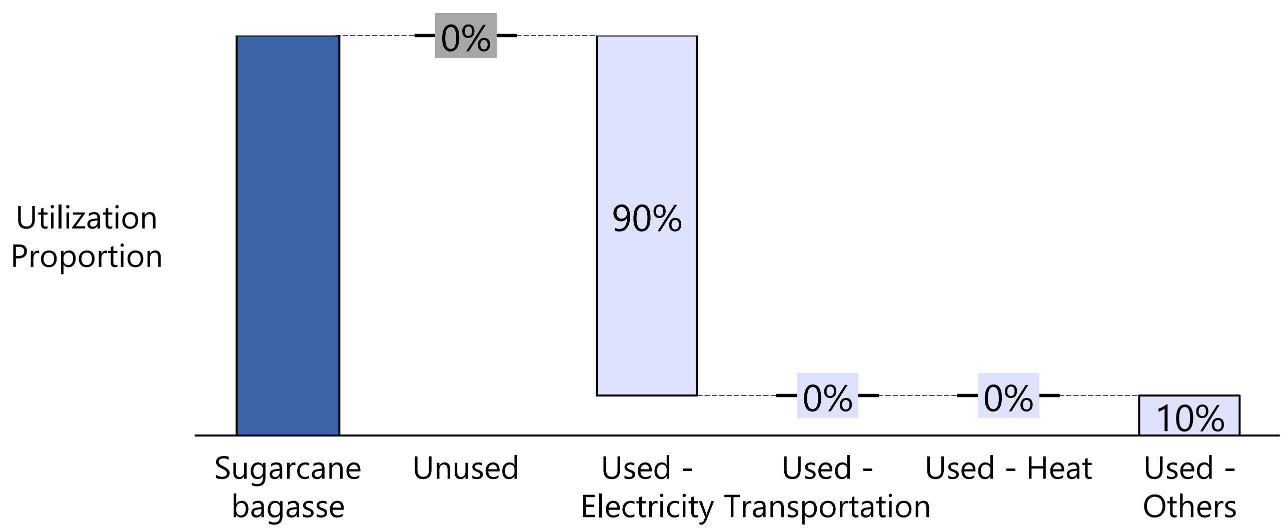
Utilization Proportion

Sugarcane bagasse is 90% utilized as resource for electricity generation, mainly used within internal production. The other 10% is utilized for paper, fiberboard and food container production

Utilization Proportion

Unit: million tons/year

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
23.94	0	21.55	0	0	2.39



Others:
- Paper production
- Fiber board production
- Food container production

Note: total amount is estimated based on FAO's data while utilization proportion is obtained from interview.
The utilized amount is calculated from total amount x utilization proportion
Sources: Food and Agriculture Organization, Interview

Wood Residues in Thailand

Wood Types

In the south of Thailand, 70% of the wood plantations consist of rubberwood, whereas other regions have a greater variety of tree species, with the distribution more evenly balanced among them

Wood Types and Usages

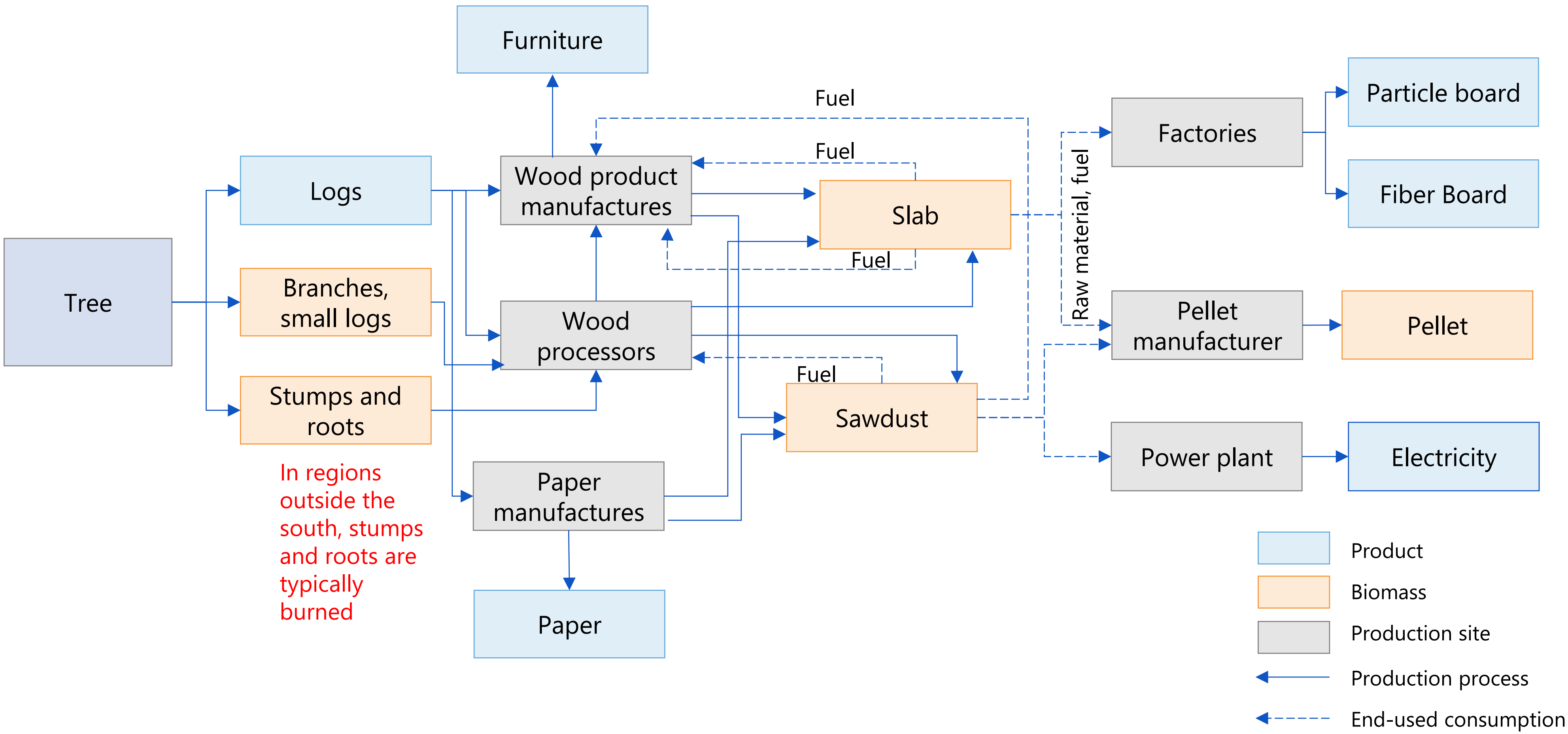
Wood Type	Plantation Type	• Rubberwood: ○ 90% is owned by the private sector ○ 10% is owned by the Forest Industry Organization (Public)
	Tree Type	• In the northern, northeastern, and eastern parts: • There are more types of wood such as eucalyptus and acacia and rubber tree, with each making up roughly 20-30%. • In southern part: • 70% is rubberwood • 30% is palm trees • Rubberwood is primarily utilized in wood processing, particularly for furniture production. In contrast, eucalyptus and acacia are mainly used as whole trees for paper production and fuel. Their application in wood processing, such as furniture manufacturing, is not as common. • The technology used to process eucalyptus and acacia is similar to that used for rubberwood. Additionally, the quality of wood pellets produced from eucalyptus and acacia is comparable to those made from rubberwood.

Source: Interview

Supply Chain

Branches, stumps, and roots are collected from the plantation, while slabs, sawdust, and bark are by-products from the manufacturers

Supply Chain



Sources: Department of Alternative Energy Development and Energy Conservation, Caraga State University, NRI experts, Interview

Current Acquisition Practice

Challenge is found in transportation. Stumps and roots in regions outside the south remain underutilized due to lower demand.

Current Acquisition Practice

Current Acquisition Practice	Collection	• Stump and root: excavated from the plantation and processed through a wood chipper. However, only in the southern part of Thailand are roots excavated and sold due to the high demand for wood residues, while in other regions, they are typically left unused and often burned • Branch and tip: wood tips larger than 1 inch are collected at the plantation during tree cutting while tips smaller than 1 inch are burned at the plantation • Slab and sawdust: produced as by-products in wood processing factories
	Pre-Processing	• Stump and root: shredded into smaller pieces, wood chips, before entering the chipping process. • Branch, tip and slab: processed through chipping, then fed into a hammer mill to be coarsely ground. The material undergoes a drying process to reduce moisture from 45% to 15%, followed by fine grinding before being made into pellets. • Sawdust: enter the drying process before being made into pellets. Processor that do not have a dry process for wood will sell the sawdust to other factories e.g. particleboard and pellet factories.
	Storage	• Branch, tip and slab: stored in a warehouse for about 3-5 days to lower the moisture content, making it suitable for electricity generation. However, prolonged storage can cause the wood to decay into powder, rendering it unusable • Sawdust: stored in the factory's silo, which directly feeds the sawdust into the boiler.
	Transportation	• Branch, tip, stump and root: transported from the plantation to a wood chipper and wood processor by truck. Small wood tips are bulky and lightweight causing high transportation cost. • Slab: loaded into a truck. This process could take about 1 hour with a machine or half a day with manpower, which is considered as a challenge of transporting slab. • Sawdust: moved from the silo to the truck by either manpower or machinery. Then, transported to factories and power plants by truck.

Source: Office of Energy Regulatory Commission, Interview

Current Acquisition Practice

Wood residues cost around 21-50USD/ton while when it is processed, the price becomes 120-141 USD/ton.

Current Acquisition Practice

Acquisition Cost	
	• Purchasing price of wood materials by end user (include transportation price) ○ Tips: price range 21 – 38 USD (700-1,300 THB) per ton ○ Slab: price range 21 – 35 USD (700-1,200 THB) per ton ○ Sawdust: price range 38 – 50 USD (1,300-1,700 THB) per ton ○ Root: price around 9 USD (300THB) per ton ○ Pellet: 120-141 USD (4,100 - 4,800 THB) per ton ○ Logs is 50-53 USD (1,700-1,800) THB per ton • Transportation cost is 6-9 USD (200-300 THB) per ton • Wood material prices fluctuate based on supply and demand; for example, a cement plant's high sawdust demand with limited supply can drive prices up

THB to USD conversion rate: 1 USD = 34 THB (as of 7 November 2024)

Source: Interview

Utilized Portion

Wood residues are used for fiberboard and particle board production, for electricity and heat generation and for biochar production in small portion.

Utilized Portion

Utilized Portion	**Application**	• Stump and root:
		  ○ Used as wood chips in biomass power plants for electricity generation
		  ○ Used for heat generation in factories
		  ○ Used for biochar production
		
		• Branch and tip:
		  ○ Used for plywood and Medium Density Fiberboard, particleboard production
		
		• Slab:
		  ○ Used for heat generation at wood processing factories
		  ○ Used as wood chips in biomass power plants for electricity generation
		  ○ Used for making wood pellet
		  ○ Used for particleboard production
		  ○ Used for biochar production
		
		• Sawdust:
		  ○ Used for heat generation at wood processing factories
		  ○ Remain amount will be used for making wood pellet
		    ▪ Sawdust is easy to convert into wood pellets, but the amount available is not sufficient.
		  ○ Used for biochar production
		
		• Pellet
		  ○ In Thailand, 99% of wood pellets are used in industrial boilers at smelting plants, fabric dyeing factories, canned fish factories, glove factories, etc. while 1% of wood pellets are used for power plants.
		  ○ About 10% are used in Thailand, while 90% are exported to South Korea and the Netherlands.

Source: MGR Online, Thai Health, Interview

Utilized Portion

Challenges lie in preparation processes like impurity separation, moisture reduction, and sizing. Rising demand and technological advancements are expected to increase the use of stumps, roots in biomass production.

Utilized Portion

Utilized Portion	Challenge in Utilization	• The biomass storage area should be covered and enclosed to prevent moisture, dust dispersion, and unpleasant odors that may cause inconvenience or pose risks to the surrounding operations. Additionally, the storage facility should be large enough to accommodate a sufficient amount of fuel to support operations for at least 2-3 days. However, wood residues are bulky and require larger space, compared to fossil fuels for the same amount of thermal energy. • The separation of impurities, moisture reduction, and size preparation suitable for usage are key factors in maintaining system efficiency and the quality of the gas produced.
Utilization Outlook		• In the future, if pellet prices rise to match processed wood and if slab prices increase to the level of logs, logs could be used for pellet production. • The utilization of stumps and roots has grown over the past five years, driven by technological advancements such as the introduction of shredders. If demand for wood residues continues to rise, the use of stumps and roots is likely to increase further.

Source: Department of Primary Industries and Mines, Interview

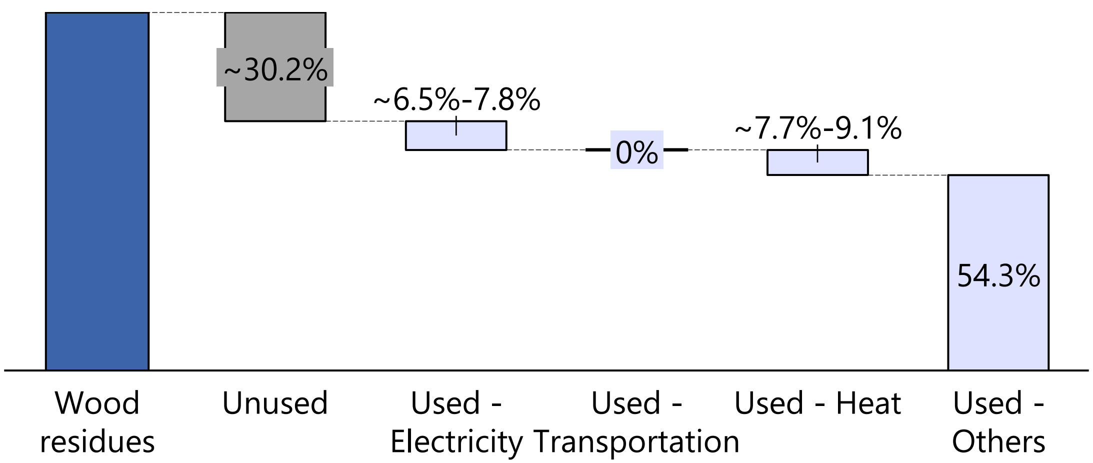
Utilization Proportion

In overall, half of wood residues are utilized for particle board and fiberboard production, around 11% is used for electricity and heat generation and 30% unused

Utilization Proportion

Unit: million tons/year

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
10.61	~3.21	~0.69-0.83	0	~0.82-0.96	5.76



Others:
- Particleboard (main application for branch & tip)
- Fiberboard (main application for branch & tip)
- Biochar

Note:
1. this total amount of wood residues is the sum of amount of each wood residue (stump & root, branch & tip, slab and sawdust)
2. the utilized amount of wood residues for each application is the sum of the utilized amount of each wood residue (stump & root, branch & tip, slab and sawdust) for each application
3. Then, the percentage of each application is calculated based on the result of step 1 and 2

Sources: Food and Agriculture Organization, Interview

Unutilized portion

Stump and root are difficult to collect, transport and prepare for other utilization such as wood pellet production.

Unutilized Portion

Unutilized Portion	Current Management	• Stump and root are left in the plantation after logging. For some trees such as eucalyptus, it is to promote natural regeneration through coppicing, where new shoots emerge from the remaining stumps. For replantation, they are harvested.
	Barriers to Utilization	• Challenges in collection, transportation, and the necessary preparation for impurity separation contribute to the high costs of utilizing stumps and roots leading to less profitable.
Potential Use for Unutilized Portion	Potential Applications	• Used for wood pellet production for electricity generation • Used for biochar production
	Required support	• Investment promotion from government to support the purchasing on stump and root for electricity generation.

Source: Royal Forest Department, Manager Online News

Government Policies in Thailand

Government policy

Thailand is increasing plantation and cultivation of major agricultural economic crops which will result in more biomass residues accordingly

Government Policies

	Policy	Description	Issuers	Effective year

Government Policies	Agricultural Development Plan under The 12th National Economic and Social Development Plan	The government launched roadmap for 4 key agricultural economic crops. The initiative aims to strengthen and balance agricultural production in terms of food and energy security. With this roadmap, the agriculture crop will increase, hence, a higher volume of biomass is expected accordingly. The roadmaps for each crop are as following.
		• **Sugarcane Production Plan (by 2026)**
		  • Expand plantation areas from 10.07 M. rai to 16.07 M. rai
		  • Boost sugarcane production from 103.68 Mt. to 182.04 Mt.
		  • Boost sugar production from 11.29 Mt. to 20.36 Mt.
		• **Oil Palm Production Plan (by 2026)**
		  • Expand plantation areas by 250,000 rai annually, increasing the total area from 4.5 M. rai to 7.5 M. rai
		  • Replant 30,000 rai of old plantations annually
		  • Increase yield per rai from 2.86 tons to 3.5 tons
		• **Cassava Production Plan (by 2026)**
		  • Increase average cassava yield to 5 tons per rai by 2019 and 7 tons per rai by 2026
		  • Manage cassava cultivation across 8.5 M. rai
		• **Animal Feed Corn Production Plan (by 2026)**
		  • Increase yield per rai from 659 kg to 835 kg by 2019 and 1,000 kg by 2026
		  • Raise total production from 4.81 Mt. to 6.18 Mt. by 2019 and 7.40 Mt. by 2026
		  • Reduce cultivation in 4.08 M. rai of forested and unsuitable areas
			Ministry of Agriculture and Cooperatives	2014

Source: News, Office of Agricultural Economics

Government policy

AEDP 2024 sets target for energy from biomass and continues to implement several programs encouraging biomass from the previous AEDP 2018

Government Policies

	Policy	Description	Issuers	Effective year

Government Policies	**Alternative Energy Development Plan (AEDP) 2024**	The Alternative Energy Development Plan (AEDP) 2024 aims to expand renewable energy sources, including biomass, while enhancing energy security, reducing emissions, and promoting sustainability in Thailand.
		
		The 2037 total targets for energy from biomass are as following.
		• In electricity sector: 5,490 MW out of total renewable energy 73,286 MW (7%). The capacity in 2023 was 3,873 MW
		• In thermal sector: 15,551 ktoe out of total renewable energy 17,061 ktoe (91%). The capacity in 2023 was 5,300 ktoe
		
		Sub-policies and programs supporting the usage of biomass will continue to be implemented as following.
		• **Community Power Plant Project for Grassroots Economy**
		  • Government tries to encourage community enterprise to take part in generating clean electricity for the community from local-sourced energy crop, both biomass and biogas
		  • Community enterprise group with>200 households registering as juristic persons will own 10% share of the power plant, while government and private organizations will own the remaining of 90%. With this criteria, community enterprise will receive a share of the income from the distribution of electricity
		  • Additionally, power plant will have a contract farming with community enterprise to purchase at least 80% of the crop used as fuel from that community enterprise. Therefore, local farmers will gain income from supplying the energy crop
		  • The target electricity procurement will be announced for each scheme. The latest scheme in 2023 was set at 150MW
			Ministry of Energy	Drafting

Source: News, Ministry of Energy

Government policy

In the future, Ministry of Energy will launch more program to support bioenergy from biomass by setting additional electricity purchase target

Government Policies

	Policy	Description	Issuers	Effective year

Government Policies	Alternative Energy Development Plan (AEDP) 2024	• **Support Program for the use of Renewable Energy in Thermal Sector**
		  • In this program the government will support 3 groups of people; biomass collector (e.g. farmer), biomass processors, and bio-thermal users
		  • The government will give 30% subsidy for investment in machine and equipment not exceeding 3mTHB per facility
		
		Additionally, Ministry of Energy is planning to add more programs supporting biomass in the future as following.
		• **Promoting electricity and thermal energy production from energy crop**
		  • Ministry of Energy signed an MOU with several organizations such as Ministry of Agriculture and Cooperatives to manage areas with environmental constraints and unsuitable for rice or rubber plantation to plant energy crop instead. This aims to increase farmers' income and strengthen the country's energy security.
		  • The energy purchase targets are 100 MW from biomass of fast-growing tree and 100MW from biogas of Napier grass
		• **Promoting biomass power plants to reduce PM2.5**
		  • The government sets additional electricity purchase target for biomass power plant to reduce the residue burning which can lead to PM2.5 and air pollution
		  • The electricity purchase target is set at 100MW
			Ministry of Energy	Drafting

Source: News, Ministry of Energy

Government policy

There are several policies that will indirectly encourage the usage of biomass such as the policy of SAF and residue burning ban policy

Government Policies

	Policy	Description	Issuers	Effective year
Government Policies	Oil Plan 2024	• In Oil Plan 2024, aviation sector is set to promote the production and usage of SAF (Sustainable Aviation Fuel), utilizing domestic raw materials such as used cooking oil, crude palm oil, and ethanol. • A blend of SAF in aviation fuel with 1% ratio will be proposed to start in 2026 and higher blend ratio is expected in the future. • This can lead to increasing demand of palm oil, hence, higher volume of palm oil residues from higher production.	Ministry of Energy	2024
	Public Health Act B.E. 2535, Section 25 Ban of object burning	• Law enforcement banning the burning of objects including biomass residues has been in place for many years • Even though the main objective of this regulation is to reduce the air pollution which can harm health of people in the area, this regulation can indirectly encourage other usage of biomass residue including application as material for bioenergy	Ministry of Public Health of Thailand	1992
	Policies encouraging the use of sugarcane leaves	**Increased purchasing of electricity from leaves** • Government also increased the electricity purchasing quota specifically for electricity generated from sugarcane top and leaves • The price may increase from 2.7 THB to 3.4-3.5 THB per MW as well **Penalty for mishandling sugarcane leaves** • Starting from 2025, government will request penalty for those factories that do not utilize the leaves as well and just leave or burn the residue	Ministry of Industry	2024

Source: News, Ministry of Energy, PRD

Government policy

There are also tax exemption and subsidy measure from BOI and Ministry of Industry encouraging the usage of biomass residues

Government Incentives

	Incentive	Description	Issuers	Effective year
Government Incentives	BOI Investment Promotion	BOI incentive program offers tax benefits, investment support, and streamlined processes to attract domestic and foreign investments. Apart from fundamental incentive, incentive for biomass power plant will receive CIT* exemption up to 8 years	Thailand Board of Investment	2015
	Subsidy for cutting fresh sugarcane and sugarcane leaves	• Sugarcane farmers will receive a subsidy of 120 THB per ton for cutting fresh sugarcane without burning before harvesting. In one year, the government have spent over 8,000 million THB for this policy. However, this will indirectly encourage farmers to find other method to manage and handle the sugarcane leaves • Additionally, Ministry of Industry is finalizing measure to increase the purchase price of sugarcane leaves and tops by another 300 THB per ton from the current market price of 900 THB per ton. The residue will be used, for example as fuel in biomass power plant. The measure is expected to be effective in 2025	Ministry of Industry	2023

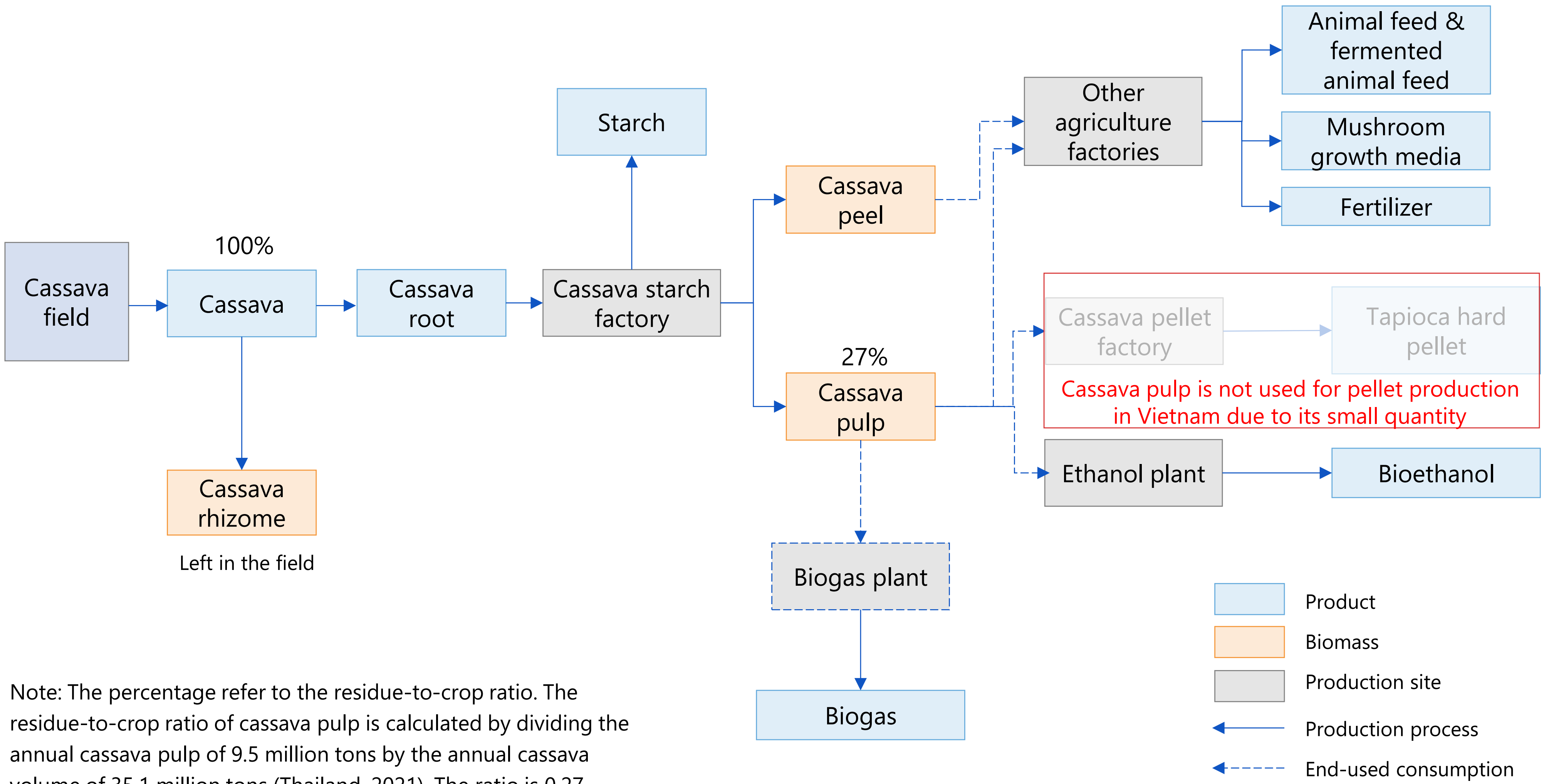
Note: CIT refers to corporate income tax
Source: News, Ministry of Energy, BOI, PRD

目次

Cassava pulp in Vietnam

Supply Chain

Fresh cassava roots are sent to starch factories, where biomass products such as cassava pulp and peels are produced and further sent to various factories



Note: The percentage refer to the residue-to-crop ratio. The residue-to-crop ratio of cassava pulp is calculated by dividing the annual cassava pulp of 9.5 million tons by the annual cassava volume of 35.1 million tons (Thailand, 2021). The ratio is 0.27

Source: Food and Agricultural Organization, Interview

Current Acquisition Practice

Challenges in acquiring cassava pulp include its seasonal availability and the need for pre-processing steps such as drying, spoilage prevention, and contamination removal.

Current Acquisition Practice

Current Acquisition Practice	Collection	• The cassava pulp can be collected at the starch factory after the starch is produced. The starch factory usually sets up a collection spot where buyers can come to purchase and collect the cassava pulp.
		• Challenge:
		    o Seasonal availability: The availability of residues is seasonal, which lead to inconsistent supply and challenges in planning and logistics.
		    o Lack of infrastructure: Inadequate infrastructure for efficient collection, such as lack of proper equipment and collection centers.

	Pre-Processing	• The required pre-processes depend on the application of cassava pulp. To be used for biogas and bioethanol production, the pre-processes are strict to follow.
		    o Drying process:
		        ▪ Cassava pulp is dried under the sun by spreading it out in an open yard to reduce moisture content, which helps prevents spoilage.
		        ▪ The challenge is that drying process can be energy-intensive and costly, especially in regions with high humidity. Inadequate drying can lead to spoilage and reduced efficiency in bioenergy production.
		    o Contamination removal:
		        ▪ Any contaminants are removed to ensure the pulp is safe for use and maintain cleanliness.
		    o Toxin and pesticide removal:
		        ▪ If chemicals or pesticides are used in cassava farming, efforts are made to clean the pulp.
		        ▪ The challenge is that if chemicals are absorbed into the pulp, it becomes difficult to remove, though surface contamination can be cleaned.

Source: Interview

Current Acquisition Practice

A covered storage area and container trucks are used to minimize spoilage. The cost of cassava pulp is 0.06 USD per kilogram.

Current Acquisition Practice

Current Acquisition Practice	Storage	• Cassava pulp, with high humidity and susceptibility to spoilage and insects, is stored in silos or covered areas to maintain quality. • Chemical substances are often mixed with cassava pulp to prevent spoilage during storage. • Typically, cassava pulp is stored temporarily, awaiting buyer collection, as extended storage increases the risk of spoilage.
	Transportation	• Cassava pulp is transported daily by truck from starch factories to various production facilities, such as animal feed factories. The truck should have a container to prevent the cassava pulp from being exposed to air during transportation. • Often transported within 20-50 km from cassava starch processing facilities to end-use locations. • Challenge: o High transportation costs: The cost of transportation can be high due to the bulk and weight of the materials o Poor road conditions: Many rural areas have poor road conditions, which can hinder the efficient transportation. o Limited transportation options: There are limited options for transporting large volumes of residues, which can lead to delays and increased costs.
Acquisition Cost		• The cost of purchasing cassava pulp is 60 USD per ton for all types of buyers and all applications.

Source: Interview

Utilized Portion

It is primarily used as animal feed. Its utilization as bioenergy faces several barriers, including a lack of technology, equipment, and investment, limited acceptance as a fuel, and its fluctuating and limited supply.

Utilized Portion

Utilized Portion	Application	• Animal feed • Organic fertilizer • Substrate for mushrooms cultivation • Biogas production • Bioethanol production • Biodegradable plastics and other eco-friendly products
	Challenge in Utilization	• Lack of policies incentivizing investment in advanced technologies for cassava pulp processing. • Insufficient regulations promoting the use of biofuels in transportation sectors. Currently, biofuels are not widely available at gas stations. • High capital costs for establishing bioethanol and biogas plants, limit the commercialization of pilot projects. Most of cassava starch factories (90% of total 130 factories) do not have bioethanol or biogas plants. • The supply volume of cassava pulp is small which limits its potential use. Moreover, cassava pulp cannot be consistently collected year-round which cause fluctuations in the supply of cassava pulp. • Scarcity of affordable advanced processing technologies to effectively convert cassava pulp into bioethanol, biogas, animal feed, and biodegradable products.
Utilization Outlook		• The demand for cassava pulp in the animal feed industry is rising as farmers seek cost-effective and nutritious feed options. • In the next 3-5 years, the use of cassava pulp for bioenergy in Vietnam is expected to increase by 5-10% due to government incentives, technological advancements, and increased foreign direct investment (FDI).

Source: Interview

Utilization Proportion

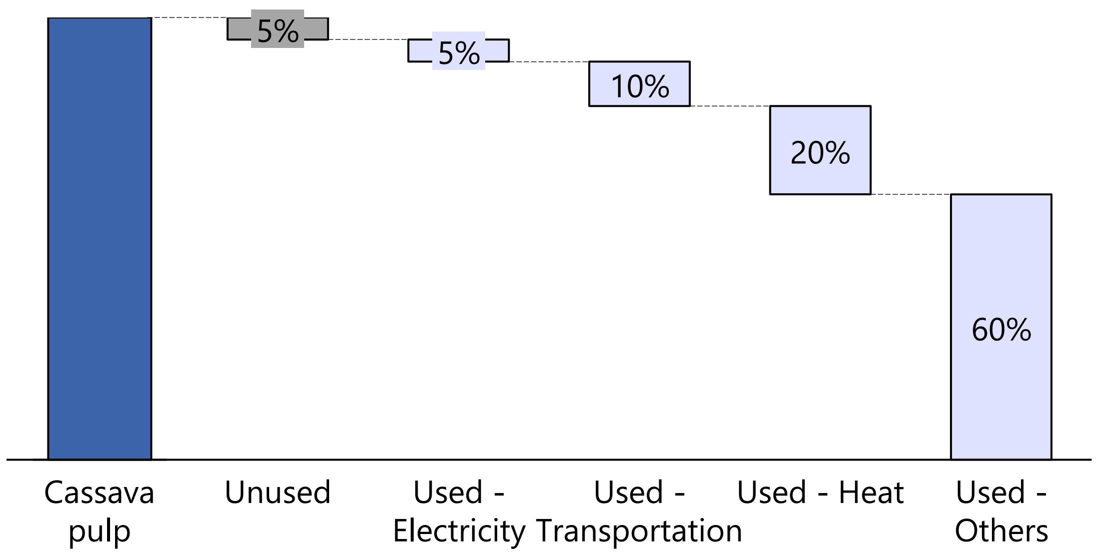
The majority of 65% is utilized for non-bioenergy. 20% of cassava pulp is used for heat generation and 10% for transport and 5% for electricity.

Utilization Proportion

Unit: million tons/year

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
2.87	0.14	0.14	0.29	0.57	1.72

Utilization Proportion



Others:
- Animal feed (main application)
- Organic fertilizer
- Substrate for mushrooms cultivation
- Biodegradable plastics and other eco-friendly products

Note: total amount is estimated based on FAO's data while utilization proportion is obtained from interview with industry's expert.
The utilized amount is calculated from total amount x utilization proportion
Sources: Food and Agriculture Organization, Interview

Utilization Proportion

Vietnam's bioethanol production relies on cassava, supported by significant foreign investments, but remains limited compared to sugarcane due to competing uses for cassava feedstock

Bioethanol production from Cassava in Vietnam

Bioethanol production in Vietnam	Bioethanol production	• By 2019, Vietnam had seven ethanol plants with a total capacity of 612 million liters per year. Four of these plants are designed to use 1.05 million tons of cassava to produce 420 million liters of bioethanol annually for gasohol blending. • The amount of ethanol produced from cassava is very limited compared to that from sugarcane. This is partly due to cassava feedstock being used by starch and glutamate processors.

	Capital investment	• Major investment from foreign and private enterprises:
		  • Petrosetco & Itochu (Japanese company): A $100 million joint venture established a 100-million-liter/year plant to produce bioethanol from cassava chips in Hiep Phuoc Industrial Park, completed in 2009.
		  • Petrosetco & Bronzeoak Group (UK company): An $86.73 million (VND 2,200 billion) investment was made for a 150-million-liter/year plant to produce bioethanol from cassava chips in the Dung Quat Economic Zone. The completion date is not available.

	Pilot Project	• Climate Protection through Energy Plants (CPEP)
		  • Period: Implemented from 2015 to 2018
		  • Operator: A German-Vietnamese consortium
		  • Objective: To enhance Vietnam's bioenergy production by utilizing post-mining lands, which are unsuitable for food cultivation due to poor soil quality.
		  • Details: The study explored the potential of post-mining sites in Vietnam for cultivating biomass as feedstock for bioenergy technologies. Energy crop systems were tested on these degraded lands.
		  • Results: Cassava cultivation on post-mining sites was found to be agriculturally feasible and provided substantial climate and economic benefits. Using cassava as feedstock for bioethanol production supported Vietnam's existing processing technology and achieved CO2 emission savings of up to 50% with E5 and E10 petrol blends.

VND to USD conversion rate: 1 USD = 25,365 VND (as of 7 November 2024)

Sources: Government publication, aticles

Wood residues in Vietnam

Wood Types

Plantations are government-owned, but the government allocates land to public and private organizations to operate plantations.

Wood Types and Usages

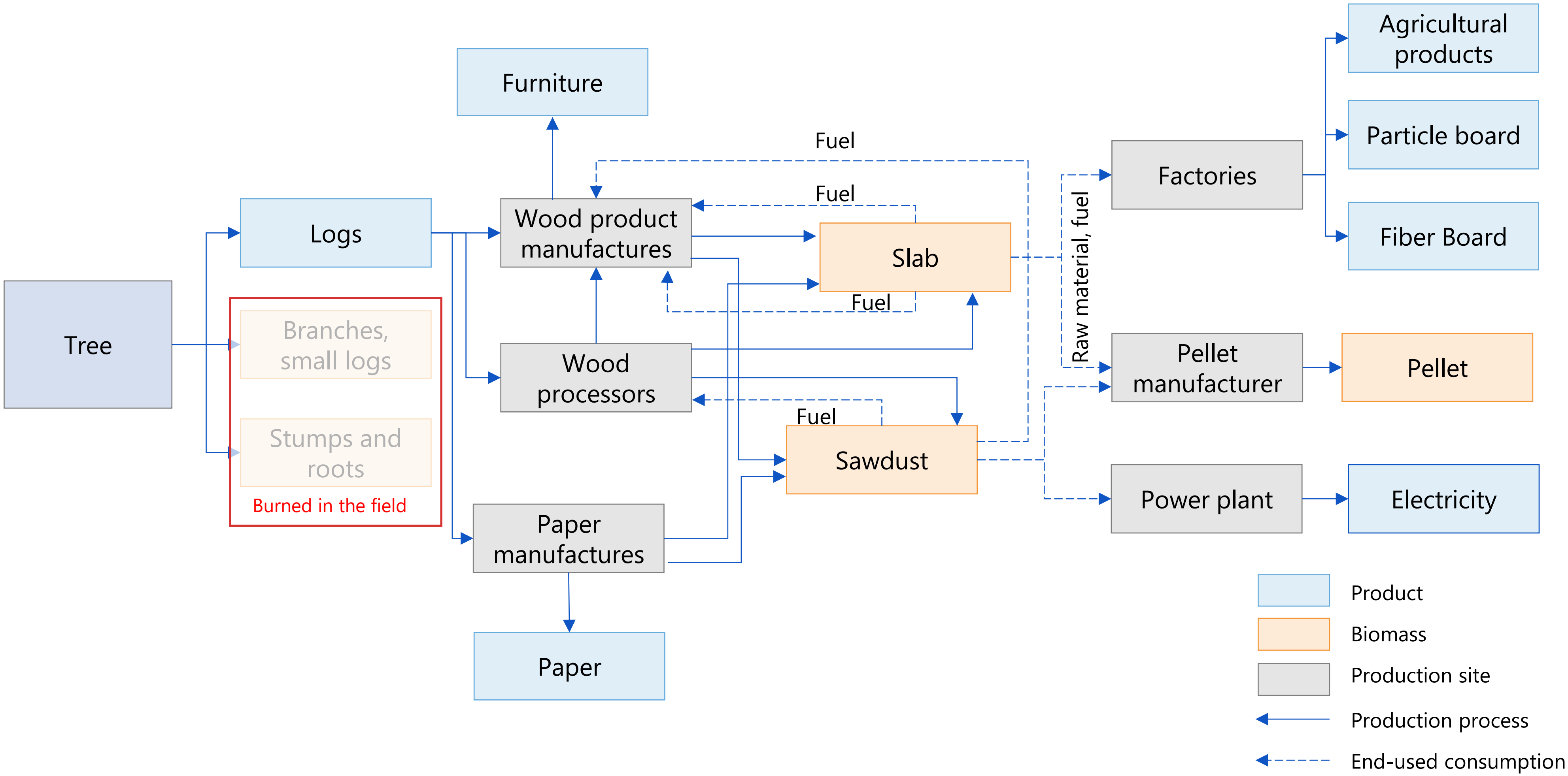
Wood Type	Plantation Type	• In Vietnam, plantation ownership is entirely government-controlled, with the government retaining full ownership of the land. However, the land is allocated to various entities, including government agencies, private farmers, and households, for plantation management and operation. • Rubber Tree plantation: ○ 60% are operated by public entities ○ 40% are operated by private entities • Eucalyptus and Acacia: ○ 50% are operated by public entities ○ 50% are operated by private entities
	Tree Type	• Acacia Tree: 40-70% • Eucalyptus Tree: 20-30% • Rubber Tree: 10-30%

Source: Interview

Supply Chain

In Vietnam, branches, stumps, and roots are burned in the field, while logs and trunks are collected and transported by middlemen. Slabs and sawdust are collected from wood processor

Supply Chain



Sources: Department of Alternative Energy Development and Energy Conservation, Caraga State University, NRI experts, Interview

Current Acquisition Practice

Delivering wood residues from plantations is challenging due to location and inadequate infrastructure. Sawdust and slabs, however, are easier-to-handle residues. The estimated cost of wood residues is around 69-90 USD per ton.

Current Acquisition Practice

Current Acquisition Practice	Collection	• Branch: burnt in the field • Stump and root: burnt in the field • Slab: Factories or wood processors use equipment like loaders or excavators to collect wood residues. • Sawdust: Factories or wood processors use equipment like loaders or excavators to collect wood residues. • Wood residues are mostly collected manually by workers and the process is challenging due to the manual labor involved.

	Pre-Processing	• Slabs are fed into grinders or chippers to break them down into smaller pieces before being used in pellet production.
		• Challenge:
		  ○ Controlling the moisture level because high moisture level can affect the processing and quality.
		  ○ Size reduction requires specialized equipment and can be labor-intensive and costly. Inconsistent sizing can also impact the efficiency of bioenergy conversion processes.

	Storage	• Slabs and sawdust must be stored in warehouses to shield them from rain and moisture, which can lead to damage. • Manufacturers strive to process wood residues promptly to minimize losses caused by prolonged storage. Slabs and sawdust are prone to rotting if stored for extended periods.
	Transportation	• Trucks are commonly used for transporting wood residues, handled by the middleman (trader or broker) • In some mountainous or hard-to-reach regions, animals (e.g., buffalo or cows) are used to transport wood residues to gathering points. Then, wood residues are transferred to trucks for further transport. • The frequency of transportation varies based on location and weather conditions, ranging from daily to every 2–3 days. During the rainy season, typically in the last quarter of the year, transportation may be delayed due to adverse weather.
Acquisition Cost		• Total estimate cost of Wood Residues: 69-90 USD per ton • Export Prices for wood chips: 110-150 USD per ton

Source: Interview

Utilized Portion

Slab and sawdust are used for bioenergy; however, challenges in their utilization remain, including residue contamination, higher costs, and technological limitations

Utilized Portion

Utilized Portion	Application	• Branch, tip, stump and root:
		  ○ Mostly burned by farmers and not used for factories or processing.
		• Slab and sawdust:
		  ○ Primarily used for wood pellet production
		    ▪ Wood pellets made from slabs and sawdust are exported to other countries
		  ○ Used as fuel in boilers for heating.
		    ▪ In Vietnam, slabs and sawdust are used for heating, not for electricity generation due to the higher cost compared to coal.

	Challenge in Utilization	• Lack of policies or incentives to promote advanced technologies for processing wood residues. • The higher costs associated with electricity generation from wood residues, compared to coal, present a significant barrier to investor interest and limit its competitiveness as an energy source. • Technological limitations in Vietnam hinder the processing and utilization of wood residues, especially for biomass power plants. • Contamination of wood residues (e.g., sand and soil) damages equipment, highlighting the need for improved technology to address these issues. The lack of advanced technology to effectively reduce or eliminate contamination in wood residues leads to increased operational expenses, including higher maintenance costs.
Utilization Outlook		• In the future, with enhanced government support and technological advancements, the use of wood residues could shift from primarily producing wood products to generating more biomass for electricity.

Source: Interview

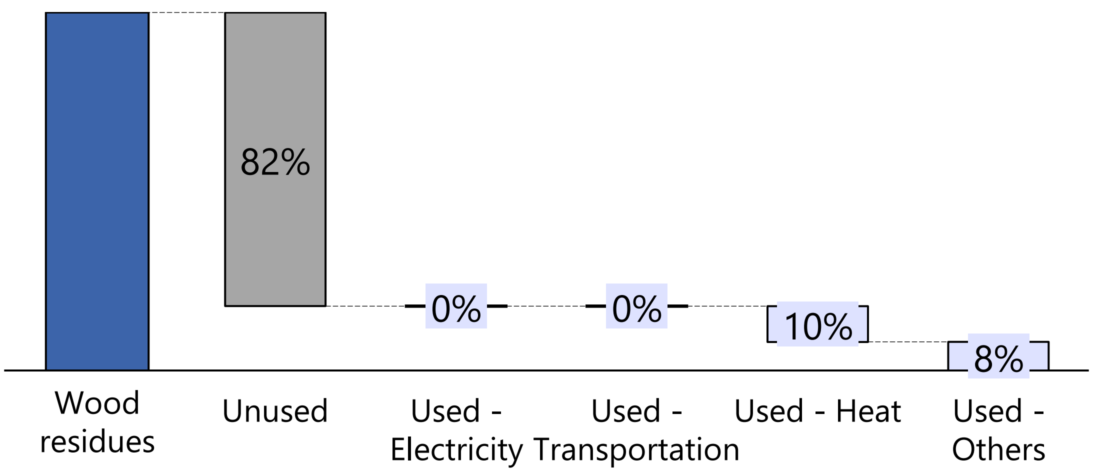
Utilization Proportion

In overview, wood residues are 80% unutilized, 10% is used for heat generation and 8% for other applications such as particle board production

Utilization Proportion

Unit: million tons/year

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transport	Heat	Others
18.10	14.86	0	0	1.81	1.43



Others:
- Particle board production
- Activated carbon

Note:
1. this total amount of wood residues is the sum of amount of each wood residue (stump & root, branch & tip, slab and sawdust)
2. the utilized amount of wood residues for each application is the sum of the utilized amount of each wood residue (stump & root, branch & tip, slab and sawdust) for each application
3. Then, the percentage of each application is calculated based on the result of step 1 and 2

Sources: Food and Agriculture Organization, Interview

Unutilized portion

Stumps, roots, and small branches are burnt in the field or used as firewood. The barriers are high transportation cost, lack of technology, investment limitation

Unutilized Portion

Unutilized Portion	Current Management	• Burnt in the field or used as firewood
		  ○ Stumps, roots, and small branches are generally not used by factories. Most of the time, they are either burned by farmers or, in some cases, small branches may be taken home for firewood.
		  ○ Farmers believe that burning wood residues, including stems and roots, enriches the soil by adding nutrients from the ash.
		  ○ After burning, the land is cleared and immediately replanted with new crops to begin the next growing cycle.

	Barriers to Utilization	• High transportation cost: High transportation costs make it unfeasible to transport larger roots and stumps, so they are typically discarded or burned. • Technological limitations: The technology available in Vietnam for processing and using wood residues, especially for biomass power plants, is still underdeveloped compared to countries like Japan or Korea. • Capital limitations: There is a lack of sufficient capital or financial support to invest in the required infrastructure and technology for biomass power plants in Vietnam. • Insufficient government incentives: While the government has plans to increase biomass electricity generation, the incentives currently offered are not enough to attract widespread investment or participation.

Source: Interview

Unutilized portion

Branches, stumps, and roots can be processed as wood chips with the technological supports and education of potential applications to farmers

Unutilized Portion

Potential Use for Unutilized Portion	Potential Applications	• Branches, stumps, and roots could be produced as wood chips
	Required supports	• Technological supports from private sector could encourage farmers to shift from burning wood residues, which can lead to environmental issues like forest fires, to more sustainable practices. ○ Example of technological support: mini-wood chippers or cutters which can process branches, stumps, and roots at the plantation, making transportation easier and more efficient. • Education and awareness programs would help farmers understand the benefits of utilizing wood residues beyond burning, such as through profitable applications.

Source: Interview

Government Policies in Vietnam

Government policy

The government supports biomass energy development through regulations, including incentives, mandatory electricity purchase, feed-in tariffs, and streamlined approval processes

Government Policy

	Policy	Description	Issuers	Effective year
Government Policy	Vietnam Renewable Energy Development Strategy (VREDS)	VREDS prioritizes the use of biomass energy for the production of power, biogas, pellets/briquettes and liquid biofuels. Increase the utilization rate of wastes generated from industrial/agricultural plants for energy purposes from 45% in 2015 to 50% in 2020, approx. 60% in 2030 and 70% in 2050.	Prime Minister	2016
	Decision No. 24/2014/QD-TTg	The decision established a regulatory and framework to enhance the development and utilization of biomass energy in Vietnam. Key aspects include: • Planning and integration: Biomass projects are included in national energy plans to align with Vietnam's energy strategy. • Investment and capital mobilization: Projects can access domestic and international funding, with state-backed credits and financing. • Land and tax incentives: Projects receive land-use exemptions and corporate tax reductions. • Electricity purchase commitments: The electricity buyer must buy all electricity from grid-connected biomass projects*. • Feed-in Tariffs and pricing: Introduces Feed-in Tariffs and fair pricing for biomass electricity. • Streamlined procedures: Simplifies approvals, licensing, and grid connections while enforcing technical standards. *Note: Grid-connected biomass power projects are biomass power plant projects built and connected to the national power grid for supply of a part or entire power for production to the national power grid.	Prime Minister	2014

Source: Interview, news, Vietnam law library website

Government policy

The government supports biomass energy through feed-in tariffs, tax incentives, and land-use benefits to encourage investment and sustainable energy development

Government Incentives

	Incentives	Description	Issuers	Effective year	Eligible for foreign company
Government Incentives	Feed-in Tariff (FiT) 2014 (revised 2020)	The FiT mechanism offers a fixed purchase price for electricity generated from biomass sources to encourage investment. As of 2020, the rates are: • Combined Heat and Power (CHP) projects: 0.0703 USD/kWh • Non-CHP projects: 0.0847 USD/kWh • However, news articles such as Bioenergy Insight comment that the rates are insufficient to cover high operational costs, especially when compared to Thailand (0.17 USD/kWh) and the Philippines (0.13 USD/kWh), making biomass projects less competitive compared to other renewable energy investments.	Ministry of Industry and Trade (MOIT)	2014 (revised 2020)	No information
	Corporate Income Tax (CIT)	Incentives for renewable energy projects aim to encourage sustainable energy investments. These include: • 10% corporate income tax rate for the renewable energy sector for 15 years. • 4-year tax exemption and a 50% tax reduction for the following 9 years for enterprises with specified new investment projects.	Ministry of Finance (MOF)	2014	Yes

Source: Articles, news

Government policy

The government supports biomass energy through feed-in tariffs, tax incentives, and land-use benefits to encourage investment and sustainable energy development

Government Incentives

	Incentives	Description	Issuers	Effective year	Eligible for foreign company
Government Incentives	Import Tax	Renewable energy projects on the approved list qualify for a 5-year import tax exemption on fixed assets, materials, and components. (Project investors must provide customs declaration forms and VAT payment vouchers during import)	Ministry of Finance (MOF)	N/A	Yes
	Land-Related Incentives	Renewable energy projects in socioeconomically disadvantaged or environmentally sensitive zones receive land lease and tax exemptions for up to 3 years after lease contracts take effect. Post-construction exemptions last 11 to 15 years, subject to specific conditions and authorized approval.	Ministry of Natural Resources and Environment (MONRE)	N/A	Yes

Source: Articles, news

Government policy

Vietnam collaborates with international organizations and development agencies to promote biomass energy

Examples of Government Collaboration

	Collaboration	Description	Partner	Project term
Government Collaboration	Climate Protection through Sustainable Bioenergy Markets in Vietnam (BEM)	The BEM project, implemented by the German Agency for International Cooperation (GIZ), aims to improve the conditions for sustainable biomass use in Vietnam. The project focuses on three main action areas: • Legal and regulatory framework: Supports adjustments to regulations for planning and licensing biomass energy projects, particularly at the provincial level. • Capacity development: Enhances the capacities of private sectors and financial institutions involved in biomass energy investments through needs assessments and tailored financing mechanisms. • Technology cooperation: Facilitates collaboration between Vietnamese and international enterprises, research institutions, and universities to promote technology transfer and innovation.	German Agency for International Cooperation (GIZ)	2019 - 2023
	• Erex's Biomass Power Plant Project	• Erex is building two 50 MW biomass power plants in Yen Bai and Tuyen Quang, each plant using 500,000 tons of wood residue annually, with operations set for mid-2027. • The government prioritizes Erex's projects under the National Power Development Plan (PDP VIII), with local authorities committed to providing support throughout the project lifecycle to ensure success and mutual benefits.	Erex (Japanese company)	From mid-2027

Source: News, company’s website, organization websites

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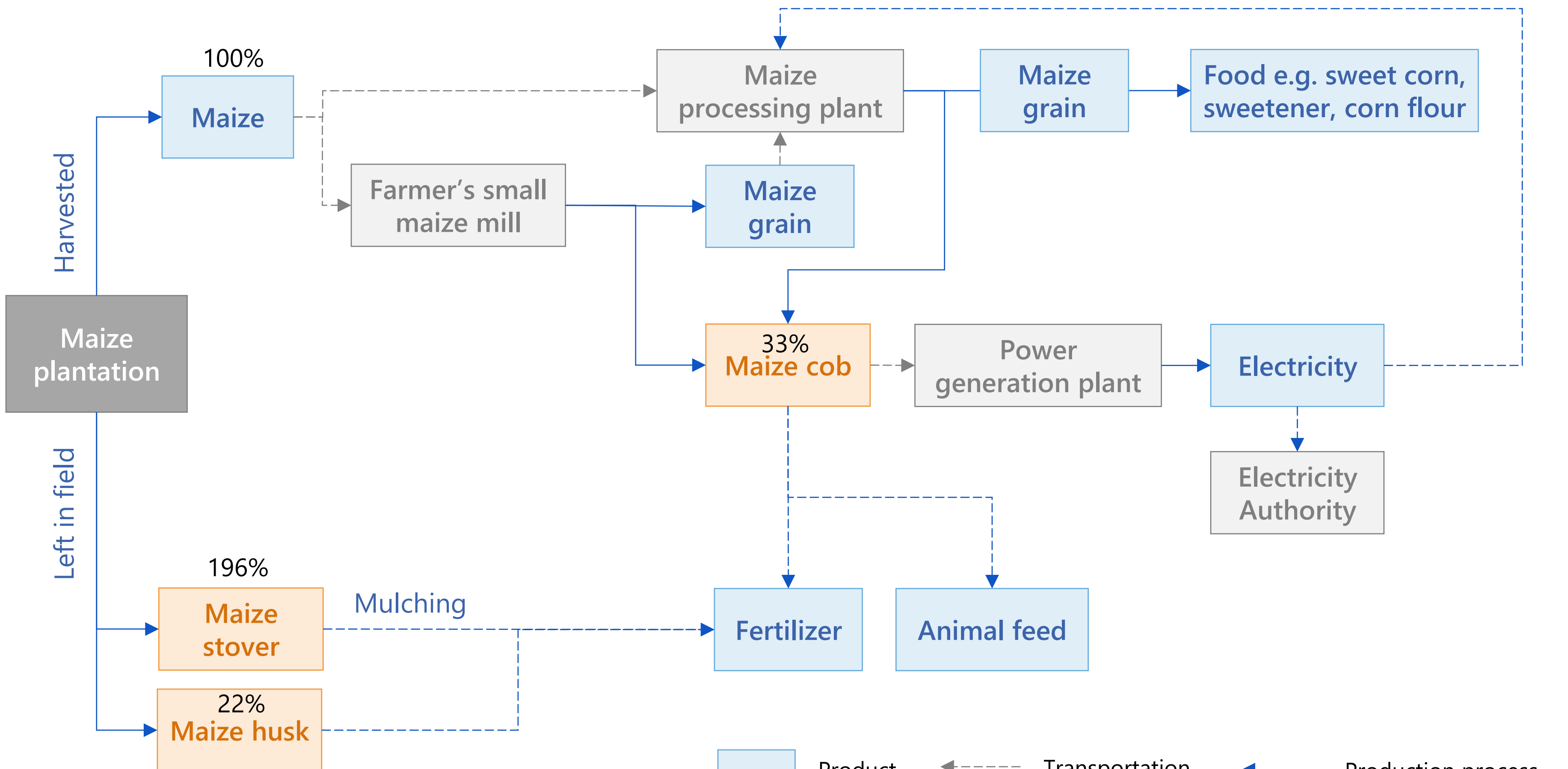
Maize cob in the Philippines

Supply Chain

Maize cob is a residue from processing facilities while stover and husk are residues in the field. From mills, cob is sold for animal feed and used for electricity generation

Supply Chain



Note: The percentage refer to the residue-to-crop ratio (the definition is explained in task1 page …), obtained from FAO

Source: Interview

Current Acquisition Practice

The main challenge in the acquisition process is transportation. The bulkiness of maize cobs makes transportation difficult and costly, reducing the attractiveness of utilizing cobs.

Current Acquisition Practice

Current Acquisition Practice	Collection	• Maize cob can be collected at the facilities during the grain separating process.
		  ○ 95% of total maize cob can be collected at the plantation. Farmers will separate and harvest only the grain, leaving maize cob pile up at the field
		  ○ Around 5% of maize cob can be collected at mills of maize processing plant
		    ▪ This situation occurs particularly during the rainy season when high moisture levels can potentially damage maize grains. To address this, the mill of maize processing plant will first process the entire maize, then separates the cob and dries the grain.

	Pre-Processing	• Drying process
		  ○ Cobs need to be dried before being utilized This process can be done with minimal challenge with the current machine and technology. Power plants can also dry cobs in an open space without additional process or machine usage to control the cost.
		• Sizing
		  ○ Cob will be cut into a certain size, based on each power plant's criteria for residue size.

	Storage	• Cobs do not require a specific condition for storage. It can be stored in an open space in a farm or in a small storage.
	Transportation	• Farmers transport cob from mills to power plant by trucks. However, the bulkiness of maize cobs presents a significant challenge for transportation, as it increases the difficulty and transportation cost. This high transportation cost reduces the feasibility and attractiveness of using maize cobs for power generation.
Acquisition Cost		• No price is available due to limited transactions between parties. Most maize cobs are used as fertilizer within plantations rather than being sold.

Source: Interview

Utilized Portion

Currently, maize cobs are primarily used as fertilizer, with a smaller portion utilized for electricity generation, though this use is not yet widespread

Utilized Portion

Utilized Portion	Application	• Used as fertilizer (main application) ○ Most of the utilized maize cob portion are for fertilization in the mulching process within the maize plantation • Used for electricity generation ○ Approximately 10 out of the 60 biomass power plants registered with the DOE utilize maize cobs to generate electricity. These 10 biomass power plants locate in one of main islands in the southern Philippines, where large maize plantations are found. ○ Some of these power plants use maize cobs mixed with other residues for electricity generation. These plants may purchase maize cobs from maize mills that do not own power plants. In contrast, power plants owned by maize mills primarily use their own maize cob waste as the main resource. These plants typically supply electricity for the mill's internal operations first, with some selling any surplus electricity back to the grid. • Used as animal feed ○ Only a small number of farmers with livestock use maize cobs for feed, accounting for a very minor portion. • Used as fuel for residential cooking ○ Some people use maize cobs as fuel for activities like cooking; however, this represents only a very small portion of the total volume

Source: Interview

Utilized Portion

Currently, maize cobs are primarily used as fertilizer, with a smaller portion utilized for electricity generation, though this use is not yet widespread

Utilized Portion

Utilized Portion	Challenge in Utilization	• Transportation would be a significant challenge to acquire maize cob to biomass power plants ○ The bulkiness of maize cobs makes transportation challenging, as fewer cobs can be transported per trip, requiring more trips to move the same quantity compared to other residues. This increases fuel consumption, and the additional trips, combined with handling inefficiencies, result in higher transportation costs, reducing the economic viability of using maize cobs.
Utilization Outlook		• In the future, if there are establishment of biomass power plant near the maize plantation, maize cob might be used more for electricity power generation

Source: Interview

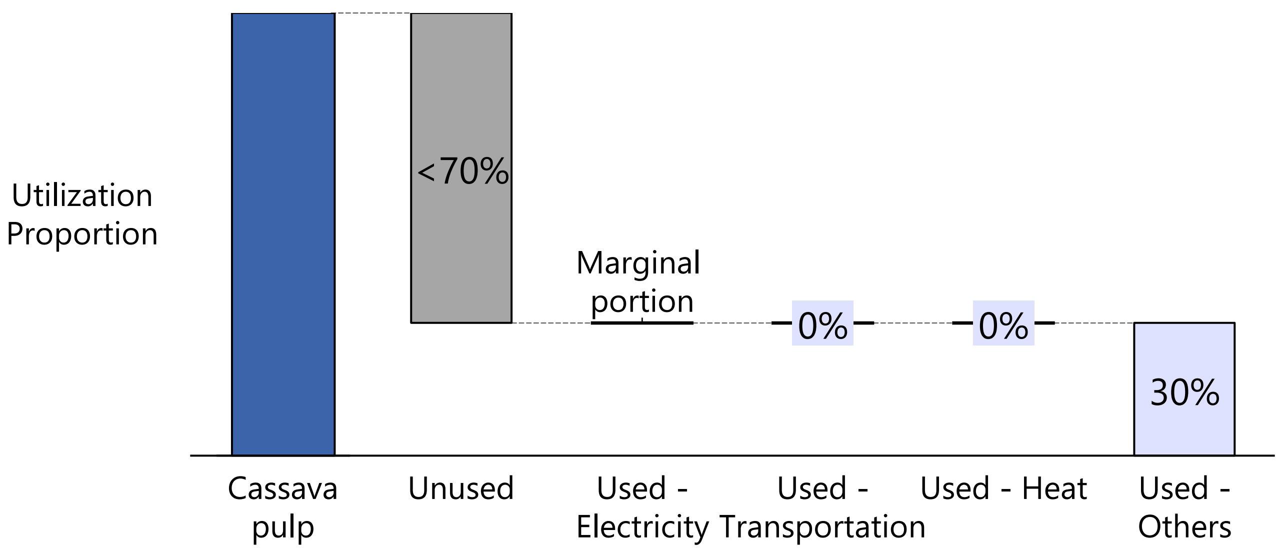
Utilization Proportion

It is estimated that 30% of maize cobs are used as fertilizer, with the marginal portion for electricity generation. In the future, the utilization of maize cobs for electricity generation is expected to increase.

Utilization Proportion

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transportation	Heat	Others
2.72	<1.91	Marginal	0	0	0.82

Unit: million tons/year



Others:

- Fertilizer (main application)
- Animal fed
- Fuel for residential cooking

Note: total amount is estimated based on FAO's data while utilization proportion is obtained from interview.
The utilized amount is calculated from total amount x utilization proportion

Sources: Food and Agriculture Organization, Interview

Unutilized portion

Addressing challenges in collection and transportation could reduce the amount left in the field, make prices more competitive, and enhance its attractiveness for utilization.

Current Practice for Unused Portion	Current Management	• Left unused at the field or burnt to get rid of the residue
	Barriers to Utilization	• Difficulty in collecting and transportation of bulky maize cob to biomass power plants. • Higher competition from other residues which are more readily available, easier to transport and acquire. • Other biomass residues already used for electricity generation remain readily available and sufficient to meet demand. As a result, biomass power plants can rely on these established resources without the need to conduct new trials or invest in costly boiler modifications to accommodate maize cobs or other alternative residues.
Potential Use for Unused Portion	Potential Applications	• Used for electricity generation ○ The electricity demand is growing in the Philippines, so more biomass power plants will be necessary.
	Required supports	• Financial and technological support, such as loans for farmers to acquire advanced machinery and equipment, can simplify biomass collection. For instance, certain machines can harvest husks, stover, and cobs simultaneously, leaving no residues behind in the field. • Greater incentives and support from the government will be essential for developing biomass power plants. Establishing such plants requires substantial capital investment, and without government backing, it becomes challenging to promote their expansion.

Source: Interview

Wood Residues in the Philippines

Wood Types

95% of plantations in the Philippines are owned by the government. Top 3 trees are Falcata, Mahogany and Yamane.

Wood Types and Usages

Wood Type	**Plantation Type**	• There are 100,603 hectares of plantation area.
		  ○ 95% is owned by the government.
		    ▪ 60-62% is under Community-Based Forest Agreements.
		    ▪ 27.5% is under Integrated Forest Management Agreements.
		  ○ 5% is privately owned.

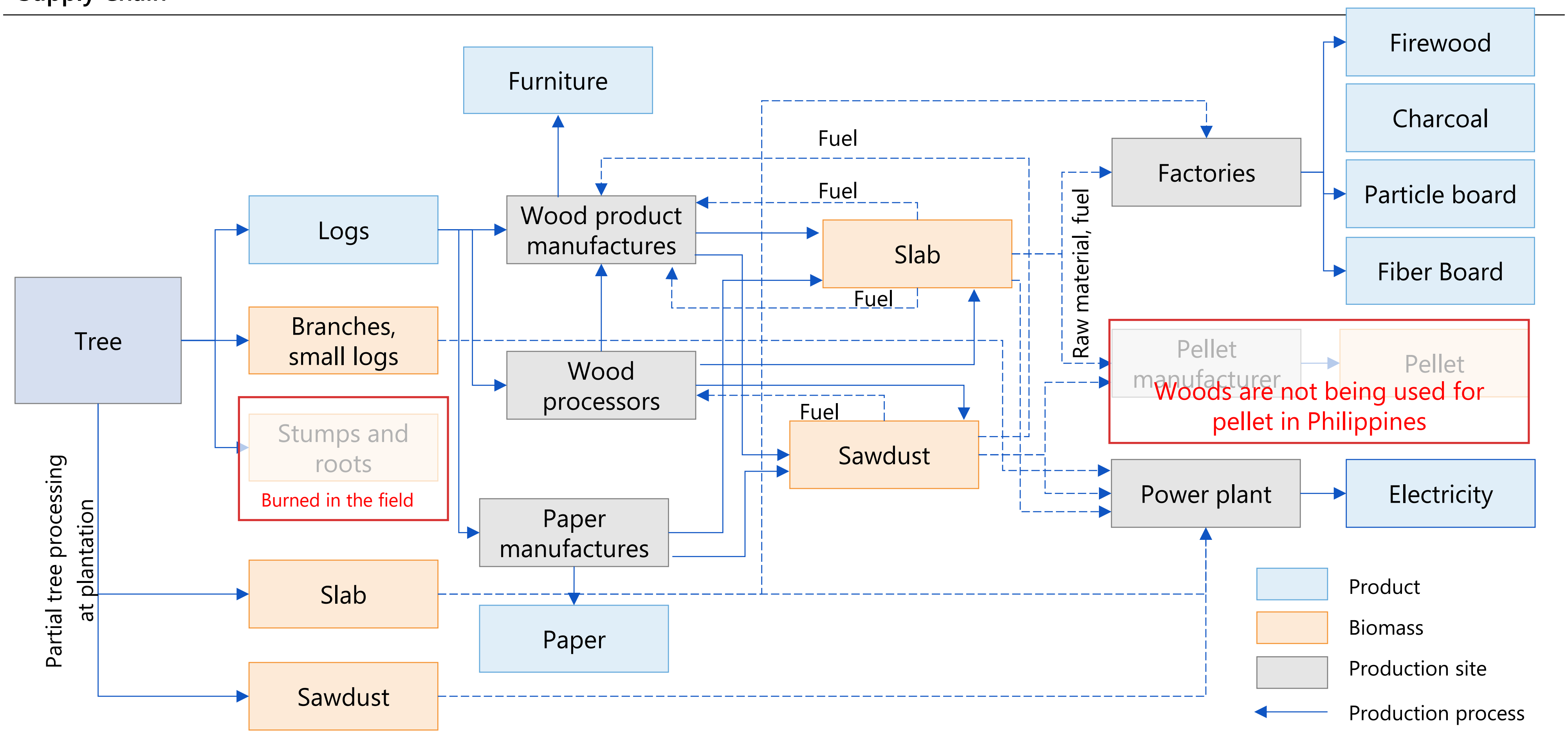
	Tree Type	• The top 5 trees in the Philippines are:
		  1. Falcata (71%): 449,928.75 m^3
		  2. Mahogany (9.1%): 57,822.54 m^3
		  3. Yemane (6.2%): 39,488.01 m^3
		  4. Assorted species (6.5％): 41,425.67 m^3
		  5. Acacia (1.3%): 17,486 m^3
		• Some power plants uses fast-growing tree like eucalyptus for biomass. They avoids harvesting the roots, allowing the trees to regrow and be harvested again in three years.

Source: Department of Environment and Natural Resource, Interview

Supply Chain

During harvesting, stump and root are left unused while branches are collected for further use. Slabs and sawdust are produced at the plantation during partial tree processing

Supply Chain



Sources: Department of Alternative Energy Development and Energy Conservation, Caraga State University, NRI experts, Interview

Current Acquisition Practice

Transportation is a big challenge to acquire wood residues to either wood processors or power plant.

Current Acquisition Practice

Current Acquisition Practice	Collection	• Stump and root: Left unused at the plantation. • Branch and tip: Collected from plantations during log cutting. • Slab: Generated during partial tree processing • Sawdust: Generated during partial tree processing but being left.
	Pre-Processing	• Sizing for woodchips ○ For woodchips, some power plants may have certain criteria such as sizing, so power plant will request the wood processing factories to cut them into certain size.
	Storage	• Wood residues are stored in open areas or warehouses
	Transportation	• In mountainous areas, woods are manually transported using bull carts due to the lack of roads and challenging terrain. Once the woods are brought down from the mountains, they are loaded onto dump trucks for further transport. • The plantation's mountainous location makes road construction for wood transportation challenging. Additionally, its distance from power plants further increases transportation costs.
Acquisition Cost		• Cost for collecting the wood from the plantation is 64-68 USD (3,720-3,970.55 PHP) per ton. ○ This includes cost of cutting down trees, cost of bucking the tree into 6-ft lengths, and transportation cost. • Cost of woodchips: 71 USD (4,126 PHP) per ton.

PHP to USD conversion rate: 1 USD = 58 PHP (as of 7 November 2024)

Source: Interview

Utilized Portion

Wood residues, except stump and root, are used as supplementary feedstock for electricity generation.

Utilized Portion

Utilized Portion	**Application**	• Stumps and roots :
		  ○ Left unused at the plantation
		• Branches and small logs :
		  ○ Used for electricity generation
		  ○ Only a small amount is used for fuel in the mountains
		• Slab:
		  ○ Used for electricity generation
		  ○ Used for firewood and charcoal production
		• Sawdust:
		  ○ Used for electricity generation
		  ○ Used as fuel for residential cooking
		• For electricity generation, wood residues are supplementary feedstock.
		  ○ Usually, factories and power plants will mix maximum 10% of woodchips and sawdust with other agricultural residues such as rice husk and sugarcane bagasse in multi feedstock boilers.

Source: Interview

Utilized Portion

Despite challenges such as high costs, moisture control, and low density, wood residues hold significant potential for sustainable energy and industrial use

Utilized Portion

Utilized Portion	Challenge in Utilization	• Higher cost compared to other feedstocks
		  ○ The higher calorific value of wood residues, such as wood chips, is one reason they are more expensive than other biomass residues. As a result, wood residues are primarily used as supplementary feedstock rather than the main fuel due to their higher cost compared to other residues.
		• Moisture content control
		  ○ Another challenge is in the management of wood residues’ moisture content because high moisture levels reduce the efficiency of electricity generation. Storing wood residues in open areas could increase their moisture level.
		• Sawdust’s suitability for boilers
		  ○ In some power plants, sawdust's low density makes it inefficient for use in their boilers.

Utilization Outlook		• The future utilization of wood residues in the Philippines is promising, driven by a growing recognition of their potential to reduce waste, support industrial growth, and enhance sustainability. • Research efforts led by the Forest Products Research Institute aim to explore and optimize the applications of wood residues. These initiatives include developing uses for wood waste in veneer manufacturing and charcoal briquetting.

Source: Interview, FAO

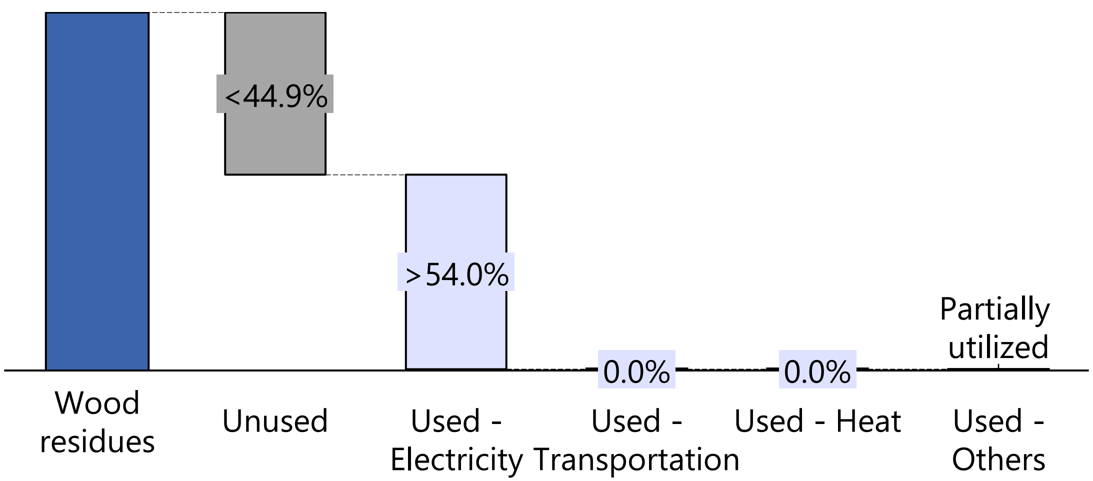
Utilization Proportion

It is estimated that wood residues in the Philippines is 54% utilized for electricity, 45% left unused.

Utilization Proportion

Unit: million tons/year

Total Amount	Unused Amount	Utilized Amount			
		Electricity	Transportation	Heat	Others
3.67	<1.65	>1.98	0	0	Partially utilized



Others: fuel for cooking

Note:
1. this total amount of wood residues is the sum of amount of each wood residue (stump & root, branch & tip, slab and sawdust)
2. the utilized amount of wood residues for each application is the sum of the utilized amount of each wood residue (stump & root, branch & tip, slab and sawdust) for each application
3. Then, the percentage of each application is calculated based on the result of step 1 and 2

Sources: Food and Agriculture Organization, Interview

Unutilized portion

To increase the utilization of stumps, roots, and sawdust, cost-effective solutions for collection and transportation are needed, along with technology to produce value-added products.

Unutilized Portion

Unutilized Portion	Current Management	• Sawdust, stumps, and roots, are usually left in the field to decompose

	Barriers to Utilization	• Economic viability
		  ○ High cost for digging up roots and transporting them outweigh their market value, making their utilization economically unfeasible.
		• Resource value perception
		  ○ The low perceived value of small wood components discourages investment in their collection, transportation, and processing, further limiting their utilization.
		• Ash generation challenges
		  ○ Stumps and roots generate a large amount of ash, posing challenges for power plants in utilizing them effectively.

Potential Use for Unutilized Portion	Potential Applications	• Potentially used for electricity and heat generation

	Required supports	• Establishment of power plants, and the development of logistics facilities.
		  ○ If more processing plants or power plants are established nearby, along with improved logistics facilities, there will be potential for utilizing the unused wood materials.
		• Technology or machine for residues collection
		  ○ Invest in technology or machinery that reduces the cost of digging up roots and transporting them, such as specialized root-harvesting equipment or efficient transport vehicles designed for difficult terrain.
		• Technology innovation
		  ○ Develop or invest in technology that can process small wood components more efficiently, transforming them into higher-value products (e.g., advanced biofuels)
		  ○ Research and implement pre-processing methods that minimize the amount of ash generated during combustion or conversion processes

Source: Interview, NRI analysis

Government Policies in the Philippines

Government policy

The government has established laws aimed at increasing the overall use of biomass

Government Policy

	Law	Description	Relevant Entities	Year
Government Policy	Department of Energy Circular No. DC2024-06-0018	The new guideline for regulation of renewable resource, aiming to attract more investment in renewable energy business and ultimately increase the portion of renewable energy in the overall energy mix	Department of Energy (DOE)	2024
	Department of Energy (DOE) Circular No. DC2022-02-0002	Promotes the development of biomass waste-to-energy (WTE) facilities, applying to RE developers, LGUs, and ERC.	DOE, Local Government Units (LGUs), Energy Regulatory Commission (ERC)	2022
	Republic Act No. 9513 (Renewable Energy Act of 2008)	Provides incentives for renewable energy development, including biomass energy. It promotes energy efficiency and supports projects using biomass. • 7 years of income tax holiday • Duty-Free importation for renewable energy machine and equipment	DOE, RE Developers, Energy Regulatory Commission	2008
	Republic Act No. 9367 (Biofuels Act of 2006)	Mandates the use of biofuels (including biomass) as part of the country's fuel mix to reduce dependence on fossil fuels and mitigate climate change.	DOE, Biofuels producers, Energy Sector	2006

Source: Interview

Government policy

The government has established laws aimed at increasing the overall use of biomass

Government Policy

	Law	Description	Relevant Entities	Year
Government Policy	Republic Act No. 8749 (Clean Air Act of 1999)	Establishes policies to improve air quality, including encouraging the use of cleaner and renewable energy sources like biomass to reduce harmful emissions from traditional fuels.	Department of Environment and Natural Resources (DENR), Energy Sector	1999
	National Energy Plan	A framework for the efficient use of energy resources, ensuring energy availability, minimizing environmental impact, and promoting renewable energy like biomass	DOE, Energy Sector	Varies
	Master Plan for Forestry	Aims to manage, conserve, and utilize forest resources efficiently, with a focus on sustainable practices that support renewable energy projects, including biomass.	Department of Environment and Natural Resources (DENR), Forestry Sector	Varies
	Philippine Strategy for Sustainable Development (PSSD)	Aims for economic growth while ensuring the protection of biological resources and the environmental quality, fostering sustainable biomass and renewable energy use.	National Economic and Development Authority (NEDA), Environmental Agencies	Varies
	National Renewable Energy Program (NREP) 2020-2040	Aims to increase the share of renewable energy in the power generation mix to 35% by 2030 and 50% by 2040, including the addition of 277 MW of biomass power capacity by 2030.	Department of Energy	2021

Source: Interview, DOE, article

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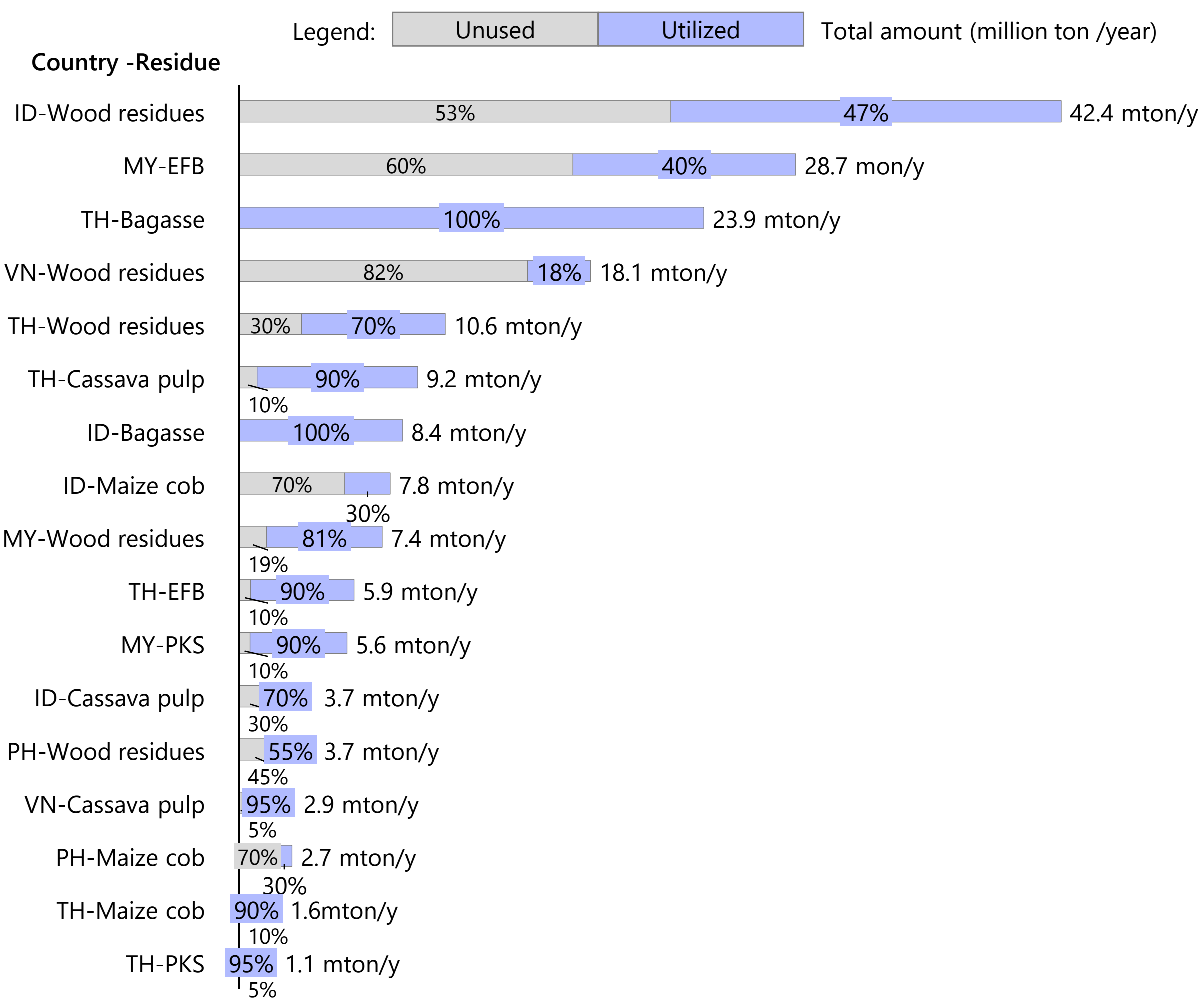
Utilization rate and type of usage for each biomass residue differs across residue, in which electricity and non-energy usage are they key usage methods

Summary of Estimated Utilization Proportion and Utilization Type



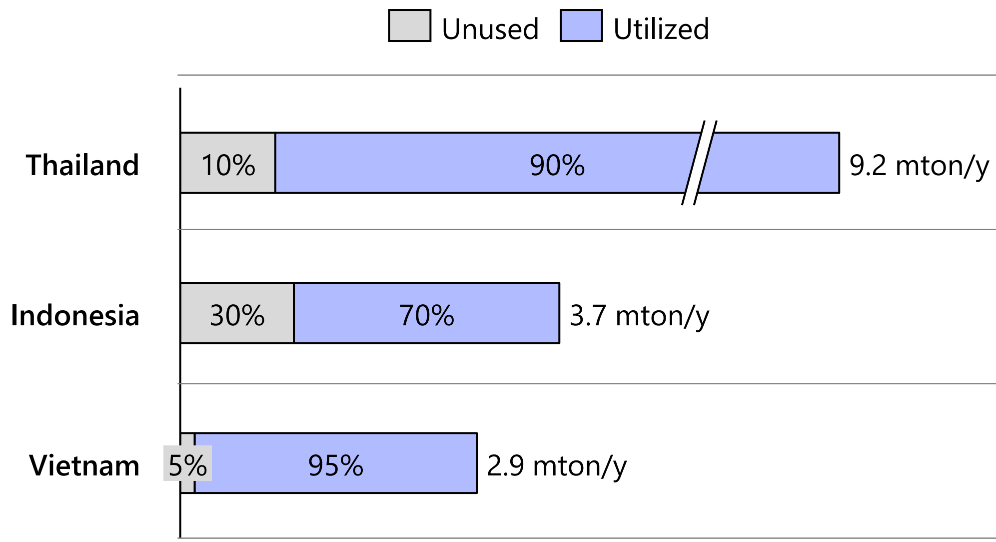
% Unused	% Utilized			
	Electricity	Transport	Heat	Others
52%	21%	0%	14%	13%
60%	20%	0%	5%	15%
0%	**90%**	0%	0%	10%
82%	0%	0%	10%	8%
30%	6.5%-7.8%	0%	7.7%-9.1%	**54%**
10%	10%	8%	15%	**57%**
0%	**80%**	0%	10%	10%
70%	20%	0%	partial	10%
19%	8%	0%	**36%**	**36%**
10%	**75%**	0%	5%	10%
10%	**80%**	0%	10%	0%
30%	10%	10%	10%	**40%**
45%	**54%**	0%	0%	0%
5%	5%	10%	20%	**60%**
70%	marginal	0%	0%	30%
10%	1%-22%	0%	23%-44%	**45%**
5%	**90%**	0%	5%	0%

Source: NRI estimation based on desktop study and interviews

Summary of Estimated Utilization Proportion of Cassava Pulp

Thailand leads in cassava pulp utilization, while Vietnam and Indonesia have similar levels. However, limited supply in Indonesia and Vietnam could restrict large-scale investments and development.

Estimated Utilization Proportion of Cassava Pulp



	% Unused & Amount	% Used & Amount	% Used & Amount by Application			
			Electricity	Transport	Heat	Others
Thailand	10%	90%	10%	8%	15%	**57%**
	0.9	8.3	0.9	0.7	1.4	**5.2**
Indonesia	30%	70%	10%	10%	10%	**40%**
	1.1	2.6	0.4	0.4	0.4	**1.5**
Vietnam	5%	95%	5%	10%	20%	**60%**
	0.1	2.7	0.1	0.3	0.6	**1.7**

Unit of amount is million tons/year

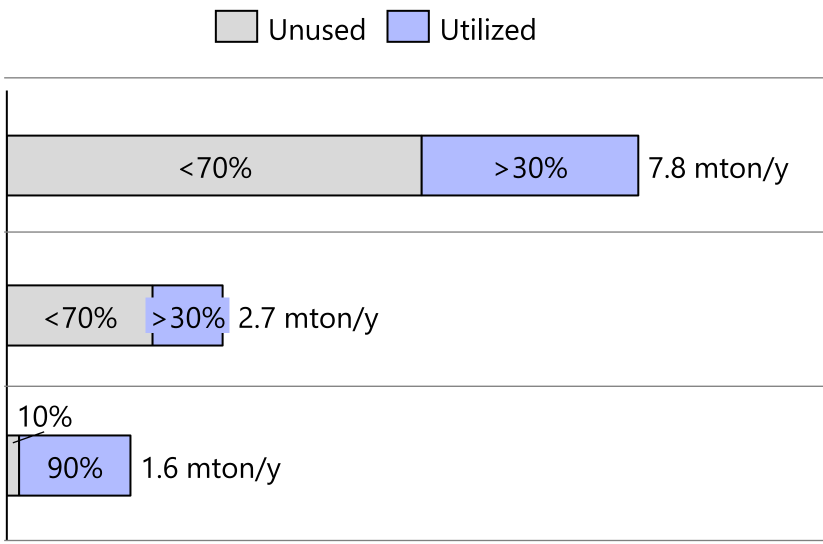
- In Thailand and Vietnam, cassava pulp utilization is nearly 100%, while Indonesia lags behind at around 70%.
- Thailand leads in total usage across all applications, whereas Vietnam and Indonesia show similar utilization levels. However, the limited supply in Indonesia and Vietnam constrains opportunities for large-scale investments, development, and broader application potential.

Source: NRI estimation based on desktop study and interviews

Summary of Estimated Utilization Proportion of Maize Cob

Maize cobs have minimal utilization in value-added applications due to challenges such as limited suitability as fuel, incompatible infrastructure, and high transportation costs.

Estimated Utilization Proportion of Maize Cob



	% Unused & Amount	% Used & Amount	% Used & Amount by Application			
			Electricity	Transport	Heat	Others
Indonesia	**<70%**	>30%	20%	0%	Partial	10%
	<5.4	>2.3	1.6	0	Partial	0.8
Philippines	**<70%**	>30%	Partial	0%	0%	30%
	<1.9	>0.8	Partial	0	0	0.8
Thailand	10%	90%	~1%-22%	0%	~23%-44%	**45%**
	0.2	1.4	~0.02-0.36	0	~0.37-0.71	**0.7**

Unit of amount is million tons/year

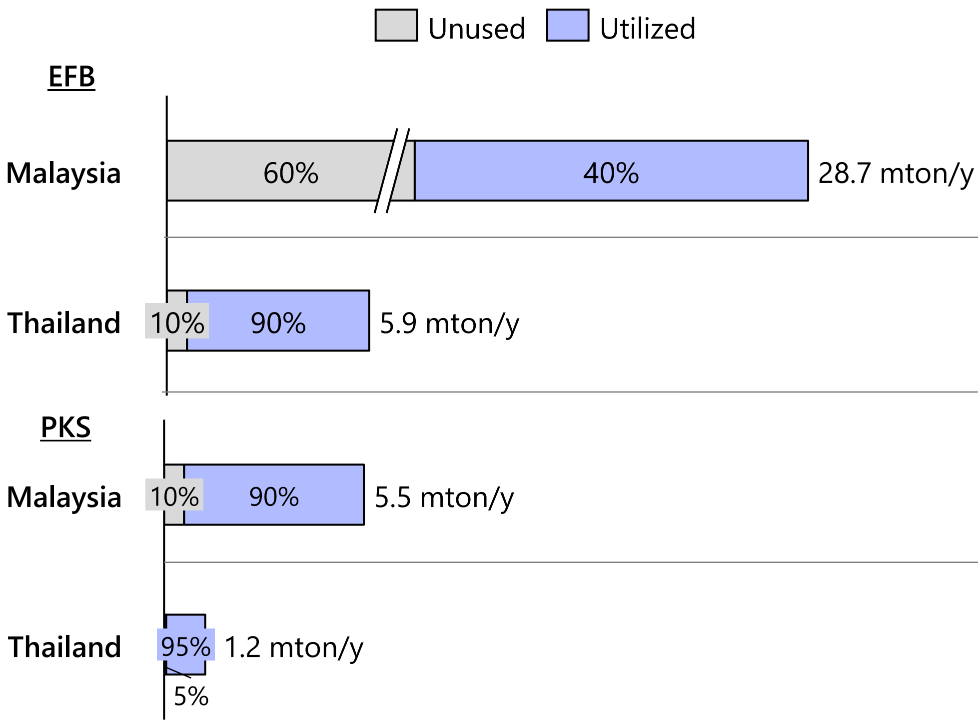
- The utilized amount of maize cobs ranges from 0.8 to 2.3 million tons per year across these three countries. Indonesia and the Philippines have high unused proportions of maize cobs (70%), indicating a supply-demand imbalance, while Thailand demonstrates a more balanced situation with 90% utilization, since Thailand produce less maize cob.
- The high unused amount of maize cobs as biomass arises from several challenges. Maize cobs produce limited biogas, making them less suitable for energy production. Existing boiler technologies are not compatible with maize cob characteristics, requiring significant new investments. Furthermore, their bulkiness results in high transportation costs, further complicating utilization.

Source: NRI estimation based on desktop study and interviews

Summary of Estimated Utilization Proportion of Oil Palm Residues

Despite the abundant supply of EFB in Malaysia, a portion remains unused. Enhancing technology can improve its utilization.

Estimated Utilization Proportion of Oil Palm Residues



		% Unused & Amount	% Used & Amount	% Used & Amount by Application			
				Electricity	Transport	Heat	Others
EFB Malaysia	%	**60%**	40%	20%	0%	5%	15%
	Amount	**17.2**	11.5	5.7	0.0	1.4	4.3
EFB Thailand	%	10%	90%	**75%**	0%	5%	10%
	Amount	0.6	5.3	**4.4**	0.0	0.3	0.6
PKS Malaysia	%	10%	90%	**80%**	0%	10%	0%
	Amount	0.5	5.0	**4.4**	0.0	0.6	0.0
PKS Thailand	%	5%	95%	**90%**	0%	5%	0%
	Amount	0.1	1.1	**1.0**	0.0	0.1	0.0

Unit of amount is million tons/year

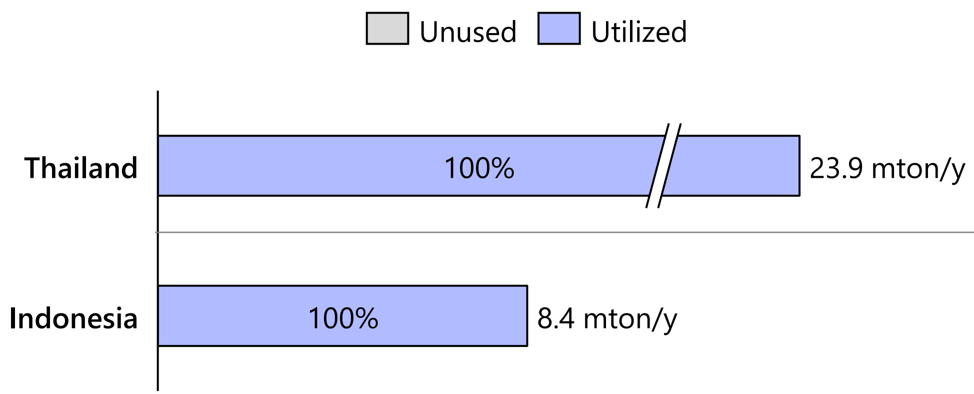
- Malaysia has a significantly larger supply of EFB, nearly five times more than Thailand. Despite Malaysia utilizing a greater quantity, a substantial portion remains unused. However, there are challenges in using EFB. Its bulky nature makes handling difficult and increases transportation costs. Additionally, its high moisture content requires specialized technology or machinery for pellet production, necessitating additional investment.
- Regarding PKS, the supply poses a challenge. The available volume of PKS could be insufficient if demand keeps growing in both countries.

Source: NRI estimation based on desktop study and interviews

Summary of Estimated Utilization Proportion of Sugarcane Bagasse

Sugarcane bagasse is fully utilized in Thailand and Indonesia due to its easy collection, suitability as a fuel, and established technology and infrastructure.

Estimated Utilization Proportion of Sugarcane Bagasse



	% Unused & Amount	% Used & Amount	% Used & Amount by Application			
			Electricity	Transport	Heat	Others
Thailand	0%	100%	**90%**	0%	0%	10%
	0	23.9	**21.5**	0	0	2.4
Indonesia	0%	100%	**80%**	0%	10%	10%
	0	8.4	**6.7**	0	0.8	0.8

Unit of amount is million tons/year

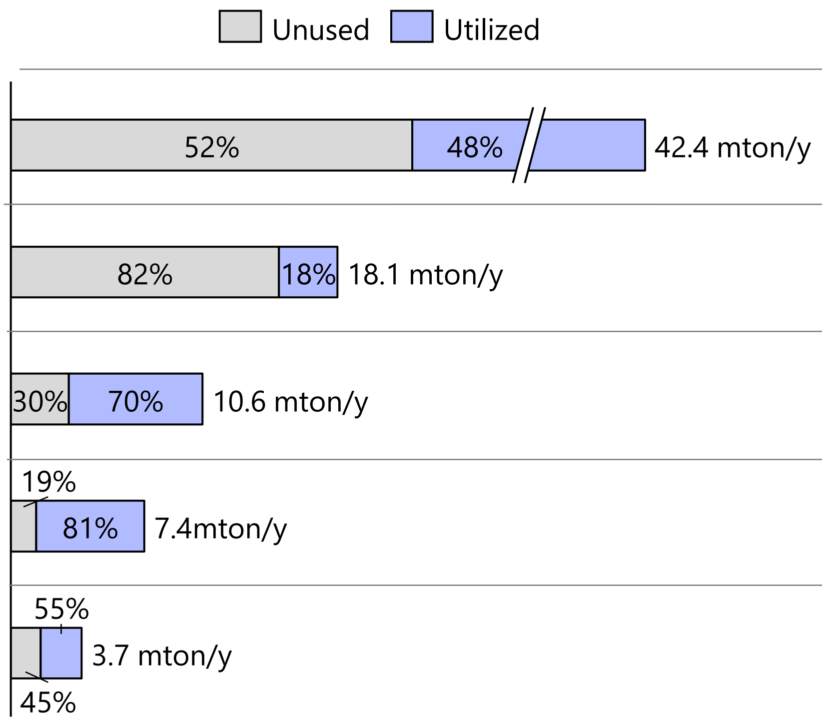
- Sugarcane bagasse is fully utilized in Thailand and Indonesia, mainly for electricity generation, due to its on-site availability at sugar mills with no additional collection costs. Its suitability as biomass fuel by having low heating value, combined with well-developed technology and infrastructure, makes it a cost-effective energy source.
- Additionally, other sugarcane residues, such as sugarcane leaves, are being considered for utilization to alleviate handling constraints and supplement the limited bagasse supply.

Source: NRI estimation based on desktop study and interviews

Summary of Estimated Utilization Proportion of Wood Residues

The high utilization rates in Thailand and Malaysia are driven by the use of stumps and roots, which are typically left unused in other countries.

Estimated Utilization Proportion of Wood Residues



	% Unused & Amount	% Used & Amount	% Used & Amount by Application: Electricity	Transport	Heat	Others
Indonesia	**52%**	48%	21%	0%	14%	13%
	22.3	20.1	8.8	0	5.7	5.6
Vietnam	**82%**	18%	0%	0%	10%	8%
	14.9	3.2	0	0	1.8	1.4
Thailand	30.2%	69.8%	~6.5%-7.8%	0%	~7.7%-9.1%	**54.3%**
	3.2	7.4	0.6-0.8	0	0.8-1.0	**5.8**
Malaysia	19%	81%	8%	0%	**36%**	**36%**
	1.4	6.0	0.6	0	**2.7**	**2.7**
Philippines	<45%	>54.0%	**>54.0%**	0%	0%	Partial
	<1.6	>2.0	**>2.0**	0	0	Partial

Unit of amount is million tons/year

- Indonesia shows the highest used amount around 20 million tons/year, followed by Thailand and Malaysia with the utilized amount around 6-8 million tone/year. Vietnam and the Philippines utilized wood resides only around 2-3 million tons/year.
- Thailand and Malaysia demonstrate higher utilization proportions, primarily driven by the use of stumps and roots. These materials are processed into woodchips for electricity generation and particleboard production, with both countries are exporters of particleboard. This application is economically viable, as the income generated outweighs the processing costs, making it a valuable investment.

Source: NRI estimation based on desktop study and interviews

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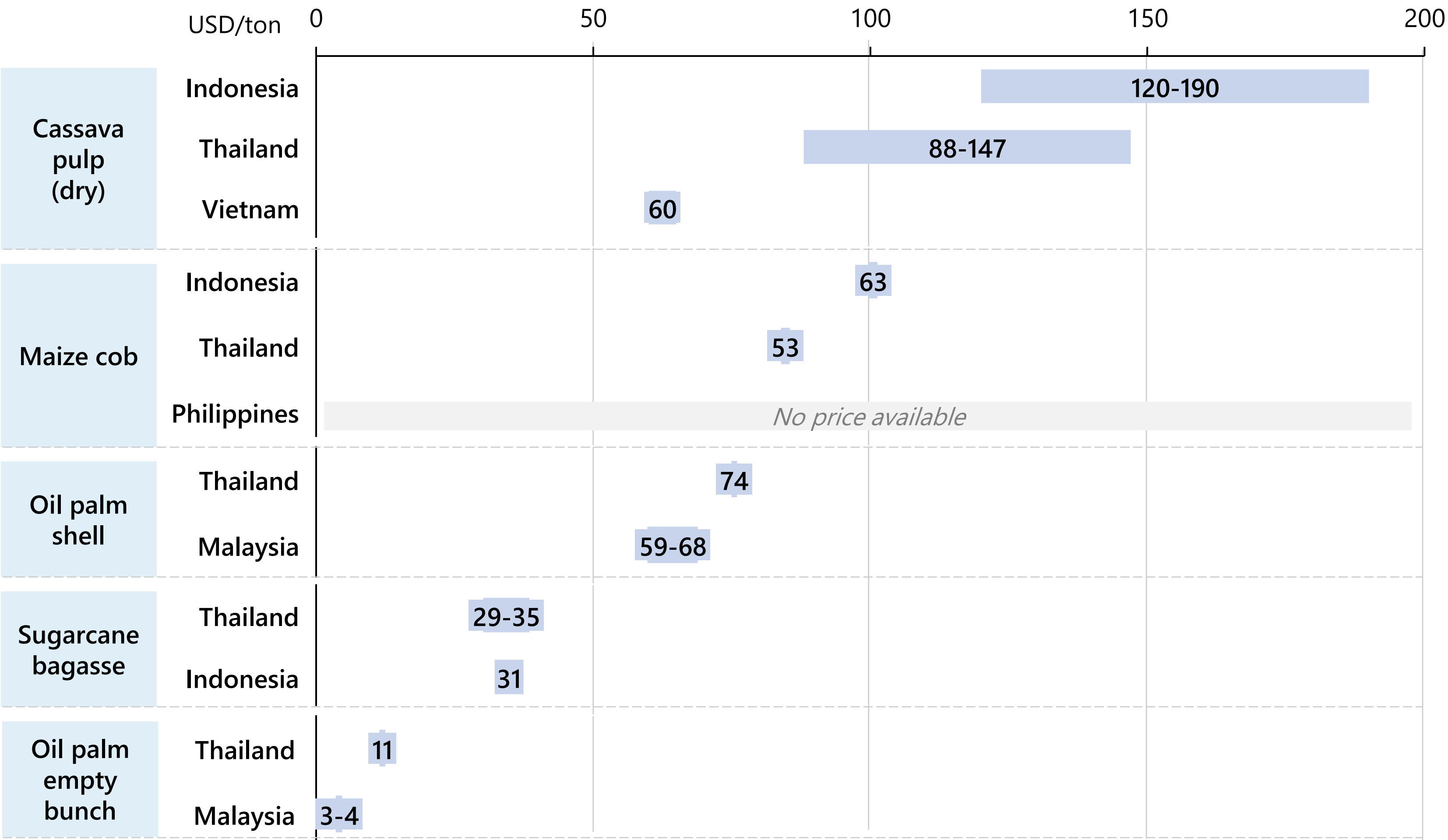
Summary of Purchasing Price

Cassava pulp has the highest purchasing price whereas for sugarcane bagasse and oil palm empty bunch it is lower than the other residues

Purchasing Prices of Agricultural Residues



- The prices shown in this graph are the purchasing prices of agricultural residues, included transport fee
- PH-Maize cob: no price is available due to limited transactions between parties. Most maize cobs are used as fertilizer within plantations rather than being sold.

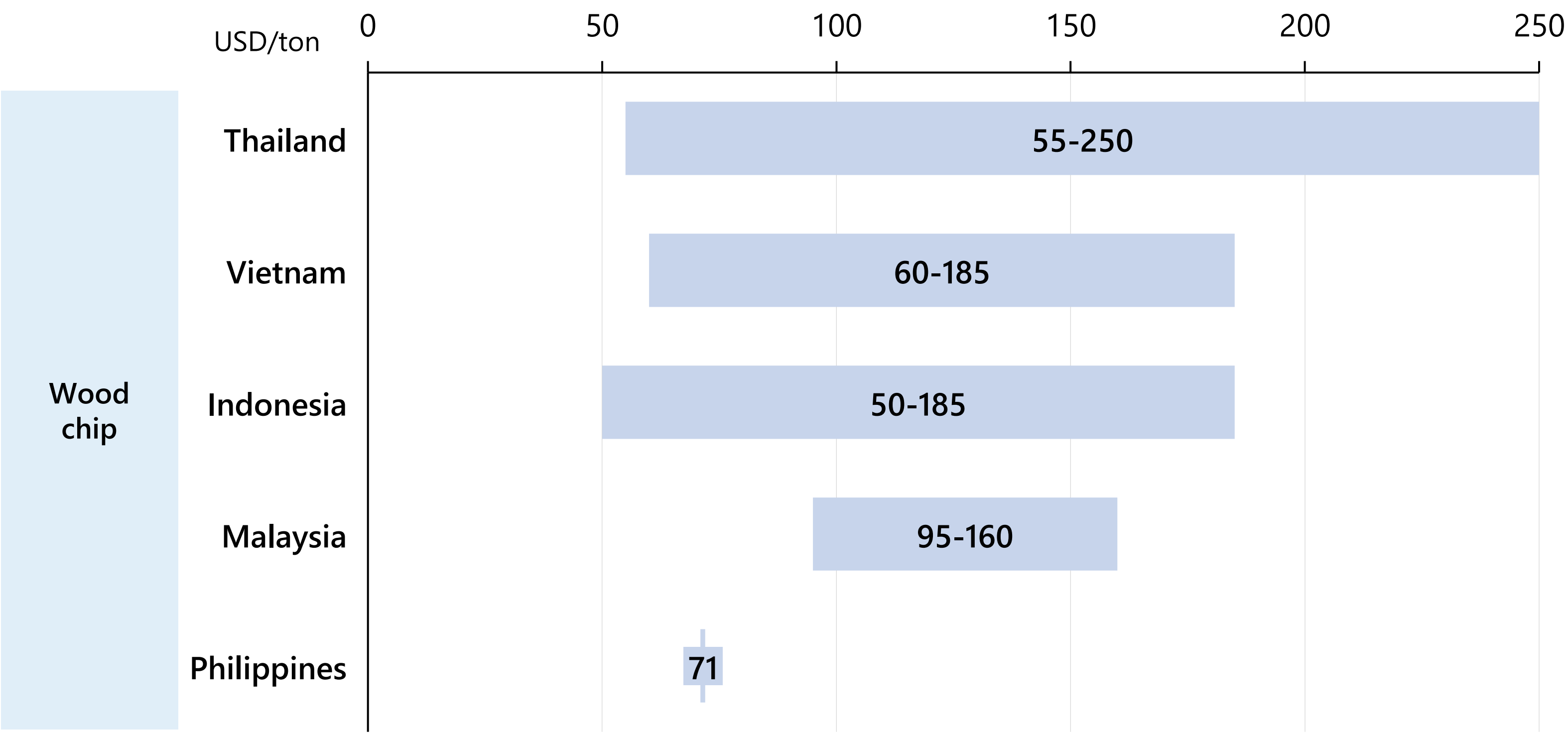
Exchange rate to 1 USD, as of 7 Nov 2024

IDR	15,565 IDR
MYR	4.40 MYR
THB	34 THB
PHP	58 PHP

Sources: Interview

Wood chips price is sold at around USD50-250, which is also a higher price range compared to sugarcane bagasse and oil palm empty bunch

Purchasing Prices of Wood Chip



- The prices shown in this graph are the general purchasing prices of wood chip, included transport fee, regardless types of tree or quality of wood chips. At some prices, the minimum order quantity is required.

Exchange rate to 1 USD, as of 7 Nov 2024

IDR	15,565 IDR
MYR	4.40 MYR
THB	34 THB
PHP	58 PHP

Source: Interview, Tradekey, Paperindex

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Potential Biomass Resource

Sorghum is the biomass with high potential since it is a non-food residue that contains starch, making it is easy to produce bioethanol

Potential Biomass Resource

Underused Biomass Residues	Types and Volumes of Underused Biomass Residues	Sorghum • Bran (husk) • Stem: roughly 30 tons/ha • Leaf
	Barriers to Utilization	• The needed technology to produce bioethanol from sorghum is not widely implemented yet • The profitability of sorghum need further study to be confirmed. However, if the factory utilize many part of sorghum for many applications, such as bioethanol, co-firing, and animal feed combined, not only for bioethanol, they may be able to make profit
Potential Use	Potential Applications and Market Demand	Sorghum's application • Bran (husk): animal feed, fertilizer, bio-pellet • Stem: animal feed, fertilizer, sugar production, bio-pellet, bioethanol, biogas • Leaf: animal feed, fertilizer The Indonesian government anticipates that the demand for sorghum will increase in the future
	Research and Development Initiatives	Sorghum • Currently BRIN is researching the feasibility of residues from sorghum to be used as biomass resource • The current research project in Java has capacity to handle 100-200 ha of sorghum plantation, aiming to increase to 400 ha in the future. And partners of this research project are Post-harvest mechanization and equipment research group (internal partner) and private sectors which are CV Agri Utama-Jombang, Sukabumifarmers, and Bogor farmers Other type of residue • BRIN is conducting research for characteristic and feasibility of over 70 various residues such as wood residues, coffee husk (specifically the ash generated from the boiler processing), resource composition and limitation for co-firing • However, some information is not disclosable right now

Source: Interview

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Potential Biomass Resource: Rice Husk and Rice Straw

Rice straw and rice husk are underused but holds potential for pellet production, though challenges such as limited volume, high costs, and lack of market interest hinder its growth

Potential Biomass Resource (Task 3)

Underused Biomass Residues	Types and Volumes of Underused Biomass Residues	• Type: Rice straw and rice husk • Volume: The estimated volume of rice straw and rice husk in Malaysia for 2023 is approximately 2 million dry tons in total. • Currently, most of the rice straw and rice husk are used locally for burning in boilers to generate heat.
	Barriers to Utilization	• Economic challenges: There is a lack of interest in processing rice straw and rice husk due to high processing costs. • Limited volume: The small volume of rice straw and rice husk in Malaysia, resulting from limited rice plantations and small-scale processing factories, makes large-scale utilization challenging. • High transport costs: The small scale of rice straw and rice husk production and the dispersed nature of rice fields increase transportation costs.

Potential Use	Potential Applications and Market Demand	• Pallet production:
		  • Rice straw and rice husk have the potential to become valuable products, especially if commercialized. However, due to their small volume in Malaysia, they face challenges in meeting larger market demands.
		• Market demand:
		  • The volume of pellets made from rice straw and rice husk in Malaysia is relatively small. As a result, Japanese companies have not yet shown interest in purchasing pellets from Malaysia, although pellets from rice straw and rice husk are generally used in Japan. Additionally, Japanese power plants typically require a strict R&D process for any new type of biomass.

	Research and Development Initiatives	• In the past, there was an initiative in northern Malaysia to convert rice straw and rice husk into pellets. However, this factory has since closed, particularly after the COVID-19 pandemic.

Source: Interview

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Potential Biomass Resource: Sugarcane Leaves

Sugarcane leaves are considered as potential biomass resource in Thailand with potential for power generation, if technological barriers can be addressed.

Potential Biomass Resource (Task 3) – Sugarcane Leaves

Underused Biomass Residues	Types and Volumes of Underused Biomass Residues	• Sugarcane leaves with estimated utilization rate of 50%.
		  ○ In 2022, approximately 9.8 million tons of sugarcane leaves were recorded, based on data from the Office of the Cane and Sugar Board.
		  ○ Of this amount, only 50% was utilized (40% as fertilizer and 10% for power generation in biomass power plants), leaving about 5 million tons of leaves unused and burnt in he fields.

	Barriers to Utilization	• New type of boiler that can take more than 15% of sugarcane leaves is also available. However, the cost of purchasing and changing boiler is extremely high. • Collection: Sugarcane leaves collection can be challenging since most will be left in the field. The collection will require additional manpower and cost-effective machines • Storage: Raw sugarcane leaves require significant storage space. Moreover, piling them in large quantities poses a risk of explosion due to methane gas generated by their high heat value and moisture content. • Utilization: Currently, most boilers in biomass power plants can accommodate a mixture of up to 15% sugarcane leaves with bagasse. This is because sugarcane leaves have high heat value. Using more than 15% of bagasse could potentially damage the boilers.

Source: Interview

Potential Biomass Resource: Sugarcane Leaves

Currently the research regarding sugarcane leaves pellet and briquette is being conducted and may soon reach the commercialization

Potential Biomass Resource (Task 3) – Sugarcane Leaves

Potential Use	Potential Applications and Market Demand	• Potential application for electricity generation ○ If sugarcane leaves are processed into pellets or briquettes, power plants can use them with existing boilers (no need for replacement) and store them for extended periods ▪ Sugarcane leaves pellet is expected to be sold at a higher price, roughly 94 USD (3,200 THB) per ton. Thailand is trying to develop the pellet aiming for exporting to South Korea and Japan ▪ Sugarcane leaves briquette is expected to be sold at roughly 68 USD (2,300 THB) per ton, given it requires less process than the pellet production. Thai government plans to promote briquette for domestic usage, aiming to help reduce the leaves burning and to become another source of income for the farmers • Potential demand in the future ○ The Thai government expects that once sugarcane leaf briquettes are commercialized and compatible with all boilers at higher mix ratios, demand may surpass supply.
	Research and Development Initiatives	• Research regarding sugarcane leaves pellet and briquette ○ Currently, the Office of The Cane and Sugar Board is collaborating with engineer department of the university, KMUTNB* to research about the briquette production machine. They are in the process of finalizing the price of machine and are nearly ready for commercialization. ○ One of the key goals of this research is to improve pellet quality to meet international standards, such as those in Japan, and support exports. ○ The organization is also open to collaboration with both public and private entities, particularly from Japan, to further enhance pellet quality.

Note: THB to USD conversion rate is 1 USD = 34 THB (as of 7 November 2024). KMUTNB refers to King Mongkut's University of Technology North Bangkok
Source: Interview

Potential Biomass Resource: Rice Straws

Thailand produces 45 million tons of rice straw annually, mostly left in fields due to harvesting challenges, bulkiness, and high transport costs. The government is seeking solutions for its use in power generation and biochar production.

Potential Biomass Resource (Task 3) – Rice Straws

Underused Biomass Residues	Types and Volumes of Underused Biomass Residues	• Rice straw and stubble ○ There is a large volume (45 million tons per year) due to significant number of rice fields. This is higher than other parts of the rice such as the husk (8.6 million tons per year) *Refer to task 1 for details Majority of residues are left in the field
	Barriers to Utilization	• Collection and transportation: Harvesting rice straw and stubble is difficult due to their widespread distribution across fields. Their bulky nature further complicates the process, leading to increased transportation costs, especially in areas lacking adequate logistical infrastructure.
Potential Use	Potential Applications and Market Demand	• Potential application for electricity generation • Potential application for biochar
	Research and Development Initiatives	• Research regarding sugarcane leaves pellet and briquette ○ The NSTDA is researching the conversion of rice straw into biochar using pyrolysis, with a trial underway in Suphan Buri province. ○ In 2025, DEDE plans to study effective technologies and strategies to improve the handling and utilization of rice straw, stubble, and similar biomass. This includes options like converting them into pellets or briquettes for easier transport and optimizing plantation planning, such as cultivating crops in plain areas or large fields to simplify machine-based collection of crops and residues.

Source: Interview

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Potential Biomass Resource

Rice straw, rice husk, coffee husk and maize stover are identified as potential resources with current utilization around 20%-30%. Barriers include collection challenges, limited technology and knowledge, and uncertain profitability

Potential Biomass Resource

Underused Biomass Residues	**Biomass**	• Rice straw with estimated utilization rate of 20% • Rice husk with estimated utilization rate of 20% • Coffee Husk with estimated utilization rate of 25% • Maize stover with estimated utilization rate of 30%
	Barriers to Utilization	• Challenges in collection and transportation: o Some biomass materials such as rice husk and rice straw are lightweight, requiring multiple trips for transportation, making the process inefficient. Moreover, rice fields are often spread out, making it difficult and costly to collect rice husk and straw. • Seasonality: o Some biomass materials such as rice husk and rice straw are only available twice a year, creating challenges in storage and logistics due to the sudden volume. • Unclear Policies and Incentives: o Lack of clear and consistent policies and incentives for biomass energy projects. This creates uncertainty for investors and can discourage investment in biomass projects • High Initial Investment Costs: o Significant capital investment is required to set up biomass processing facilities and technologies. High costs can be a barrier for small and medium-sized enterprises. • Lack of Advanced Processing Technologies: o Limited availability of advanced and efficient processing technologies for converting biomass into energy and other products. This restricts the ability to utilize biomass resources effectively. • Knowledge and Capacity Gaps: o Limited knowledge and technical expertise among stakeholders, including farmers, processors, and policymakers. This can hinder the effective implementation and scaling up of biomass projects.

Source: Interview

Potential Biomass Resource

Rice husk, rice straw, and maize stover show potential for electricity generation, while coffee husk is suitable for biogas production. Biomass power plants in Vietnam are still in their early stages of development.

Potential Biomass Resource

Potential Use	Potential Applications and Market Demand	• Potential application for electricity generation
		  ○ Residues such as rice husk, rice straw and maize stover, can be used as fuel in biomass power plants to generate electricity.
		• Potential application for biogas production:
		  ○ Residues such as coffee husk can be used in anaerobic digestion to produce biogas, which can be utilized for electricity and heat generation.
		• Potential for pellet for heating
		  ○ Pellet for industrial heating could be another application for these residues

	Research and Development Initiatives	• In 2021, there was an initiative to promote utilizing rice husk for boilers, instead of diesel. This initiative was a part of the Climate Protection through Sustainable Bioenergy Markets in Vietnam (BEM). The German Development Cooperation Agency (GIZ) supported Sanofi Vietnam in implementing its "Rice is the New Green" (RING) project. They evaluated RING's technical and economic feasibility, including the project's potential size and cost, energy cost savings, and business models with an aim to help the enterprise power its boilers with rice-husk energy instead of diesel, and promote the value of rice husk.

Source: GIZ, Interview

Potential Biomass Resource

Research and development initiatives, such as the Biomass Town Plan and Biomass Resource Mapping, aim to promote biomass utilization, focusing on sustainable energy production and environmental benefits

Potential Biomass Resource

Potential Use	Research and Development Initiatives	• Rice straw was one of residues in an initiative to promote the production of value-added biomass products such as compost, biogas, and biofuels. ○ It was a part of The Biomass Town Plan in Cu Chi District, Ho Chi Minh City. This initiative aimed at establishing a recycling-based society through the effective utilization of local biomass resources, such as livestock waste, rice straw, and household food waste. The initiative is supported by Japan's Ministry of Agriculture, Forestry, and Fisheries (MAFF). • Rice husk was evaluated its potential use and was found that rice husk was suitable mainly for captive power plants meeting the energy needs of rice mills, wood processing mills, or livestock farms. Unlike bagasse and municipal solid waste which could support high electricity generation. ○ This is an outcome of Biomass Resource Mapping in Vietnam. This initiative was part of the broader program, "Renewable Energy Resource Mapping and Geospatial Planning – Vietnam," funded by the Energy Sector Management Assistance Program (ESMAP) and administered by the World Bank. It is a project designed to support the sustainable development of biomass-based energy by identifying, assessing, and mapping the country's biomass resources.

Source: World bank, and Ministry of Agriculture, Forestry and Fisheries

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Potential Biomass Resource: Rice straws

Rice straw is viewed as an underutilized biomass in the Philippines, with potential for future usage particularly for power generation

Potential Biomass Resource – Rice Straws

Underused Biomass Residues	Types and Volumes of Underused Biomass Residues	• There is a large volume (26 million tons per year) due to significant number of rice fields. This is higher than other parts of the rice such as the husk (4.9 million tons per year) *Refer to task 1 for details • Majority of residues are left in the field, and DOE has been receiving many proposal regarding utilization of the rice straw from investors which find potential in leveraging the materials
	Barriers to Utilization	• Collection: Difficult to collect compared to rice husk which is generated in the rice mills and ready to be used easily • Utilization: Difficult to utilize as the rice straw is long and has a lot of fibers. In comparison, the straw is harder to utilization than the husk

Source: Interview

Potential Biomass Resource: Rice straws

Rice straw is viewed as an underutilized biomass in the Philippines, with potential for future usage particularly for power generation

Potential Biomass Resource – Rice Straws

Potential Use	Potential Applications and Market Demand	• Potential application for power generation ○ The rice straw can be use as a material for biomass power plant • Potential demand in the future ○ The Philippines government anticipates that the demand of rice straw for power generation should increase. Since currently Philippines is facing problems in the decreasing agricultural plantation areas as many are turned into industrial sites, power plants have to start looking for other biomass residues that has not been used from the existing plantation
	Research and Development Initiatives	• Research regarding power generation from rice straw • A British company has been doing a full research regarding the utilization of rice straw for biomass power plants • No incentives are currently available from the government side • The R&D project for potential biomass is mainly private-sector-driven. Companies can conduct research and the government will get the result from them

Source: Interview

Potential Biomass Resource: Coconut Frond

Coconut frond is another biomass viewed to have potential due to the large volume, mainly for power generation usage

Potential Biomass Resource – Coconut Frond

Underused Biomass Residues	Types and Volumes of Underused Biomass Residues	• There is a large volume (7 million tons per year) due to significant number of coconut fields. This is within the top 5 agricultural residues in the Philippines (refer to task 1) • However, majority of residues are left in the field and unutilized
	Barriers to Utilization	• Collection: The frond is scattered in the rice field, and hard for the industry players to collect the residue • Transportation: The frond has bulky and large characteristic which make it difficult to transport • Utilization: It is hard to handle and requires a lot of pre-processing before the utilization
Potential Use	Potential Applications and Market Demand	• Potential application for power generation ○ The frond is viewed by the Philippines government (DOE) as a material for biomass power plant same as the coconut husk

	Research and Development Initiatives	• Solid fuel from torrefaction
		  ○ In 2016, University of Santo Tomas, Department of Chemical Engineering has researched the production of solid fuel by torrefaction using dried coconut fronds. Torrefaction is a biomass pre-treatment technology that use thermal method for the conversion of biomass operating in the low temperature range. In this research, dried coconut fronds were torrefied at different feedstock conditions and compared to the untreated fronds.
		  ○ As the result, torrefaction significantly improved the heating value compared to that of the untreated biomass. Proximate compositions of the torrefied biomass also improved and were comparable to coal.
		  ○ However, palletization, biological degradation, large scale production feasibility and dust forming of the torrefied biomass need to be studied further
		• Weed and insect pest management
		  ○ In 2015, Bohol Island State University has researched about the effectiveness of coconut frond in managing weed and insect pest population in tomato crops. As the result, coconut frond was as effective as black plastic mulch in suppressing the dominant broadleaf and certain weed and insect

Source: Interview

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Promising Biomass Resource :
（有望なバイオマス資源）
Issues in ASEAN and Solutions from Japanese Companies

Cassava pulp is dispersed for both seasonality and geographical perspective, but has potential to be used for high-value usage such as biofuel

Supply Chain	Issues & Challenges		
Collection / Transportation/ Storage	Efficiency of processing		• Drying the cassava pulp improves the quality and allows higher selling price • However, drying in sun is manual labor and inefficient, but implementing dryers are costly
	Efficiency of transportation		• Transportation cost can be high due to the bulk and weight of the materials, as well as poor road conditions especially for rural areas
Utilization	Overall	Seasonality	• Dispersed seasonal availability of cassava pulp, leads to inconsistent supply and challenges for planning
	By Type – Power Generation	Funding support	• Incentives for capital expenditure (e.g. power plant construction) and power generation (e.g. FIT) is limited
	By Type – Transp.	Adoption of biofuel	• Adaption of bioethanol is still limited due to the lower efficiency compared to gasoline and biofuels not widely available at gas stations
	By Type – Others	Alternative utilization	• Lack of technology and innovation for utilization methods which may potentially have high value

Sources: Interview

Adoption of new technology from Japanese companies can support the issues for seasonality and value-added products

Supply Chain	Issues & Challenges			Potential Solutions by Japanese Companies	
Collection / Transportation / Storage	Efficiency of pre-processing			Alternative Processing Methods	• Technology to dry the cassava pulp in a cost-efficient manner
	Efficiency of transportation			Supply chain optimization	• Supply chain optimization solutions (e.g. self-sustaining local biomass energy systems)
Utilization	Overall		Seasonality	Co-usage of other biomass	• Utilization method which other biomass material (e.g. bagasse) can be used as an alternative material during cassava's low season
	By Type	Power Generation	Funding support	Subsidies from Japanese gov.	• Pilot projects developed which includes Japanese government (e.g. METI, NEDO) subsidies
		Trans-portation	Adoption of biofuel	Next generation bio-fuel	• Technology transfer and development of factories for biofuel with high demand in future (e.g. SAF)
		Others	Alternative utilization	New technology	• Technology for application in high-value products (e.g. nano-cellulose and fiber production)

Sources: Interview, company webpage of Japanese companies

Efficiency of transportation is an issue for supply-side, whilst the limitations for power plant infrastructure a common issue for the demand-side

Supply Chain	Issues & Challenges			
Collection / Transp. / Storage	Efficiency of transportation			• In some countries (e.g. Thailand) the maize cob fields are mainly located in high hills. • Also, for some countries (e.g. Philippines, Indonesia) the location of corn field and biomass power plant are far, resulting in high transportation cost
Utilization	Overall		Seasonality	• Dispersed seasonal availability, which leads to inconsistent supply and challenges
	By Type	Power Generation	Funding support	• Adjusting the boiler of existing old biomass power plant to be able to handle new residues such as maize cob will cost a lot of investment, but there is limited government support
			Compatibility	• Each residue has different size, heat values, silica content and ash generated in the process etc. Therefore, the boiler can only handle residues with certain specifications
			Material procurement	• Selling price for bioenergy is not high in some countries (e.g. Indonesia) • This makes it challenging to secure the supply as farmer may choose to sell their cob for animal feed instead of for bio-energy
		Others	-	• -

Sources: Interview

Advanced technology, equipment for material conversion, and supply chain optimization solutions can support the issues in the supply and demand

Issues & Challenges				Potential Solutions by Japanese Companies	
Collection / Transp. / Storage	Efficiency of transportation			Supply chain optimization	• Supply chain optimization solutions (e.g. self-sustaining local biomass energy systems)
Collection / Transp. / Storage	Efficiency of transportation			Equipment	• Equipment for easy conversion to biomass pellets, which is easier to transport at a higher price
Utilization	Overall		Seasonality	Co-usage of other biomass	• Provide new technology which various types of biomass material can be used, so that maize cob's low season will not cause issues to the supply
Utilization	By Type	Power Generation	Funding support	Subsidies from Japanese gov.	• Pilot projects developed which includes Japanese government (e.g. METI, NEDO) subsidies
Utilization	By Type	Power Generation	Compatibility Material procurement	Flexible Boilers	• Boilers with compatibility for various types of biomass residues (e.g. CFB boilers) including both maize cobs and other residue types
Utilization	By Type	Others	-	-	• -

Sources: Interview, company webpage of Japanese companies

EFB is difficult to pre-process and transport, but infrastructure in mills is not sufficient for processing and treating the EFB

Supply Chain	Issues & Challenges for EFB		
Collection / Transp. / Storage	Ease of pre-processing		• EFB need to be cut into smaller piece before utilization. Therefore, it is difficult and expensive to handle and transport
	Pellet production		• EFB high moisture content (over 50%), bulky, and also has a high content of “lignin” which can damage a normal pellet production machine (e.g. wood pellet machine). These characteristics make it challenging to process EFB into pellets efficiently.
Utilization	Power Generation	Limited infrastructure (electricity) for processing	• Many mills are located in a remote location near plantation area with limited electricity. In this case, many will have to use 100% of the electricity to produce the oil. Hence, many mills do not have enough power to process and treat EFB properly

Sources: Interview

Japanese companies has equipment to support pre-processing and pellet production, and can support optimization of supply chain

Supply Chain	Issues & Challenges for EFB		Potential Solutions by Japanese Companies	
Collection / Transp. / Storage	Ease of pre-processing		Machinery for efficient pre-processing	• "Chipper machines" which can be used to cut the EFB into small pieces, which can also be used for other biomass materials as well (e.g. wood)
	Pellet production		Machinery and equipment for pellet production	• Equipment and machinery for easy conversion from biomass material to pellets
Utilization	Power Generation	Limited infrastructure (electricity) for processing	Supply chain development and optimization	• Development of processing plants to centralize and optimize the processing of EFB

Sources: Interview, company webpage of Japanese companies

Technology for waste management and utilization enhancement is required, while financial support from the local government is limited

Supply Chain	Issues & Challenges		
Collection / Transportation / Storage	Efficiency of collection		• Mostly collected by manual labor and some parts of tree difficult to collect
	Efficiency of transportation		• Some located in remote or hard-to-reach area (e.g. mountain), resulting in high transportation cost
	Farmer's custom and education		• Many farmers prefer burning rather than energy usage, utilization believing that it enriches soil with nutrients
Utilization	Power generation	Funding support	• Incentives for capital expenditure (e.g. power plant construction) and power generation (e.g. FIT) is limited
		Compatibility	• Technological challenges with wood residue compatibility of biomass residues with existing boilers
		Contamination	• Contamination of dust and soil can cause damages to the equipment such as boilers
		Ash generation	• Combustion of wood biomass can generate ash and emissions, which without proper management and pollution control, may result in maintenance issues
	Others	-	• -

Source: Interviews

Wood Residues – Potential Solutions from Japanese Companies

Japanese companies can provide a holistic approach, leveraging partnerships with Japanese government and advanced technologies for market development

Supply Chain	Issues & Challenges		Potential Solutions by Japanese Companies	
Collection / Transportation / Storage	Efficiency of collection		Equipment	• Machinery and equipment to make the collection process more efficient (e.g. portable wood chippers)
	Efficiency of transportation		Supply chain optimization	• Supply chain optimization solutions (e.g. self-sustaining local biomass energy systems)
	Farmer's custom and education		Education in the local community	• Educational programs, online community/platforms introducing economic benefit for energy usage
Utilization	Power generation	Funding support	Subsidies from Japanese gov.	• Pilot projects developed which includes Japanese government (e.g. METI, NEDO) financial support
		Compatibility	Flexible Boilers	• Boilers with compatibility for various types of wood residues (e.g. CFB boilers)
		Contamination	Equipment and O&M	• Machinery (e.g. sorting) to prevent contamination, and O&M services to monitor manufacturing process
		Ash generation	Ash utilization	• Machinery and facilities to recuse ash efficiently (e.g. convert into fertilizer and construction materials such as cement)
	Others	-	-	• -

Sources: Interview, company webpage of Japanese companies

Japanese companies have a wide range of solutions available from the collection to utilization, to support local companies for biomass business development

Example of Solutions Available by Japanese Companies for Biomass

Supply Chain	Residue Type	Description of Solution	Example of Japanese Company & Associations	Overview of Solution
Collection	All types	Supply chain optimization	Mitsubishi Corporation, Mitsui & Co.	Develop local utilization ecosystem leveraging biomass residues within the local market
	Wood	Wood chipper	Fujitex	Provides portable wood chipper to make the collection process more efficient
	Wood	Education	Japan Woody Bioenergy Association	Provides online database/platform regarding the effective utilization of wood biomass
Transportation	Wood	Equipment for conversion to wood pellet	Mitsubishi Chemical	Provides facility and machinery to convert wood residues into wood pellets
	Wood	Production of wood pellet	Sumitomo Forestry	Produces wood pellets for biomass power generation utilization
Utilization	Sugarcane (Bagasse)/Cassava	Advanced co-utilization of multiple residues	Toray	Production cellulosic sugar derived from bagasse and cassava using membrane separation technology
	All types	Circulating Fluidized Bed (CFB) Boilers	MHI, IHI	Provides CFB boilers which can utilize various types of biomass residues for a cheap price
	Maize	Production of sustainable aviation fuel (SAF)	ENEOS, Idemitsu, JGC	Produces SAF utilizing various residues including maize

Source: Desktop study from each company’s webpage

Potential Biomass Resource:
（未利用分の利用可能性の高いバイオマス資源）
Current Situation and Potential Areas for Collaboration

Residues from rice, coconut, coffee, and maize are considered biomass materials which can potentially be utilized in the future

Country Name	Residue Name	Volume (Annual, Mn ton)	Current Utilization Status	Potential Application & Demand Observed by Local Government and Industry Players: Power generation	Transportation	Heat	Others
Indonesia	Sorghum husk	n/a	Not widely used				● (animal feed, fertilizer)
	Sorghum stem	n/a	Not widely used		● (bioethanol)		● (animal feed, fertilizer)
	Sorghum leaf	n/a	Not widely used				● (animal feed, fertilizer)
	Coffee husk	1.0	Not widely used	●			
Malaysia	Rice straws	3.1	Not widely used	●			
	Rice Fronds	0.6	Not widely used	●			
Thailand	Sugarcane leaves	9.8	50% used	●			
	Rice straws	45.6	Not widely used	●			● (biochar fertilizer)
Philippines	Rice straw	26.3	Not widely used	●			
	Coconut frond	7.0	Not widely used	●			
Vietnam	Rice straw	56.8	20% used	●			
	Rice husk	10.7	20% used	●			
	Coffee husk	2.6	25% used	●			
	Maize stover	8.7	30% used			●	

Source: Interview

The potential biomass materials are difficult to collect and transport, and the facilities in the utilization-side needs to be enhanced as well for further usage

<table>
<tr><th colspan="2">Residue Name</th><th>Collection</th><th>Transportation</th><th>Utilization</th></tr>
<tr><td rowspan="3">Sorghum</td><td>Sorghum husk</td><td colspan="2" rowspan="3">• -</td><td rowspan="3">• Technology to produce bioethanol from sorghum is not widely implemented</td></tr>
<tr><td>Sorghum stem</td></tr>
<tr><td>Sorghum leaf</td></tr>
<tr><td>Sugarcane</td><td>Leaves</td><td rowspan="5">• Scattered in the field, and collection will require additional manpower</td><td rowspan="4">• Lightweight but requires significant storage space and results in multiple transportation required
• (Sugarcane) piling in large quantities poses risk of explosion due to methane</td><td>• Most boilers can only accommodate limited amount of sugarcane leaves with bagasse</td></tr>
<tr><td rowspan="2">Rice</td><td>Straws</td><td rowspan="2">• (Straw) Difficult to use as the straw is long and has a lot of fibers</td></tr>
<tr><td>Husks</td></tr>
<tr><td>Maize</td><td>Stover</td><td>• Limited knowledge and capacity for usage</td></tr>
<tr><td>Coconut</td><td>Fronds</td><td>• Bulky, large and difficult for transportation</td><td>• Hard to handle and pre-processing is tedious</td></tr>
<tr><td>Coffee</td><td>Husk</td><td colspan="2">• -</td><td>• Limited knowledge and capacity for usage</td></tr>
</table>

Source: Interview

There are ongoing studies and demonstration projects to enhance the transportation and utilization, which Japanese companies can potentially support

Example of studies and demonstration projects in ASEAN region

Residue Name		Collection	Transportation	Utilization
Sorghum	Sorghum husk	-		**Usage for power generation, transportation, and animal feed**
	Sorghum stem			
	Sorghum leaf			
Sugarcane	Leaves	Scattered in the field, and collection will require additional manpower	**Conversion to pellets/briquettes for easy transportation and higher sales value**	Most boilers can only accommodate limited amount of sugarcane leaves with bagasse
Rice	Straws			**Usage in power generation**; **Usage for biochar**
	Husks		explosion due to methane	
Maize	Stover			Limited knowledge and capacity for usage
Coconut	Fronds		Bulky, large and difficult for transportation	Hard to handle and pre-processing is tedious
Coffee	Husk	-		**Utilization of ash from boiler**

Source: Interview

Industry associations and ministries aim to introduce efficient ways to convert the biomass materials into easy-to-carry format such as pellets and briquettes

Residue Name		Collection	Transportation	Utilization
Sorghum	Sorghum husk			
	Sorghum stem			
	Sorghum leaf			
Sugarcane	Leaves		Thailand: Office of the Cane and Sugar Board	
Rice	Straws		Thailand: Ministry of Energy, DEDE	
	Husks			
Maize	Stover			
Coconut	Fronds			
Coffee	Husk			

Thailand: Office of the Cane and Sugar Board
- Collaborating with engineer department of the university, KMUTNB to research about the briquette production machine. They are in the process of finalizing the price of machine and are nearly ready for commercialization.
- One of the key goals of this research is to improve pellet quality to meet international standards, such as those in Japan, and support exports.
- The organization is also open to collaboration with both public and private entities, particularly from Japan, to further enhance pellet quality.

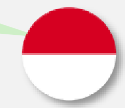
Thailand: Ministry of Energy, Department of Alternative Energy Development and Efficiency (DEDE)
- In 2025, DEDE plans to study effective technologies and strategies to improve the handling and utilization of rice straw, stubble, and similar biomass. This includes options like converting them into pellets or briquettes for easier transport and optimizing plantation planning, such as cultivating crops in plain areas or large fields to simplify machine-based collection of crops and residues.

Source: Interview

Overseas organizations are supporting the utilization of biomass in areas including power plant usage and conversion to biochar

Residue Name		Collection	Transportation	Utilization
Sorghum	Sorghum husk			
	Sorghum stem			
	Sorghum leaf			
Sugarcane	Leaves			
Rice	Straws			
	Husks			
Maize	Stover			
Coconut	Fronds			
Coffee	Husk			

Indonesia: National Research and Innovation Agency (BRIN)
- Conducting feasibility study for biomass utilization with 100-200 ha. of sorghum plantation, partnering with domestic private sector and farmers



Vietnam
- German Development Cooperation Agency (GIZ) supported Vietnam in implementing its "Rice is the New Green" (RING) project, evaluating technical and economic feasibility, to support usage of boilers with rice-husk to replace diesel

Thailand: National Science and Technology Development Agency (NSTDA)
- Conducting research/pilot project for conversion of rice straw to biochar

Philippines
- A British company has been doing a full research regarding the utilization of rice straw for biomass power plants

Source: Interview

Envision the value,
Empower the change