Review Report

Biomass Energy from Agriculture Wastes in APEC Region

APEC Agricultural Technical Cooperation Working Group

January 2025

Asia-Pacific
Economic Cooperation

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Produced by
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FOREWORD

The Review Report on Biomass Energy from Agricultural Wastes (BAW) in the APEC region has been conducted from April to December 2024. Information used in the Report is primarily derived from available sources such as FAO statistical yearbooks, economies' reports, information from energy data systems, documents from domestic and international workshops, and results from scientific research published in journals. Additional information was collected through electronic surveys / questionnaires with APEC member economies, particularly from the Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region was organized in hybrid manner in Ha Noi, Viet Nam from 18 – 20 September 2024.

The Report aims to share information and raise awareness among relevant stakeholders such as policy makers, scientific researchers, businesses, and rural communities in the APEC region about the development of biomass energy from agricultural wastes.

The Report is the outcome of the Project within the Agriculture Technical Cooperation Working Group | APEC (ATCWG), titled Promoting APEC Cooperation for Sustainable Biomass Energy from Agriculture Wastes (ATC 02 2023A), which was conducted by the International Cooperation Department (ICD) of the Ministry of Agriculture and Rural Development (MARD) of Viet Nam, in collaboration with the Science Institute of Rural Development (SIRD).

On behalf of the Project Overseer, I sincerely thank the member economies for their support in providing information so that the Report can provide a comprehensive overview of the current utilization of agricultural wastes for biomass energy production in the region, and thereby proposed appropriate solutions to promote APEC cooperation in this area. The Project Overseer also express gratitude to the APEC Secretariat for their great support and collaboration throughout the project implementation by Viet Nam.

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ABBREVIATIONS

APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of South East Asian Nations
BAW	Biomass energy from agricultural wastes
CHP	Combined heat and power
CIT	Corporate income tax
DOE	United States Department of Energy
FAO	Food and Agriculture Organization of the United Nations
FIT	Feed-in Tariff
GDP	Gross Domestic Product
GHG	Green House Gas
GNI	Gross National Income
GIS	Geographic Information System
IEA	International Atomic Energy Agency
ITC	Investment Tax Credit
MIDA	Malaysian Investment Development Authority
MOSTI	Ministry of Science, Technology and Innovation, Malaysia
OECD	Organization for Economic Cooperation and Development
PTC	Production Tax Credit
R&D	Research and Development
R&D&C&I	Research, Development, Commercialization and Innovation
RES	Renewable energy sources
TES	Total energy supply
UNFCCC	United Nations Framework Convention on Climate Change
USDA	US Department of Agriculture
USDE	US Department of Energy
VAT	Value-added tax

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MEASURMENT UNITS

CO_2	Carbon Dioxide
EJ	Exajoule
g	Gram
GJ	Gigajoule
Gt	Giga tonne (109 tons)
GW	Gigawatt
ha	Hectare
hm^3	Cubic hectometer or 1,000,000 m3 or 109 L, described in some sources as a GL (Gigaliter)
km^2	Square kilometer
kWh	Kilowatt per hour
Ktonne	Ktonne means thousands of tons
Ktoe	Ktonne of oil equivalent
m^2	Square meter
m^3	Cubic meter
MJ	Mega joule (10^6 joule)
Mt	Megaton (10^6 ton)
MW	Megawatt
Ton (t)	Metric ton

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I. INTRODUCTION

1. Issues

Due to economic development and population growth, the demand for energy is increasing, fossil fuel energy production leads to depletion of natural resources, environmental pollution, and climate change. Finding alternative renewable energy sources is an urgent global issue, particularly within the APEC region. One such renewable energy source is biomass energy from agricultural wastes (BAW). Apart from environmental and energy benefits, BAW offers economic advantages such as enhancing agricultural value additions, reducing fossil fuel imports, lowering waste disposal costs, creating job opportunities, and increasing income for rural communities. To promote collaboration in developing biomass energy from agricultural wastes as a renewable energy source within the APEC region, it is necessary to review relevant information and policies for sharing and collectively agreed actions.

The Report aims to: (i) Assess the current status of BAW production in the APEC region, and in specific economies and crops; (ii) Evaluate the current state of cooperation within the APEC region regarding BAW production. Scope of the review primarily focuses on BAW production from the agricultural sector, limited to crop cultivation in the APEC region (excluding livestock, forestry, fisheries).

2. Review methods

2.1 Location selection

Each economy within the APEC region has distinct characteristics in agriculture and BAW. However, to date, there has been no comprehensive study on this issue. Therefore, review is conducted across most member economies, divided into 4 regions: South-East Asia, East Asia and Far East, Americas, and Oceania. This review focused on rice and corn biomass energy production, particularly rice from China and Viet Nam, and corn from the United States.

2.2 Data collection

- *Secondary data*

Collected data that have been published through various sources such as FAO statistical yearbooks and those of economies, Government reports, energy data systems, workshop reports, and scientific research results. Out of over 200 project documents, 131 updated documents have been selected and used in this Report. Secondary data is the main source for the report formulation. The collected data is within the period 2018 – 2024.

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- *Primary data*

The project has designed the Questionnaires for conducting an electronic survey with APEC members on the current status, policies, and challenges in BAW production. The questionnaires are concise and specific, consist of 10 related questions (Appendix 1). However, only 7 members have responded, including Australia; Canada; Japan; Malaysia; Chinese Taipei; Thailand; and Viet Nam.

In addition, lots of information and data have been gathered at the Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region in Ha Noi, Viet Nam on 18 – 20 September 2024, where 9 member economies attended directly or virtually.

2.3 Data processing

Due to the dispersed, fragmented, and inconsistent nature of the collected data, the processing stage has encountered numerous difficulties and complexities, primarily relying on convenient and logical approaches: data capable of depicting the entire or partial current situation is presented in tables and figures; Data from different documents is selected from the most updated sources for inclusion in the Report; data related to renewable energy, particularly BAW, is disaggregated to extract BAW-specific contents.

2.4 Research method

The most common method used is desk research, involving document search through various sources, selecting appropriate documents and content to synthesize according to the issues. In case the same type of data is available, preference is given to the most recent and valuable sources of publications.

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II. OVERVIEW OF BIOMASS ENERGY FROM AGRICULTURAL WASTES IN THE APEC REGION

1. Overview of biomass production from some common crops in APEC region

Agriculture production and agricultural biomass of the world in general and the APEC region in particular are very diverse. FAO statistics have calculated the yields of some common crops globally, across continents, and by individual economies. Based on the production volumes and the ratio between main products and residues of each crop, estimates of agricultural waste for the APEC region are derived through Table 1.

Table 1. Yields and wastes of some common crops in APEC region

TT	Region	Sugarcane	Rice	Wheat	Corn	Palm	Potato	Total
1	**The world**							
	Output (thousand tons)	1,859,390	1,210,235	787,294	770,877	416,397	376,120	5,420,313
	Waste (thousand tons)	2,182,761	1,452,282	1,102,212	1,079,228	3,747,573	451,344	8,836,709
2	**APEC**							
	Output (thousand tons)	370,852	754,467	393,237	318,380	371,196	152,092	2,360,224
	Waste (thousand tons)	435,348	905,360	550,532	445,732	3,340,764	182,510	5,625,158
	Number of APEC members with crops	12	15	15	11	8	15	
	Number of APEC members producing energy from wastes	12	15	15	11	8	15	

[Source: FAO statistics, 2023]

Crop residues typically include straw/ wheat stalks. Rice husk, corn stalks and cobs, bagasse, fruit peels, and tree branches. As agricultural production develops, agricultural wastes also increase.

2. Status of biomass energy from agricultural waste in APEC economies

2.1. Southeast Asian economies

(1) Brunei Darussalam

With abundant oil and gas resources, Brunei Darussalam predominantly relies on fossil fuels. Agricultural land covers only 2.5%, while forestry accounts for 71.8%, and others make up 25.7%. The agricultural sector contributes a mere 1.2% to GDP (Irena, 2023),

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resulting in limited emphasis on renewable energy in Brunei Darussalam. However, aiming to diversify energy sources and enhance energy security, Brunei Darussalam has set a target to achieve 10% of electricity from renewable energy by 2035 (*ASEAN, 2020*). Agricultural wastes include coconut shells, coconut fiber, corn husks, and sawdust. The potential for BAW is approximately 8,773 kg GJ (*Maw Tun et. al., 2019*).

(2) Indonesia

Indonesia has a total land area of 188.2 million hectares with diverse types of land. They are one of the leading agricultural producers in APEC, focusing on major crops such as rice, sugarcane, palm oil, coconut, and rubber. The primary agricultural wastes for biomass energy are rice husk, bagasse, palm oil residue, and wood residue (Matthew Hardhi, 2022). Indonesia is the world's largest palm oil producer, with current production reaching 56.6 million tons. The increase in palm oil production is driven by expanding cultivation area. As of 2019, the provinces of Riau, East Java, and North Sumatra were identified as having significant potential for biomass energy production, with Riau and North Sumatra having extensive palm oil plantations and East Java being prominent in rice cultivation (*Sapuan Dani Aditva Wibawa, 2018*). Palm oil residue and rice husk dominate Indonesia's biomass energy production. Additionally, Indonesia is among the top 10 sugarcane producers globally, with an annual production of approximately 30 million tons. Currently, fuel ethanol in Indonesia is produced mainly from sugarcane molasses. Another raw material being considered for ethanol production in Indonesia is cassava, with an annual production of about 17 million tons. Indonesia plans to expand sugarcane and cassava production and dedicate more than 1.5 million hectares to growing these crops for biofuel production. The Ministry of Energy and Mineral Resources has published a map illustrating areas suitable for sugarcane and cassava cultivation to support decision-making and planning activities. Several sugar factories have started producing sugarcane-based products other than white crystal sugar (WCS), such as molasses, electricity, bioethanol, and compost, but they still face challenges in marketing (*Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region in Ha Noi, Viet Nam on 18 – 20 September 2024. Sri Suhesti & Erlita Adriani's Presentation*)

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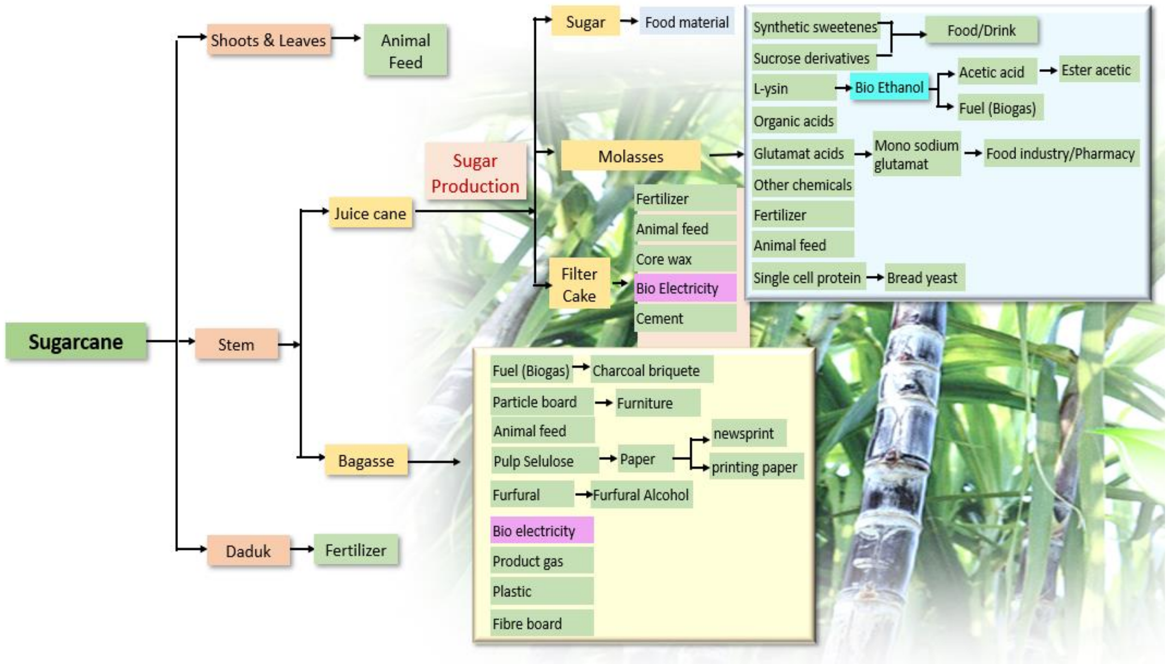
Figure 1. Sugarcane Agro Industry



Biomass is used to supply electricity generation, household energy, fuel vehicles and industrial facilities, Indonesia produces approximately 146.7 million tons of biomass annually, which equates to 470 GJ, contributing significantly to GHG emission reduction (*ASEAN, 2020*). With abundant biomass resource makes BAW the most promising resource in Indonesia.

Table 2. Biomass from agricultural waste in Indonesia

Crops	Biomass type	Estimated biomass (ton/year)
Palm	Palm oil	18,981
Sugarcane	Bagasse	1,943
Rubber	Rubber	4,172
Coconut	Coconut	266
Rice	Rice husk	14,712
Corn	Cob	2,600
Cassava	Cassava	407
Total		**43,079**

[Source: Ministry of Plantation and Commodities, 2023]

Currently, biomass co-firing power plants are gradually replacing coal power plants. Indonesia aims to gradually combine biomass with fossil fuel power plants. Co-firing

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technology plays an important role in green energy production. To realize this plan, biomass co-firing technology in power plants will eventually have to phase out coal power plants and promote biomass as a renewable energy in Indonesia. As of May 2022, Indonesia has successfully implemented co-firing technology in 32 thermal power plants, generating 487 MWh of electricity. This conversion process has reduced emission by approximately 184,000 tons of CO_2 and GHG. Indonesia aims to have 60% of their 114 power plants using biomass crop blending by 2024.

(3) Malaysia

Malaysia has forest area of up to 62% of the total area of the economy. With approximately 4.89 million hectares of agricultural land, there are abundant sources of agricultural wastes such as palm oil residue, bagasse, coconut husk, and biogas from palm oil factory. The palm oil industry alone contributes about 8% (over MYR80 billion) to the economy's Gross National Income (GNI), making it the largest contributor to agriculture and generating the largest agricultural biomass. In 2012, Malaysia produced 83 million tons of dry biomass, and by 2020, this figure has risen to 100 million tons (*ASEAN, 2020*). As of 2022, Malaysia's agricultural wastes total 182.6 million tons, with palm oil residue accounting for 164 million tons (*Ministry of Plantation and Commodities, 2023*).

Table 3. Biomass from agricultural wastes in Malaysia

Crop yield (ton)	Biomass type	Waste output (ton)
Rice production: 2,364,453	Rice straw	1,307,315
	Rice husk	534,356
Banana production: 329,573	Banana stem	790,975
Coconut production: 604,428	Coconut shell	271,993
	Coconut	72,531
Pineapple production: 377,300	Pineapple peel	154,693
	Pineapple leaves	565,950
Durian production: 455,458	Durian shell	296,048
Sweet corn production: 63,155	Stalk	113,679
	Cob/Husk/Silk	47,366
Sugarcane production: 25,032	Roots and tops of sugar cane	5,006
	Bagasse	7,510

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Crop yield (ton)	Biomass type	Waste output (ton)
	Sugarcane sludge	876
	Molasses	125
Palm oil production: 18,600,000	Leaves, fiber, seeds	164,000,000

[Source: Ministry of Plantation and Commodities, 2023]

The estimated total capacity for biomass energy installation is 29,000 MW, with 211 MW is install capacity (*Maw Tun et. al., 2019*).

Total Approved Biomass Investment in 2021 MYR442.8 million (*Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, 18 - 20 September 2024 in Viet Nam. Wan Mohd Rusydan Bin Wan Ibrahim's Presentation*)

- Approved Investment (Palm Biomass Projects): MIDA has approved three projects to produce palm biomass-based products in 2021, with total investments worth MYR152.5 million. Foreign investments dominated the industry, bringing in MYR148.3 million (97.2%) with an estimated 164 jobs created. One of the projects approved was from a wholly foreign-owned company to produce black pellets from EFB, with a proposed investment of MYR123 million and 141 employment opportunities.
- Approved Investment (Other Than Palm Biomass): In 2021 MIDA also approved four other biomass related projects not involving palm biomass, with investments amounting to MYR55.2 million. These non-palm biomass approved projects are expected to create 126 new job opportunities.
- Approved Investment (Renewable Energy Projects): Renewable Energy (RE) projects approved include 14 biogas projects with investments of MYR196.3 million, and two biomass projects worth MYR38.8 million totaling MYR235.1 million. A total of 135 employment opportunities were created from these RE projects.

(4) The Philippines

The agricultural land area of the Philippines is 13 million hectares (approximately 32% of the economy's total area), with 51% used for annual crops and 49% for perennial crops (*Ofero A. Caparino, PhD, 2018*). Biomass energy plays a significant role in the economy's energy supply. Agricultural wastes are abundant and widely distributed.

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Nearly 30% of the energy for 100 million Philippines' citizen come from biomass energy, primarily used by rural residents for household cooking (*ASEAN, 2020*). The biomass industry is rapidly developing, with a total installed capacity economy-wide of 276.7 MW. Biomass energy accounts for about 15% of the primary energy sources in the Philippines (*Florence Mojica-Sevilla, 2023*).

Table 4. Biomass from agricultural wastes in the Philippines

Crop	**Crop yield (ton/year)**	**Biomass type**	**Estimated biomass (ton/year)**	**Power generation (Kwh/kg)**	**Potential (Mw)**
Rice	17,627,245	Rice husk	3,767,824	0.627	308
		Rice straw	8,813,623	0.774	888
Corn	7,218,816	Corn cob	1,851,626	0.932	225
		Corn stalk	14,437,632	0.872	1.639
Coconut	13,825,080	Coconut shell	4,143,376	1.398	754
		Coconut leaves	1,970,074	1.139	2.027
Sugarcane	22,370,546	Bagasse	13,666,092	1.139	2.027
		Sugarcane trash	6,163,085	0.316	254

[Source: Philippine Energy Plan 2020-2040]

The key production areas for rice biomass are Nueva Ecija, Isabela, Pangasinan, Cagayan, and Iloilo (*Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, 18 - 20 September 2024 in Viet Nam. Paulino S. Ramos, Katherine C. Villota's Presentation).*

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Figure 2. Maps Describing the Realistic Spatial Distribution of Rice Husk and straw

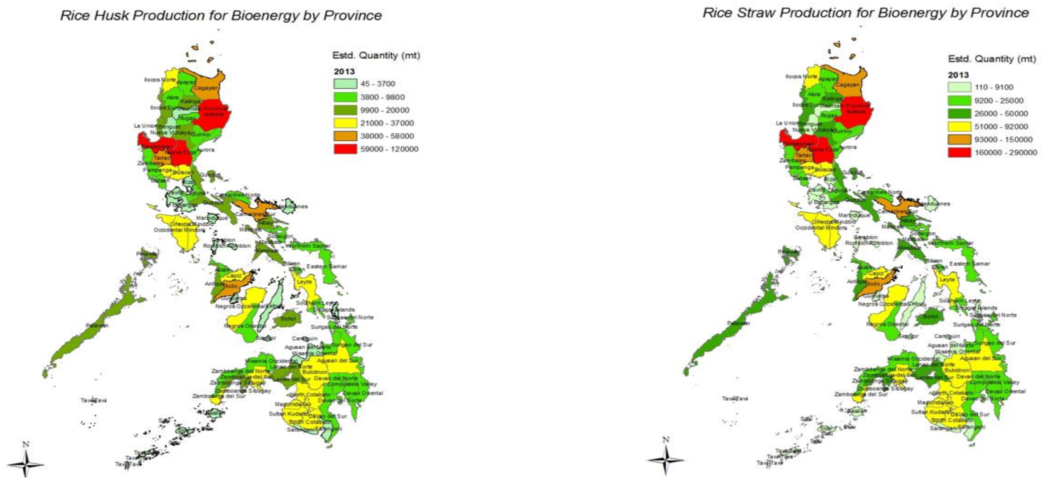
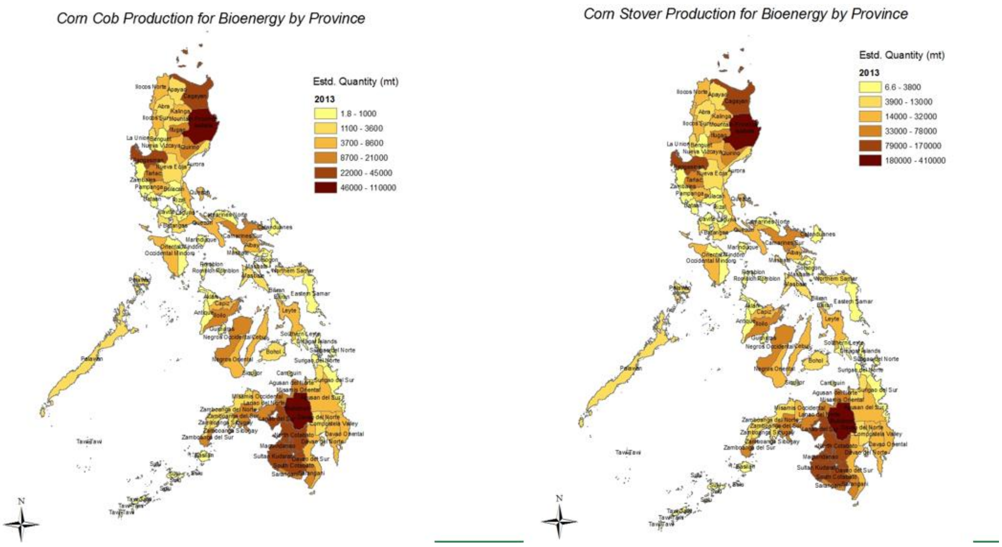


Figure 3. Maps Describing the Realistic Spatial Distribution of Corn Cob and Stove



The key production areas for sugarcane bagasse are Negros Occidental and Oriental, Bukidnon, Batangas, and Iloilo

(5) Singapore

Singapore is a highly industrialized and urbanized economy with the total land area of 697 km2 and population of 4.2 million people (*Zhong Sheng, 2021*). Biomass typically consists of urban wastes, including wood, garden, food and paper wastes. The utilization of garden and wood wastes processed by ecoWise can generate approximately 0.9 MW of electricity and 5.4 MW of heat for the electricity generation plant. With insignificant agricultural wastes totaling 144,600 tons, or 5.5% of the economy's total wastes (*ASEAN,*

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2020; Ierna, 2023). Therefore, Singapore can be considered an economy where BAW is negligible (*Beatrice Foscoli, 2020*).

(6) Thailand

Thailand is an agricultural economy, with huge biomass energy potential to meet the economy's additional energy needs. Thailand's biomass energy source can meet up to 15% of the economy's energy needs. The primary agriculture wastes include bagasse, rice straw, rice husk, cassava, and corn cobs. The estimated capacity for biomass and biogas is 7,000 MW and 190 MW respectively. Most of the industrial facilities using biomass energy are large-scale, intensive plants. The installed capacity of facilities using biomass and biogas is 1,610 MW and 46 MW respectively. The target for the installed capacity of the projects by 2021 is 3,630 GW. (*ASEAN, 2020*). Currently, Thailand leads the world in exports of rice, natural rubber, and palm oil. Approximately 80 million tons of agricultural wastes produced annually (*Axel Lund and Mattias Malmberg, 2023*)

Table 5. Biomass from agricultural wastes in Thailand

Biomass type		**Estimated biomass (ton/year)**	**Heat generation capacity (Ktoe)**
Palm oil	Leaves and branches	33,586,191	5,208
	Fiber	2,944,803	795
	Shell	619,959	248
	Oil palm chamber	1,402,455	240
Sugarcane	Bagasse	21,280,000	3,712
	Residue and leaves	5,265,619	1,929
Cassava	Rhizome	3,372,560	439
	Stem	2,084,755	769
Corn	Corn stalk	3,369,690	784
	Corn cob	80,889	18
Rice	Rice straw	4,124,630	1,204
	Rice husk	432	0.14
Rubber tree's root		1,411,834	287
Coconut	Bundles and leaves	249,026	91
	Shell	79,678	31
	Fiber	71,875	27
Total		**79,994,394**	**15,783**

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[Source: Jintawat chaichanawong and Tamio IDA, 2019]

The use of BAW for cooking and heating contributes significantly to Thailand's renewable energy (*Renewable Energy Outlook: Thailand, 2016*). Due to extensive agricultural production, traditional energy sources in rural areas primarily consist of agricultural wastes. Households in rural areas rely heavily on biomass for cooking and heating. An estimated 30% of the population (or 4 million households) still depend on traditional biomass for cooking and heating (*Jitti Mungkalasiri, 2020*). This adversely affects people's quality of life due to indoor air pollution and time spent gathering fuel.

In the industrial sector, many factories ranging from small to large scale also rely heavily on biomass energy sources. Small-scale factories focusing on agricultural and food processing use biomass fuel from agricultural development to provide heat for the production process. Larger-scale factories producing sugarcane, cassava and palm oil use biomass (from both solid biofuels as well as biogas fuel) in plants to produce heat and generate electricity mainly for the factory's own consumption needs. In the future, the expansion of biomass heat applications for industry will mainly come from on-site electricity generation plants (*Jitti Mungkalasiri, 2020*).

Currently there has been a significant expansion in biomass power plant investments using sugarcane as a raw material in Thailand. Additionally, major sugar mills have plans to further expand their biomass power plants to accommodate the expected increase in raw material supply in the future (*Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, 18 - 20 September 2024 in Viet Nam. Piyanuch Kamwean's Presentation)*

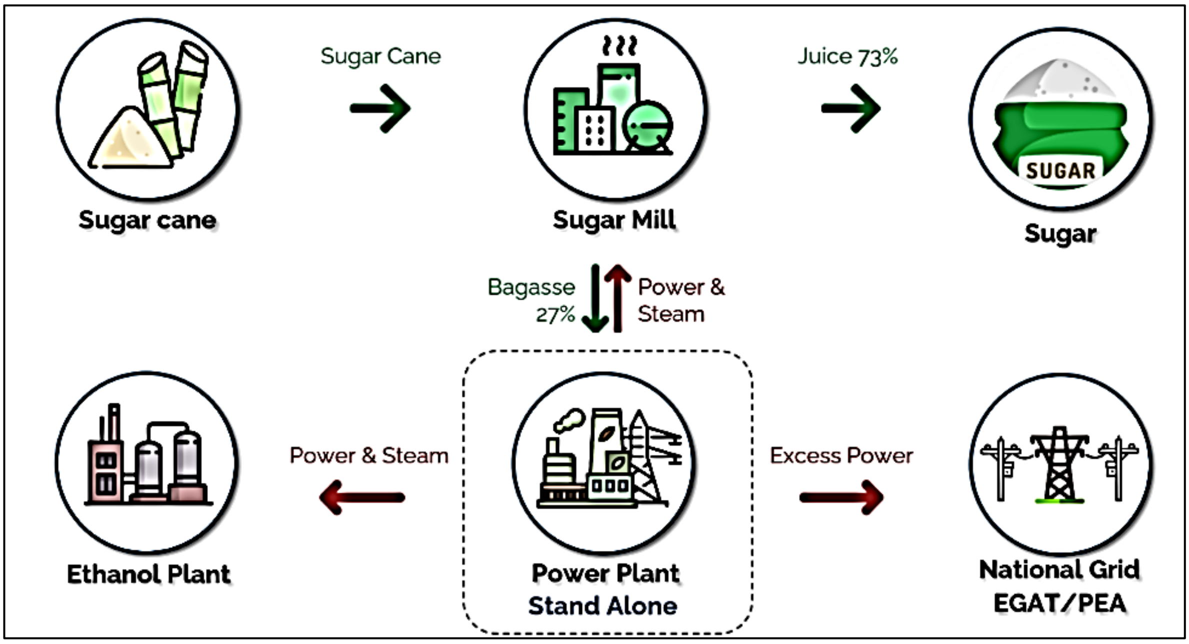
Table 6. Potential of Sugar Mills and Power Plants Using Bagasse as Fuel

Power Plant status	Number of Project	Installed Capacity (MW)	Offered for Sale (MW)
COD Completed	87	2,051.00	950.00
PPA Signed but Not Yet COD	2	50.90	37.00
Agreement Accepted but Not Yet PPA	4	99.00	67.10
Total	93	2,200.90	1,054.10

**Notes: COD: Commercial Operation Date; PPA: Power Purchase Agreement*

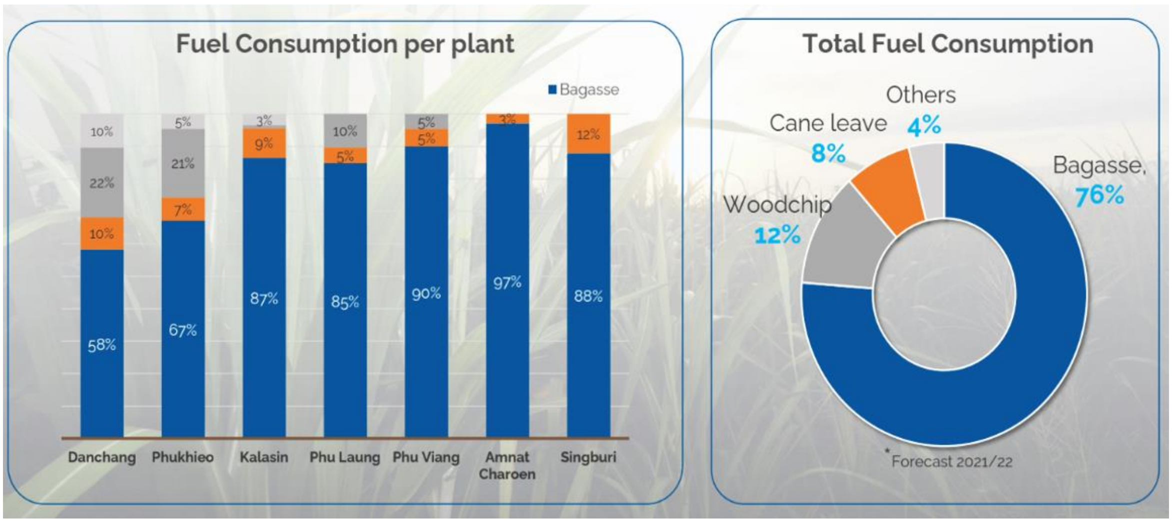
Currently, the high levels of sugarcane and sugar production in the economy have led to an increase in the amount of bagasse left over from sugar production. This surplus bagasse can be used to generate electricity and steam, which can be recycled as energy in the sugar production process. This not only helps reduce energy costs for sugar mills but also provides an additional revenue stream from selling electricity to the government.

Figure 4. Biomass Power Plant of Mitr Phol Group Power Cogeneration in Sugar Mill



Follow Information from Mitr Phol Group, Fuel Consumption (*Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, 18 - 20 September 2024 in Viet Nam. Piyanuch Kamwean's Presentation)*

Figure 5. Fuel Consumption per plant



Presently, the price of baled sugarcane leaves ranges from THB750 - 1,000 per ton (approx. USD22 – 30). Especially in Thailand, energy cane, an alternative fuel material, is promoted to farmers for cultivation to supply biomass power plants. Energy cane

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produces dry biomass up to 15 tons per rai per year. It has an average net calorific value of 17.103 MJ/kg and it can generate 2.27 times more electricity compared to bagasse with a moisture content of 50-53%. This energy cane variety has the potential to produce at least 87.5 MWh per hectare (*Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, 18 - 20 September 2024 in Viet Nam*. *Piyanuch Kamwean's Presentation).*

(7) Viet Nam

Viet Nam has abundant BAW, with a theoretical capacity exceeding 300 GW. Biomass usage in households account for 76%, while the remaining 24% is utilized in small industrial boilers, combined heat and power plants (CHP), and sugar mills (*ASEAN, 2020; Tran Minh Tuan, 2021*). Common crops such as corn, sugarcane, wood, grasses and short-cycle plants are used to produce biomass energy (*GIZ, 2018*)

In 2019, Viet Nam's estimated biomass energy production was approximately 104.4 million tons (*Nguyen Minh Nhut & colleagues, 2022*). The main sources of biomass energy include rice straw (32.1%), firewood (30.3%), corn stalks and cobs (18.5%), rice husk (6.6%), bagasse (4.0%), sugarcane residues (2.8%), cassava stalks (2.6%), peanut shells (0.2%), coconut shells (0.1%), and coffee husk (0.5%).

Table 7. Biomass from agricultural wastes in Viet Nam

Crop	Biomass type	Estimated biomass volume (ton/year)
Sugarcane	Bagasse	4,176,000
	Residue and leaves	2,923,200
Cassava	Stem	2,714,400
Corn	Corn stalk	19,314,000
	Corn cob	2,401,200
Rice	Rice straw	33,512,400
	Rice husk	6,890,400
Peanut	Peanut shells	208,800
Coffee	Coffee husk	522,000
Coconut	Coconut shells	104,400
Wood	Firewood	31,633,200
Total		**104,400,000**

[Source: Nguyen Vo Chau Ngan & colleagues, 2021]

Rice cultivation generates a significant amount of rice straw and husk. Rice straw is often left in the fields for livestock feed, burned directly, or plowed back into the soil. Rice

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husk – a byproduct of rice processing, is used as fuel for cooking stoves, as fertilizer, or as raw material in cement and brick production. Recently, rice husk has also been compressed into husk briquettes or coal to be used as fuel. Annually, Viet Nam produces approximately 17 - 50 million tons of rice straw and 2 - 8 million tons of rice husks.

At the industry level, Viet Nam has a total installed capacity of 378 MW from bagasse electricity generation, supplying power to sugar mills and feeding into the domestic grid. Currently, there are around 100 MW of electricity from rice husk and 70MW from wood in the preparation stage for investment. Viet Nam has the potential to develop 5 – 6 GW of biomass electricity generation (*Energy Institute, 2017*).

Making charcoal from coconut shells: The coconut shells that are not used as raw materials for other purposes, are used to produce coconut charcoal. Unused coconut trunks, after being dried, can be processed into different forms of biomass, for exemple: Direct burning - The tree trunk after being chopped and dried can be used directly as fuel in the furnace to produce heat and electricity; Pellet - After being crushed, old coconut tree trunks can be pressed into biomass pellets. These biomass pellets can be easily transported, stored and used in boilers or biomass power plants (*Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, 18 - 20 September 2024 in Viet Nam. Le Na's Presentation)*. At the farm level, Viet Nam is prioritizing biogas technology to treat livestock manure in rural areas. The main energy consumption potential in Viet Nam is directed towards CHP.

In summary, the use of biomass energy and market development in the ASEAN region have seen significant progress. Economies like Malaysia; Thailand; and Viet Nam have adopted more innovative solutions in biomass energy utilization. Alongside technological advancements (such as gasification, Torre faction, improved cooking stoves research and development, household biogas, etc.), these economies are also benefiting from knowledge and technology transfer. Biomass energy has the potential to bring economic and environmental benefits in the near future. (*Syarif Hidayat & colleagues, 2018*).

2.2 East Asian and Far Eastern Economies

(1) China

The main biomass sources in China are agricultural and urban wastes. Agricultural wastes are widely distributed, with tree branches alone accounting for over 600 million tons and capable of producing about 12,000 PJ of energy (*Qingfen Zhang & colleagues, 2020; Quanhui Wang, 2020*). In theory, wastes from crop processing and livestock manure could produce nearly 80 billion cubic meters of biogas. Biomass gasification is being developed in China as a way to improve energy use in rural areas (*Kejun Jiang, 2021*).

In 2018, China generated approximately 4.8 billion tons of agricultural wastes, including about 900 million tons of straw and 3.9 billion tons of livestock manure (*Ahmed Alengebawy & colleagues, 2023*). Of this total, 2.9 billion tons were collected and processed, with individuals collecting 1.3 billion tons (mostly returned to fields) and enterprises collecting 1.6 billion tons, primarily used as fertilizer (*Camera di Commercio Italiana in Cina, 2019*).

Table 8. Biomass from agricultural wastes in China

Crop	Area (10^3 ha)	Total output (10^4 ton)	Theoretical biomass (10^4 ton)	Collectable biomass (10^4 ton)
Rice	30,189	21,212.9	25,455.5	22,400.8
Wheat	13,144	13,144	15,378.5	13,533.1
Corn	25,717.4	25,717.4	26,746.1	23,536.6
Cotton	3,354	610.3	1,830.8	1,611.1

[Source: Deming Li, 2022]

By 2020, China had achieved a straw utilization rate of over 95% and a livestock manure utilization rate of 75%, thereby reducing use of chemical fertilizer and pesticide (*Deming Li, 2022*). Particularly, China is the leading economy in Asia in applying biogas technology at household and farm scales.

Table 9. Technologies for converting agricultural wastes into energy

Raw material	Technology	Output	Usage
Agricultural crops wastes	Direct combustion for electricity generation	Electricity	Electricity, heating
	Co-firing for electricity generation		
	Gasification and electricity generation		
Agricultural wastes (rice husk, corn cobs, bagasse, etc.)	Pellet fuel technology	Solid fuel	Cooking, heating
	Dry digestion	Biogas	Cooking, heating
	Hydrolysis	Ethanol fuel	Transportation
	Fischer Tropsch synthesis	Biodiesel	Transportation
Sugarcane,	Chemical	Biodiesel	Transportation,

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Raw material	Technology	Output	Usage
rapeseed, cottonseed			power generation

[Source: Camera di Commercio Italiana in Cina, 2019]

(2) Hong Kong, China

As a highly urbanized economy with a total land area of approximately 1,110 square kilometers, Hong Kong, China faces unique challenges and opportunities in the realm of biomass energy development.

Agricultural activities in Hong Kong, China are primarily restricted to urban fringes, with only about 7 square kilometers of land actively farmed. This limited agricultural space inherently restricts the availability of biomass feedstock, such as biomass agricultural wastes.

In 2022, Hong Kong, China's Total Primary Energy Supply reached 491,034 TJ, with 268,897 TJ consumed as energy end-use. Despite geographical constraints and limited indigenous energy resources, we have set an ambitious goal to increase the share of renewable energy in our electricity generation fuel mix to 15% by 2050. Hong Kong, China's current renewable energy portfolio includes solar energy, wind energy, biogas, and biodiesel.

The largest contributor to our renewable energy production is waste-to-energy (WtE), which includes sludge incineration and biogas collection, accounting for 71.5% (2,615 TJ) of our total renewable energy output. Hong Kong, China's existing WtE facilities are capable of converting 600 tonnes of food waste and 2,000 tonnes of sludge daily into electricity. Hong Kong, China is also developing modern waste-to-energy incineration facilities that will process up to 9,000 tonnes of municipal solid waste daily, alongside additional food waste treatment facilities. This approach not only addresses energy production but also promotes waste reduction and recycling initiatives.

(3) Japan

The total land area of Japan is 365,000 square kilometers, with approximately two-thirds being forestry land and 11% designated for agriculture (*IEA, 2021*). Due to the limited agricultural land, the availability of BAW is highly restricted. Currently, more than half of the fuel used for biomass electricity production comes from domestic wood biomass, but due to insufficient supply, Japan has recently begun importing wood pellets (*ERIA, 2022*).

In 2019, Japan's total energy supply (TES) reached 17.4 exajoules (EJ). Renewable

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energy accounted for only 6.3% of this total supply, with biomass energy making up approximately 40%. (*Daisuke Sasatani, 2023*).

Although biomass electricity production in Japan is modest, it has been increasing slightly (around 3% per year). Consumption of biomass for electricity generation has been rising rapidly. As of December 2020, Japan had 586 biomass power plants with the total capacity of 4.1 gigawatts (GW). As of December 2022, the Ministry of Economy, Trade and Industry (METI) had approved 900 biomass power plants, collectively capable of generating 8.3 GW under the Feed-in Tariff (FIT) (*Daisuke Sasatani, 2023*).

(4) Korea

The total land area of Korea is 97,500 square kilometers, with approximately two-thirds covered by forests and only 17% designated as agricultural land (mainly for cultivation). Therefore, biomass from crops in Korea is very limited (*IEA Bioenergy, 2021*).

In 2019, Korea's total energy supply (TES) amounted to 11.6 EJ. Renewable energy accounts for only 2% (0.23 EJ), with approximately two-thirds of which coming from biomass (*Irena, 2023; Climate Transparency, 2022*). Direct use of biomass for heat constituted only 2.5% (50 PJ)

(5) Chinese Taipei

Chinese Taipei imports over 95% of its energy. In 2017, domestic energy sources contributed approximately 2% to its TES. Chinese Taipei is moving towards a circular economy through resources recycling and converting wastes into energy (*Wen-Tien Tsai, 2019*).

Annual agricultural wastes in Chinese Taipei amount to about 4.5 – 5.2 million tons, with approximately 80% coming from rice residue (straw and husk) and livestock manure (*Chih-Chun Kung, Bruce A. McCarl, 2019*). Other significant organic wastes include: mushroom compost, oyster shells, and residues from fruits and vegetables (*Esher Hsu, 2021*). The trend of indigenous bioenergy supply is declining, primarily sourced from solid biomass such as wood waste, husk, and bagasse (*Yu-Ru Lee and Wen-Tien, 2022*).

Table 10. Biomass from agricultural wastes in Chinese Taipei

	Year (Ton)				
	2017	**2018**	**2019**	**2020**	**2021**
Agricultural waste	2,229,001	2,495,628	2,292,389	2,676,130	2,460,717
- Husk	350,810	389,959	358,242	350,146	312,174

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	Year (Ton)				
	2017	2018	2019	2020	2021
- Rice straw	1,754,049	1,949,796	1,791,211	1,750,729	1,560,870
- Used mushroom compost	124,142	155,873	142,935	156,487	175,975
- Thinning fruit branches	-	-	-	247,396	248,282
Bagasse	23,183	14,870	15,993	19,718	23,554
Fruits/vegetables residue	26,554	28,848	22,593	21,331	18,433
Flower residue	596	806	585	655	1,076

[Source: Yu-Ru Lee and Wen-Tien, 2022]

Survey showed that Chinese Taipei is focusing on fruit trees or bamboo branches and fertilizer to utilize wastes to convert into biomass.

Table 11. Estimated volume of agricultural wastes in Chinese Taipei in 2023

No	Crop	Area (ha)	Output (Tấn)	Waste	
				Ton	Used for energy (%)
1	Fruit tree	169,892	2,348,655	255,840	N/A
2	Bamboo	25,239	217,768	161,935	N/A
3	Fertilizer	5,316,431	-	2,251, 600	N/A

[Source: Distributed Questionnaires]

Renewable energy in Chinese Taipei is mainly biomass energy. About 60% of the wastes are processed by recycling and 40% are incinerated. Chinese Taipei currently has 24 large-scale waste incineration plants in operation (*Wen-Tien Tsai, 2019*).

In summary, economies in this region such as China; Japan; and Korea have adopted co-firing technologies. Production and business activities related to bioenergy in these economies have been on the rise, attracting increased interest from new investors in biomass co-firing technologies. All three economies have specific policies and regulations mandating the conversion of biomass into renewable energy sources. Wood pellets co-fired with coal are a major source of electricity production in these economies. However, there is still a portion of wood pellets that are not utilized for biomass co-firing.

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2.3. Economies of the Americas

(1) Canada

Canada has a very developed bioenergy sector, which contributes more than 6% of the economy's total secondary energy supply. This type of energy comes primarily from forest harvesting and manufacturing byproducts as well as agricultural waste and municipal solid waste. About 80% of bioenergy in Canada is from forest biomass (hog fuel wood chips, wood pellets etc.) (*The distributed Questionnaires*).

Canada ranks the third globally in agricultural land per capita, following Australia and Kazakhstan. Agricultural output of Canada is vast and diverse. In 2021, Canada produced over 73 million tons of wheat, more than 26 million tons of cereal grains, over 17 million tons of potatoes, more than 14 million tons of soybeans, and over 5 million tons of black beans. Additionally, Canada produces a wide variety of other food products including vegetables, fruits and meat (*OECD/FAO, 2023*).

Table 12. Estimated Agricultural Waste Volume in Canada 2022-2023

No	Crops	Area (Thousand hectares)	Production (Thousand tons)	Wastes	
				Million tons	Used for energy (%)
1	Corn	1,444	14,539	-	-
2	Wheat	10,082	34,335	-	-
3	Barley	2,636	9,987	-	-
4	Oat	1,402	5,227	-	-
5	Buckwheat	152	520	-	-
6	Mixed cereals	72	203	-	-
7	Canola	8,596	18,695	-	-
8	Linseed	312	473	-	-
9	Soybeans	2,118	6,543		-
10	Crop residues			31	N/A

[Source: Distributed Questionnaires]

Overall final energy consumption 2019, the share of renewables among electricity, transportation and heat sectors is 25%, the share of bioenergy making is 6%. The shares of renewables and bioenergy in final energy consumption are higher than their shares in

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Canada's total energy supply (16% for renewables and 4% specifically for bioenergy) since the latter includes unused waste heat, e.g., in fossil or nuclear power production. In 2019, bioenergy in final consumption of electricity energy occupied 1.8%; 3.2% in transport; 11.8% in fuel and heat; 6.2% in total final energy consumption (*Economy's reports, 2021*).

Many of Canada's paper and pulp mills have begun integrating new conversion processes to produce non-traditional products such as bio-methanol, cellulose fibers, and high-value lignin (*IEA bioenergy, 2020*).

(2) Chile

Agriculture, livestock, and forestry in Chile contribute approximately 2.9% to the GDP. However, the majority of agricultural and forestry waste is either discarded or sent to landfills with minimal utilization for energy purposes (*Lina Patricia Vega & colleagues, 2024*).

Each year, wastes from 20 types of crops in Chile could generate 22.2 PJ of energy, with rice, wheat, and corn stalks in the lead at 30%, 26% and 17%, respectively (*James Ludlow & colleagues, 2021*). In Chile, wheat waste amounts to 1.38 times the yield of barley, making it the highest waste production index. Corn is the most important cereal in the economy, with waste of 1.17 times its yield (*Celián Román-Figueroa, 2020*).

The potential for energy generation from crop wastes in the Araucaria region is significant. In this region, wheat waste is concentrated in 23 out of 299 districts, which account for 50% of the total wheat waste production in the area (*Celián Román - Figueroa, 2020; Sebastián Rocha & colleagues, 2020*).

(3) Mexico

Mexico, with abundant biomass resources from various types of wastes, has significant potential for a sustainable circular bio economy. Eight crops have been selected: corn, wheat, sugarcane, barley, sorghum, soybeans, rice and peach pit. The selection is based on residue volume, production volume, energy yield characteristic or chemical properties of the biomass (*J. Amador Honorato - Salazar and Jhuma Sadhukhan, 2020*).

Agricultural wastes used for bioenergy production primarily come from corn, cereals, and sugarcane. These account for 77.9% of the total, while wastes from processed sugarcane, Jatropha curcas, and palm oil make up nearly 20.1% (*Salvador Carlos & colleagues, 2023*). Sugarcane, sorghum, and sugar beets are the main crops for producing bioethanol, whereas Jatropha, castor beans, and palm oil are used for biodiesel production. Bagasse from sugar mills is the primary source for generating bioenergy. In semi-arid highland

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regions, estimated annual straw production reaches 1.9 million tons. In 2020, annual soybean production typically reached about 954 thousand tons (*Diego Fabián Lozano-García & colleagues, 2020; Salvador Carlos & colleagues, 2023*).

In Mexico, it is estimated that 87.94 million metric tons of dry matter (Mt DM) are generated from crops annually, with 37.52 Mt MD used for energy and biofuel production. Primary and secondary crop residue contributes 30.53 Mt DM and 7.01 Mt DM, respectively. Approximately 95.8% of this residue comes from corn, sorghum, sugarcane, wheat, barley, and beans, with respective proportion of 43.3%, 25.5%, 18.1%, 6.3%, 1.6% and 1.0%. The estimated bioenergy potential is 670.3 PJ/year, comprising 542.5 PJ/year from primary residue and 127.8 PF/year from secondary residue (*Jhuma Sadhukhan & colleagues, 2024*).

(4) Peru

Peru is a prominent developing economy in Latin America and the Caribbean, with an average economic growth rate of 5.8% per year and low inflation at just 2.9%. The primary energy sources come from natural resources, yet there is still a shortage of electricity for approximately 3 million people and inadequate energy supply for low-quality service (*OECD/FAO, 2023*).

Peru has significant potential for electricity generation based on renewable energy sources. It is projected that by 2040, the total installed capacity from these sources will reach 4,321 MW, accounting for 17.3% of the total installed capacity.

Peru annually generates 10,247,670 tons of agricultural and forestry wastes, capable of producing 2,993,506 TOE (tons of oil equivalent) or 125 PJ. However, this amount is not commercially utilized and is not considered as commercial primary energy in the economy's energy balance (*Daniel Marcelo & colleagues, 2017; Mg. Estela de la Gracia Assureira Espinoza, 2014*). It is estimated that there are 13 types of crops that produce sufficient wastes to generate electricity, yet approximately 31 million tons of wastes are either burned or left on the fields annually. Provinces with significant potential for bioenergy from agricultural and forestry wastes include La Libertad, Lambayeque, Lima, San Martin and Piura, with respective proportions of 26%, 16.7%, 13.0%, 7.1% and 11.7% (*Alan Clarke & partners, 2018*). Peru has relatively large potential for bioenergy production, especially from bagasse. The economy has 11 sugar mills, of which at least 9 mills use bagasse in co-generation plants (*Fit Lima, 2020*)

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Table 13. Biomass from agricultural wastes in Peru

Crops	Wastes (ton)
Sugarcane	18,967,989
Rice (husk)	4,272,540
Hard yellow corn	2,904,397
Palm fruit	1,499,188
Corn has starch	915,928
Corn	599,802
Cotton	572,083
Asparagus	499,400
Coffee	377,486
Wheat	251,682
Barley	236,006
Grapes	34265
Olives	22,007

[Source: Fit Lima, 2020]

In Peru, agriculture, agribusiness and the timber industry generate over 10,257,000 metric tons of biomass residues, equivalent to 2,991,711 TOE in energy. The biomass residue primarily comes from crop wastes such as sugarcane (20%), corn stalks, leaves, and cobs (35%), bagasse (17%), husk (4%), straw (14%), hay (2%), cotton (6%), wood chips and sawdust (1%) (*Fit Lima, 2020*).

(5) The United States

The United States is expected to collect approximately 111 million tons of agricultural wastes. More than three-quarters of this consist of corn stalk, about one-fifth is wheat straw, and the remainder comes from other cereal crops (barley, oats, sorghum). With increasing crop yield and acreage, it is estimated that by 2030, agricultural wastes in the U.S. could reach 180 million tons (*Monica Saavoss & colleagues, 2021*)

Most gasoline sold in the United States contains ethanol. Most ethanol sold is E10. Ethanol serves as a gasoline substitute and an octane booster. Nearly all commercial ethanol biofuel production is from conventional cornstarch as a feedstock. As of January 2023, there were 192 plants with a capacity of 17.4 billion gallons. Half of that capacity

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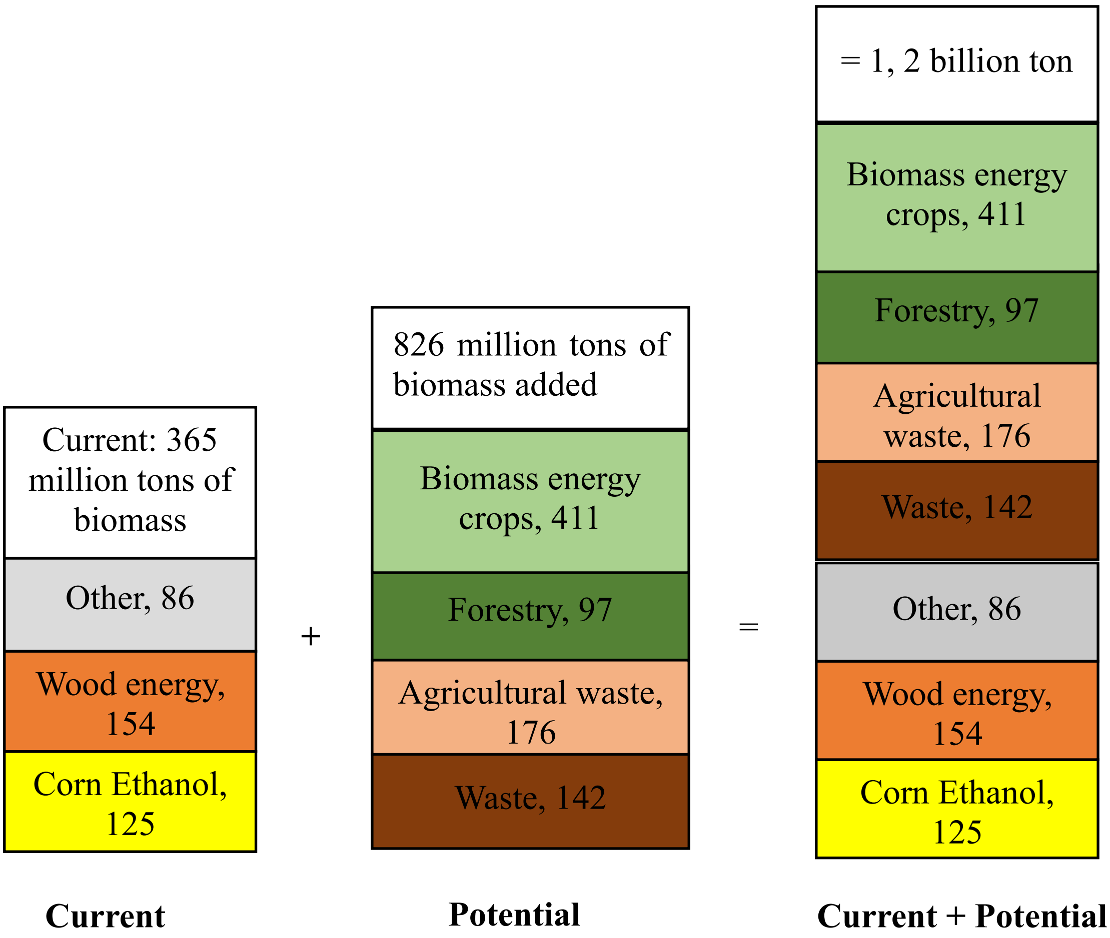
is in Iowa, Nebraska, and Illinois (*U.S. Department of Agriculture, 2024*).

The United States is the world leader in ethanol production, accounting for 55% of the world's ethanol production in 2022 (*Emily Newes & colleagues, 2020*). During the same year, the U.S. exported 1.35 billion gallons of ethanol valued at USD4.1 billion. Ethanol exports constituted 8.8% of domestic production. The U.S. exported ethanol to 50 economies, with Canada being the largest importer at 37%, followed by Korea at 12%, and the European Union at 11%. (*Kristi Moriarty & colleagues, 2022*).

The availability of biomass (from forestry, agriculture and wastes) for current and potential use by 2040 is estimated as depicted in Figure 6. (*U.S. Department of Agriculture, 2024*).

Figure 6. Agricultural Biomass Potential in the U.S.



2.4 Oceania economies

(1) Australia

Wood biomass is widely used in Australia for non-energy purposes such as paper and pulp manufacture, cereal production, fermented livestock feed, crystalline sucrose from

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sugarcane, biomass composting from wastes to rehabilitate and treat soil (*Bert Annevelink & colleagues, 2022*).

About 72% of electricity in Australia is generated from fossil fuel, while 5% comes from bioenergy (*Bert Annevelink et al., 2022*). During the 2020 - 2021 period, the annual economic growth rate was 1.5%, but energy consumption decreased by 3.6%. Among fossil fuel, oil remains the largest consumed at 36%, followed by coal at 29% and natural gas at 27%. Renewable energy makes up a smaller portion at 8%, consists of biomass (37%), hydroelectricity (12%), wind energy (19%), and solar energy (22%). Biomass energy primarily comes from wood and bagasse, contributing 18% and 19% respectively (*Enea, 2021*).

Three sources of biomass from crop wastes are sugarcane, cotton and rice, specifically:

- The sugarcane industry is predominantly located along the eastern coastal region with 28 mills situated between Lismore (New South Wales) and Cairns (Queensland). This supplied 90 PJ, approximately 2% of Australia's total primary energy demand. The energy is used to operate processing machinery, provide heat, and co-generate electricity. Due to the harvesting season from June to November, bagasse is available for about half a year. The development of renewable energy source depends on the utilization of bagasse and biomass (with only 50% currently collected). During the off-season, conversion and gasification technologies are used to produce alternative fuel. Implementing advanced conversion technologies for bagasse could generate an average electricity capacity of about 3,400 MW (20.722 GWh/year). This has helped reduce emission by 16.5 million metric tons annually or nearly 10% of Australia's total GHG emission (CO2-e) from fixed energy plants (*Australian Government, 2022*).
- The cotton industry is primarily concentrated in northern New South Wales and southern Queensland. Waste from cotton processing is estimated at about 1 million metric tons per year. Gasification processes using cotton waste are competitive at a small scale. The maximum estimated electricity generation potential is 50 MW.
- Rice cultivation is concentrated in Deniliquin (southern New South Wales), relying on irrigation. Annually, around 100,000 metric tons of rice husks from milling could potentially support approximately 5 MW of electricity generation capacity, though feasibility remains a subject of debate.

Australia's bioethanol production capacity is currently 440 mega liters per year, representing 0.48% of global bioethanol production. The biodiesel production capacity of

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the economy is 100 mega liters per year (0.17% of global production). In 2021, Australia produced 180 million liters of ethanol and 18 million liters of biodiesel. The primary feedstock for biodiesel is animal fat and used vegetable oil. Australia is the world's third-largest producer of sugarcane. Most bagasse is burned to generate electricity, whereas other economies use it for biofuel production (*Australian Government, 2022*).

(2) New Zealand

New Zealand's energy production includes both renewable and non-renewable sources. In 2021, New Zealand achieved the highest proportion of primary energy from renewable sources at 40.7%. This percentage is significantly higher than the average for the Organization for Economic Cooperation and Development (OECD), which is around 11% (*IEA bioenergy, 2021*).

New Zealand has approximately 109,900 hectares dedicated to cereal crops, including 20,600 hectares of corn, 39,400 hectares of wheat, and 49,900 hectares of barley. However, using these crops for energy production may compete with food production (*IEA bioenergy, 2021*).

In 2019, energy consumption derived from biomass in New Zealand is 51.31 PJ. Biomass energy production primarily serves wood, pulp and paper processing industries (*Ministry of Business, Innovation and Employment Hikina Whakatutuki, 2021*). In 2022, New Zealand exported approximately 22.7 million cubic meters of raw round wood, the production waste of which contained about 157 PJ of renewable biomass energy. The annual forest harvest volume in New Zealand is around 37 million cubic meters, with 60% of it being exported (*Bioenergy Association, 2022*).

(3) Papua New Guinea

Despite two-thirds of its area being covered by forests, much of the biomass is inaccessible or unsuitable for energy production. As estimated 58% of the land area in Papua New Guinea suffers from severe erosion, while 18% in permanently or regularly flooded. Papua New Guinea has significant potential in indigenous energy sources such as oil, natural gas, coal, hydroelectric power, biomass, and other renewable energy. Biomass fuel is the most important primary and secondary energy source in Papua New Guinea. Wood fuel such as firewood, crop residue, and charcoal are predominant. Annually, around 2 million m3 of agricultural and round wood residue is generated, but very little is processed locally. Only a small fraction of the biomass from waste is used for energy production (*Department of Petroleum and Energy, 2024*).

The Ramu Sugar mill, where approximately 4 million liters of ethanol are produced

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annually, has been using bagasse as fuel to operate. The company manages around 8,000 hectares of sugarcane plantations and contributes over 80% of the sugar production in the economy. Papua New Guinea installed approximately 80 gasification units to utilize biomass from wastes in industries such as coconut hush, cocoa, coffee, and tea to replace imported fuel. Wood biomass is the traditional biofuel of Papua New Guinea, accounting for over 50% of the domestic energy consumption. Recently, there have been no survey proving its usage. Wood biomass is primarily used for cooking, with some also utilized in sugar, palm oil and wood production facilities. Despite efforts to promote efficient wood and charcoal stoves, most cooking still depends on open fire. A portion of electricity and heat is generated from biomass waste in the palm oil industry, sugar factory, and wood processing sector.

Biomass fuel is the most important primary and secondary energy source in Papua New Guinea. Wood fuel such as firewood, agricultural wastes and charcoal are predominant. Each year, approximately 2 million cubic meters of agricultural and round wood processing waste are generated, but very little is processed locally. Only a small amount of biomass from wastes is used for energy production.

To sum up, in Oceania, the utilization of renewable energy and biomass energy is relatively small compared to its potential. The low demand for domestic energy may be attributed to the warm climate, which reduces the needs for indoor heating. As of 2019, renewable energy accounted for only 7% of the total energy supply, with oil, coal, and natural gas still dominating. The share of renewable energy in the final energy consumption was 11%. About half of the renewable energy comes from biomass, with the majority of biomass energy applied in industrial heating (*Enea, 2021*).

3. Potential and Opportunities

The use of BAW is a crucial factor in meeting future energy needs, beyond environmental and energy benefits, there are also economic advantages such as enhancing the value of agricultural nutrients, reducing dependence on imported fossil fuel, lowering waste disposal costs, creating jobs, and increase income for local communities.

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Table 14. Growth in biomass production of APEC economies

No	Economy	Ethanol production (min L)			Biodiesel production (min L)		
		2020 - 2022	2032	Growth (%) (2023 - 2032)	2020 - 2022	2032	Growth (%) (2023-2032)
Asian economies							
1	Brunei Darussalam	-	-	-	-	-	-
2	China	9,867	11,181	1.08	1,907	1,940	-2.01
3	Indonesia	179	220	2.00	9,418	12,385	1.52
4	Japan	54	47	-0.02	23	22	-0.71
5	Korea	158	124	-1.66	692	646	-1.09
6	Malaysia	0	3	25.14	1,250	1,679	1.86
7	The Philippines	383	604	3.13	201	321	2.36
8	Singapore	-	-	-	-	-	-
9	Thailand	1,733	1,910	0.11	1,620	2,279	4.88
10	Viet Nam	252	322	2.10	0	0	N/A
Oceania economies							
1	Australia	325	324	-0.55	26	19	0.59
2	New Zealand	3	3	0.00	0	0	N/A
American economies							
1	Canada	1,927	2,410	1.96	388	685	5.23
2	Chile	5	9	8.80	0	0	N/A
3	Mexico	157	228	0.11	0	0	N/A
4	United States	57,644	61,085	0.20	9,822	16,176	2.71

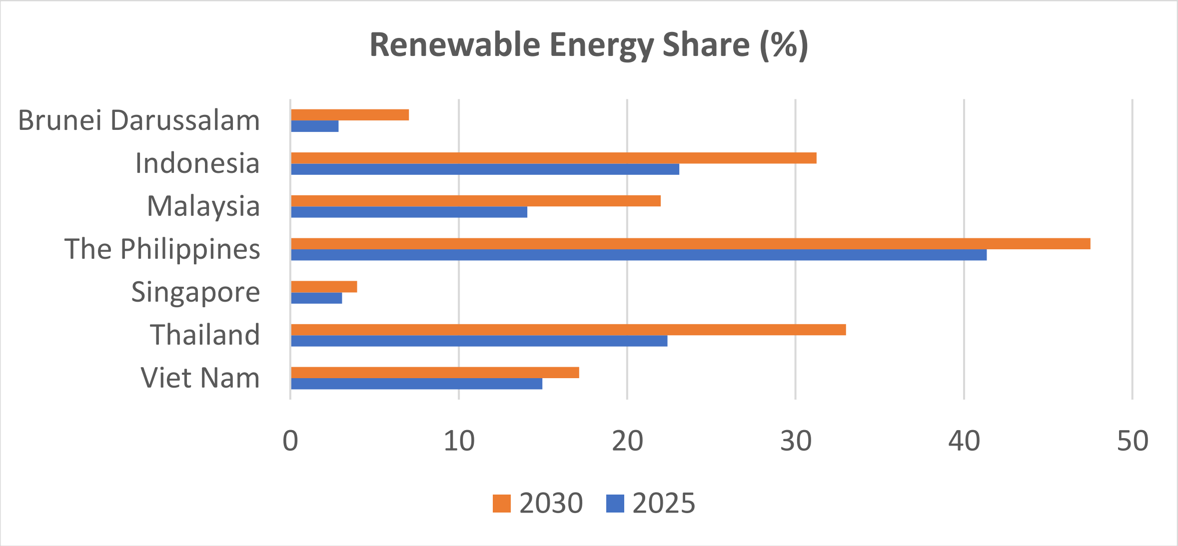
[Source: OECD/FAO, 2023]

Across the regions, fossil fuel deputation and climate change have accelerated the need for renewable energy alternatives. Some examples are:

- Most ASEAN economies have significant potential in renewable energy, especially BAW (*ASEAN, 2020*). According to the International Energy Agency (IEA), biomass energy accounts for only 8% of the total energy capacity in the region. This percentage is low considering the region's natural strength in agriculture. Major biomass sources in ASEAN include firewood, wood residue, rice husk, straw, bagasse, palm shells, and coconut husk. The estimated potential annual biomass energy capacity in the region is over 500 million tons, with potential biomass energy exceeding 8000 million GJ (*Maw Tun et al., 2019*). Reduce greenhouse gas emissions by 80% by adopting modern biomass energy techniques that complement other alternative sources such as solar, wind and water and by using agricultural residues to reduce methane produced from material decomposition.

- Several ASEAN economies, such as Indonesia; Malaysia; Thailand; and Viet Nam, have domestic policies that promote the development of biomass energy, which indirectly supports biochar production. For instance, Malaysia has been developing biochar as part of its efforts to utilize palm oil biomass, and Thailand has explored biochar through its agricultural and energy sectors *(Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, Ha Noi, 18 - 20 September 2024. Presentation of Imelda Bacudo, FAO).*

Figure 7. Potential share of renewable energy in total primary energy supply in the Southeast Asian economies



- East Asian economies serve as major suppliers of raw biomass material to European and US markets. Within the region, there are emerging opportunities for new investments in biomass. The primary potential for biomass in this area includes wood biomass, animal and crop residue, sewage sludge, industrial and municipal wastes. For instance, Japan ranks as the world's fifth-largest biomass market. The Japanese Government has set a target to double biomass output by 2030, aiming for 32.8 terawatt-hours (TWh), which would constitute

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approximately 20% of renewable energy, and attract about 20% of Government incentives for renewable generation (*IEA Bioenergy, 2021*).

APEC members have already been exploring bioenergy as part of their renewable energy strategies. For instance, APEC economies like Indonesia, Malaysia and Thailand are heavily invested in biomass energy, which can complement biochar production *(Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, Ha Noi, 18 - 20 September 2024. Presentation of Imelda Bacudo, FAO).*

- Australia's vast agricultural and post-agricultural land provides ample resource and expertise in biofuel technology. The existing skills and experiences in agriculture, forestry and technology have greatly contributed to the robust development of the biofuel industry (*Australian Government, 2022*).

4. Policy on developing biomass energy from agricultural waste

4.1 Southeast Asia

The ASEAN has interventions at agri-food systems that promote transformation from a chain of products and services that bring healthy and nutritious food from production areas to consumer tables: (1) ASEAN Guidelines on Promoting Responsible Investment in Food, Agriculture and Forestry (2018); (2) ASEAN Guidelines on Promoting the Utilization of Digital Technologies for ASEAN Food and Agricultural Sector (2021); (3) ASEAN Guidelines for Promoting Climate Smart Agriculture (CSA) Practices Vol. 3 (2022); (4) ASEAN Regional Guidelines on Sustainable Agriculture (2022); (5) Study on Nature-based Solutions (NbS) in ASEAN across forest, bare land and coastal ecosystems (2023). ASEAN developed the ASEAN Strategy for Carbon Neutrality to complement the AMS' NDCs and NAPs. A carbon-neutral future for ASEAN could unleash between USD3.0 and USD5.3 trillion GDP value-add by 2050, attracting a substantial USD3.7 to USD6.7 trillion green investment and unlocking between 49 and 66 million additional jobs for the ASEAN region. To support the implementation of the ASEAN Strategy on Carbon Neutrality, the ASEAN Guidelines on Reducing Crop Burning will be developed by ASEAN in 2024 *(Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, Ha Noi, 18 - 20 September 2024. Pham Quang Minh's Presentation)*

Some economies like Indonesia; Malaysia; Thailand; and Viet Nam have established strategies and policies for renewable energy and biofuel, but none have a comprehensive strategy for modern biomass energy in rural area. These economies have implemented

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biogas and biomass-to-energy projects successfully, but there remains a gap in comprehensive strategies specifically for modern biomass energy in rural areas. In their renewable energy strategies, these economies prioritize biofuels for industrial use more than BAW (*Maw Maw Tun & colleagues, 2019*). Some references are including:

- **Indonesia** and the International Partners Group (IPG) have initiated a Fair Energy Transition Partnership to accelerate the shift towards cleaner energy in the future. The goal of establishing this long-term partnership is to mobilize US$20 billion within 3 - 5 years from public and private sources for the energy transition process to achieve climate energy goals (*EU, 2022*). Indonesia's policy on biomass energy fundamentally adheres to the Regulation of the President (issued May 2006) on the Domestic Energy Policy, which forms the basis for biomass energy development. The goals by 2025 is to achieve an optimal energy mix, with renewable energy accounting for more than 15%, and biomass energy contributing around 5 - 10% of the total energy mix. This policy emphasizes the use of biofuel more prominently (*Sapuan Dani Aditya Wibawa, 2018*).

  The Government's mandate to develop sugarcane-based bioethanol is currently one of its main focuses. The electricity procurement policy has not yet accommodated the sale of electricity generated by sugar mills, so it remains mostly limited to the factories' own needs *(Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, Ha Noi, 18 - 20 September 2024. Presentation of Sri Suhesti & Erlita Adriani)*

  The Indonesian Government offer tax incentives for qualifying companies in pioneering industries. Capital investment (including those in the biomass sector) of IDR500 billion (MYR155 million) or more can receive a tax exemption of 5-20 years and a 50% reduction in corporate income tax (CIT) for 2 years. Investment ranging from IDR100 billion (MYR31 million) to less than IDR500 billion (MYR155 million) may receive a 50% CIT reduction for 5 years and an additional 25% reduction for 2 years. These incentives aim to support high-value strategic industries, emerging technologies, and external factors. Indonesia plans to gradually integrate biomass with fossil fuel power plants. Co-firing plays a crucial role in green energy production in the economy. Mandatory implementation of biomass co-firing at power plants will eventually phase out of coal-fired plants and promote biomass as a renewable energy source in Indonesia.

- **Malaysia**: The Department of Agriculture (DOA) Malaysia plays a pivotal role in

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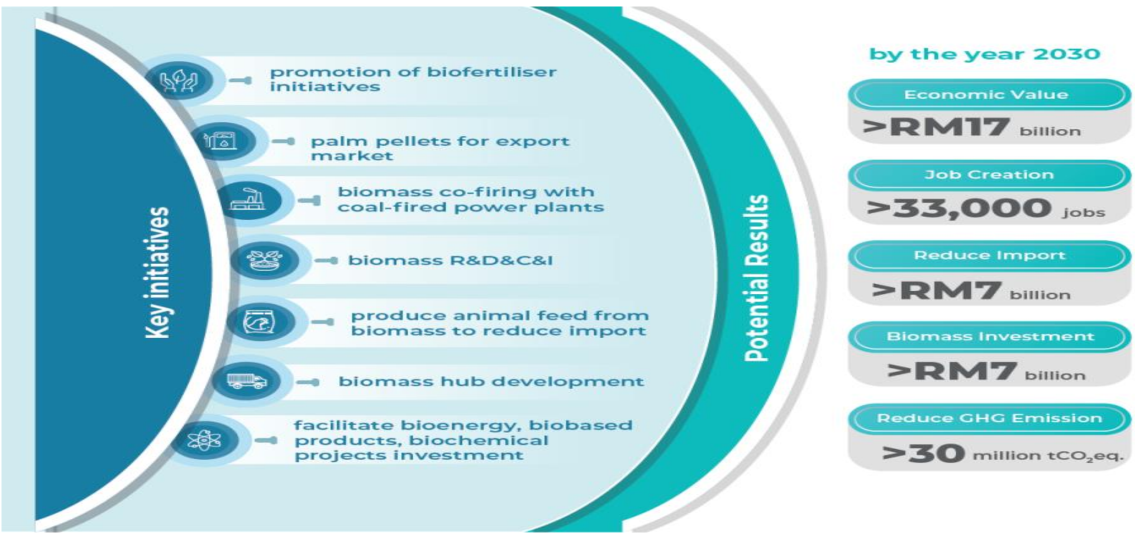
promoting the use of biomass from agricultural sectors. The main policy drivers positively impacting the development of Malaysia's biomass industry are the National Biotechnology Policy 2.0; Biofuel Policy; National Green Technology Policy and Renewable Energy Act. Malaysia has launched its National Renewable Energy Policy and Action Plan. The targeted renewable energy consumption was 11% of the total energy consumption by 2020 and 14% by 2030.

The National Biomass Action Plan (NBAP) 2023-2030 is one of the National Renewable Energy Policy and Action Plans, which includes its 5 Policy Thrusts and 17 Strategies, as shown in Figure 7. Additionally, the potential results of the NBAP are presented in Figure 8. *(Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, Ha Noi, 18 - 20 September 2024. Presentation of Wan Mohd Rusydan Bin Wan Ibrahim).*

Figure 8. Framework for the National Biomass Action Plan (NBAP)

Figure 9. Potential Results of the National Biomass Action Plan



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Relevant investment incentives for the biomass industries: Biomass companies can access this portal which provides comprehensive information on investment incentives at http:/investmalaysia.mida.gov.my/incentives/. I-Incentives is a portal that provides information on investment incentives by the Federal Government of Malaysia. The Incentives Coordination and Collaboration Office (ICCO), established under the Malaysian Investment Development Authority (MIDA), has been tasked as a central coordinator for all investments incentives to meet the domestic investment agenda. ICCO will be one-stop center to advice and coordinate businesses on incentive offerings and provide cross- agency visibility. The incentives coverage will be dynamic, whereby the list of incentives offered by all Ministries and agencies will be updated from time to time.

Additionally, private sector biomass stakeholders can always access the following website: www.krste.my; System Knowledge Resource for Science and Technology Excellence, a knowledge bank on various R&D&C&I projects funded by MOSTI. The website provides instant search results to access various R&D&C&I projects, inclusive of various biomass technologies for potential R&D&C&I with relevant research universities. This portal serves to facilitate potential biomass R&D&C&I collaboration between the industry and the government research institutions.

Types of R&D&C&I incentives Relevant to Biomass Industries: In-house R&D; Incentives for Reinvestment of R&D Activities; Incentives for Commercialization of Public Resource-based R&D; Double Deduction for R&D; Incentives for Researchers to Commercialization Research Findings; Industrial Building Allowance (IBA) and Exemption from Import Duty on Machinery / Equipment/ Samples /Materials and Components

Enhancing Private Sector's R&D&C&I Participation: The Malaysian Government has implemented: (1) R&D&C&I Synergy pillared on the Quadrilateral Collaboration Model; (2) Communication and Awareness for Development of High Value Bio -Based Products; (3) Develop Human Capital for Biomass Industries; (4) Foster Biomass Innovation Platform; (5) Research and Development Linked to Government Green Procurement; (6) Access International R&D Funding Opportunities from Japan.

- **The Philippines** Government has enacted the Biofuel Act with the goal of achieving a fuel mix of B20 and E20/85 by 2030. A biomass roadmap has also been established, with a biomass rate of 6.63 Php/kWh. To encourage investment,

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the Government has introduced policies such as income tax reductions for biofuel producers during the first 7 years of operation, reduced special property tax rates for equipment and machinery, exemption from import duties on equipment and machinery, and no value-added tax (VAT) on the purchase of goods and equipment. Specially, a 0% VAT rate on the sale of ethanol biofuel is stipulated in the Renewable Energy Act (*Florence Mojica-Sevilla, 2023*). Additionally, the Philippines Government mandates that all liquid fuels for engines and motors sold in the economy use locally sourced biofuel components, particularly local agricultural biomass.

- **Thailand** has been actively promoting and supporting the development of energy, particularly in the field of alternative energy and energy conservation. The main objectives are to enhance energy security, stabilize economic prosperity, and improve welfare. To achieve these goals, domestic renewable energy sources (solar, wind, biomass, and hydropower) are prioritized with support programs from policies. Thailand has implemented a pricing incentive policy for investors in biomass power generation, known as the "Add-On Program", which adds a payment to the electricity price for a period of 7 years (THB0.5 for projects with capacities of 1 MW or less and THB0.3 for larger projects). Thailand's 4.0 policy (Investment Incentives and Tax Benefits) aims to promote innovation, the application of technology, and collaboration with international partners for the sustainable development of various sectors, including the biomass industry. Under this policy, the Board of Investment (BOI) offers various incentives to encourage foreign investors to invest in this sector. Projects that use agricultural products and wastes for the production of electricity, steam, and biofuel can receive tax exemptions for up to 8 years. Importation of specialized machinery can also be exempt from import duties. Technologies that promote biomass energy can be exempt from corporate income tax for up to 13 years (*Maw Tun & colleagues, 2019*). Specifically, the Alternative Energy Development Plan, which aims to promote the use of biomass, has significantly impacted the utilization of biomass energy from agricultural waste. As a result, in 2018, Thailand generated 3,372 MW of bioenergy for power plants following the single buyer model. This helps plants save costs and contribute a small portion of electricity to the domestic grid. Thailand is currently operating and Energy Development Project with the goal that by 2021, renewable energy will account for 25% of total energy consumption. Thailand's renewable energy sources include solar, wind, hydropower, biomass

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energy. For biomass energy, the production targets for 2021 are 9 million liters per day of bioethanol and 7.2 million liters per day of biodiesel. Additionally, the Government has implemented incentivized pricing policies for electricity from agricultural waste, especially for the gasification of bagasse (*Jintawat Chaichanawong and Tamio IDA, 2019).*

- **Viet Nam** set a target for biomass electricity generation to reach 437.22 GWh by 2020 and 473.53 GWh by 2030 (*GIZ, 2018*). The Vietnamese Government has issued a Renewable Energy Strategy for 2030 with a vision towards 2045. This strategy aims for renewable energy (including wind, solar, biomass and biofuel) to constitute 15 - 20% of the total energy mix by 2030 and 25 - 30% by 2045. In 2020, Viet Nam implemented preferential electricity pricing policies for biomass from bagasse and wood residue, although these prices were still lower compared to the Philippines and Thailand.

  Specifically, the electricity price for biomass cogeneration projects is VND1,634/kWh, equivalent to 7.03 cents/kWh; the electricity price for other types of biomass projects is VND1,968/kWh or 8.47 cents/kWh (prices do not include value-added tax). In addition, biomass power projects are categorized as investment incentive sectors according to the Investment Law of 2020. Enterprises investing in biomass power plants will enjoy incentives such as: exemption or reduction of land use fees, land rental fees, and land use tax; exemption from import tax on goods imported to create fixed assets; preferential import tax on raw materials, supplies, and components imported for production in accordance with the law.

  Viet Nam and nearly 150 economies committed to bringing net emissions to “zero” by 2050; along with more than 100 economies participating in the commitment to reduce global methane emissions by 2030 compared to 2010; along with 141 economies participating in the Glasgow Declaration of Leaders on Forests and Land Use and along with nearly 50 economies participating in the global declaration on converting coal power to clean energy. By 2030: Develop and implement a plan to reduce greenhouse gas emissions across sectors according to the roadmap to achieve net zero emissions by 2050. Implement GHG inventory and reduce GHG emissions for facilities that annually emit 3,000 tons of CO2eq or 1,000 TOE or more from 2022. By 2050: Implement GHG inventory and reduce GHG emissions for facilities with annual emissions of 2,000 tCO2eq or more from 2030; 500tCO2eq or more from 2040; 200 tCO2eq or more from

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2050 *(Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, Ha Noi, 18 - 20 September 2024. Tran Dai Nghia's Presentation),*

4.2 East Asia and Far East

All economies have regulations and policies regarding renewable energy or industrial biofuel, and strategies for advanced biofuel. The economies' domestic policies promoting advanced biofuel have been incorporated into community action programs within the context of a circular economy (*Antar & colleagues, 2021*). Some references are including:

- **China**: The Environmental Protection Law of China has created strong opportunities for the development of biogas in rural areas, promoted the use of renewable energy, utilized non-arable land for energy crop cultivation, and significantly developed energy forest areas (*Qingfeng Zhang & colleagues, 2020*). China has a large amount of straw annually, up to 230 million tons (*Liu & colleagues, 2021*), but a significant portion of this remains unused, either discarded or burned in the fields, leading to ecological, atmospheric, aquatic, and soil degradation (*Alengebawy & colleagues, 2022*). To promote sustainable use of straw, the Government has implemented diverse policies aimed at addressing these current issues (*Ren & colleagues, 2019*).
- **Japan**: The Japanese Government implemented a biomass energy strategy early on, and as a result, the economy is actively developing biomass towns. Japan currently has 286 biomass towns. Various tax reduction measures have been enacted, such as the Energy Reform Tax System and Green Investment Tax Reduction. Efforts to increase the usage rate of non-fossil fuel energy sources are being promoted through laws and methods that change the energy supply structure (*IEA Bioenergy, 2021*). In particular, Japan has implemented a feed-in tariff program to support the increase in biomass and other renewable energies. Biomass energy approved under the FIT program us granted a fixed purchase price for 20 years. In 2021, Japan's FIT rates for biomass electricity varied by type: JPY40 (USD0.38)/kWh for unused wood with a capacity of less the 2 MW; JPY32 (USD0.3)/kWh for unused wood with a capacity of 2 MW or more; JPY24 (USD0.22) for ordinary wood with a capacity of less than 10 MW; JPY13 (USD0.12)/kWh for construction wood waste; JPY17 (USD0.16)/kWh for waste materials; and JPY39 (USD0.37)/kWh for biogas (*ERIA Study team, 2022*). Japan

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has also developed a comprehensive Green Growth Strategy to achieve carbon neutrality by 2050.

- **Korea**: The policy supporting renewable energy production has changed from "Subsidy" to "Mandatory". In particular, in 2019, the Korean Government introduced the hydrogen economy roadmap with the goal of having 6.2 million hydrogen-powered vehicles by 2040, including 40,000 hydrogen buses, 30,000 hydrogen trucks, and 1,200 hydrogen charging stations. In February 2021, the Hydrogen Economy Promotion and Hydrogen Safety Management Act was established as the legal framework for the hydrogen economy. In the short term, the Government has set targets of 11,000 electric buses, 193,000 electric trucks, 4,600 hydrogen buses, and 900 hydrogen trucks. Since 2021, the Government has provided subsidies of USD2.6/kg for hydrogen buses, USD3.1/kg for hydrogen trucks, and increased subsidies for electric taxis and trucks (*Climate Transparency, 2022*).
- **Chinese Taipei**: To diversify and expand the use of bioenergy, Chinese Taipei's central authorities [Ministry of Economic Affairs – MOEA, Council of Agriculture – COA (now known as Ministry of Agriculture, MOA), Environmental Protection Administration – EPA] have announced policies to promote bioenergy under the authorization of various laws. Among these, the Renewable Energy Development Act serves as the legal foundation for promoting biomass energy. The Government supports the development of the energy industry through economic incentives such as feed-in tariffs (FIT), installation support (or subsidies), and grid connection assistance (*Yu-Ru Lee and Wen-Tien, 2022*). In March 2020, the EPA issued additional regulations on the co-firing ratio and composition standards for energy produced from pollution sources. Furthermore, in November 2020, the MOEA released the "Energy Transition White Paper", and in July 2021, the "Key Indicators for Energy Transition". Among the 11 key indicators, the fourth focuses on promoting the development of renewable energy and biomass energy based on installed capacity. The MOEA aims to reach 913 MW of bioenergy (including biogas, biomass, and waste to electricity) by 2025, representing a 13.6% increase compared to the 716 MW of installed capacity in 2020. (*Esher Hsu, 2021*).

4.3 Americas

The economies have enacted policies and legislations for the energy sector to regulate the

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use of renewable energy sources, establish domestic strategies, and provide funding for energy transition. Some references are including:

- In **Canada**, blend mandate for gasoline and diesel are set by sub-jurisdictions and vary across the economy. The recent Clean Fuel Regulations will also require liquid fossil fuel (gasoline and diesel) suppliers to gradually reduce the carbon intensity of the fuels they produce and sell for use in Canada and compliance pathways include blending with biofuels. Currently most renewable liquid fuels are first-generation and derived from grains and oilseeds. However, many facilities are currently testing advanced biofuels (*Natural Resources Canada, 2024*). In addition, renewable energy from biomass is addressed in several initiatives of the Government, along with provincial electricity pricing incentives (information from the distributed Questionnaires).

Table 15. Plans of the Canadian Government

Plan	Result
2030 Emission Reduction Plan	- Outlines key measures needed, across each sector of the economy, for Canada to reach its 2030 target and achieve net zero emissions by 2050. - Proposal to explore domestic bioenergy strategy - Join the Global Methane Pledge
Powering Canada Forward	- Outlines the Government's vision for transforming Canada's electricity sector, decarbonizing Canada's grids and preparing the conditions for a net-zero emissions economy by 2050, keeping the electricity systems reliable, ensuring household energy costs are affordable, and lays the groundwork for Canada's first Clean Electricity Strategy.
Clean Fuel Regulations	- Regulations on the introduction of liquid fossil fuels to the market are key. - Regulation to establish a clean fuel credit market.
Clean Electricity Regulations	- Sends a clear regulatory signal that Canada is transitioning towards a decarbonized grid and a net zero emissions economy by 2050 to help drive investments in the sector
Investment Tax Credits	- Deliver on the USD93 billion suite of major economic investment tax credits (ITC), on a priority basis, to drive clean

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Plan	Result
	growth, secure the future of Canadian businesses in Canada, and create good jobs for generations to come - Clean Electricity and Clean Technology ITCs for technologies that generate electricity and/or heat from waste biomass.
Clean energy programs	- Canada has launched and financed several clean energy program, including the Smart Renewables and Electrification Pathways Program, Energy Innovation Program, Clean Fuels Fund, Forest Innovation Program, Investments in Forest Industry Transformation Program, Low Carbon Economy Fund, Clean Energy for Rural and Remote Communities - Government continues to support the transition from diesel to clean energy - Research, development and demonstration program for energy efficient buildings, greener neighborhoods

[Source: Distributed Questionnaires]

- **Chile**: Accelerating the energy transition through policy support, public-private partnership and innovative green technologies. Chile aims to convert 70% of its total energy consumption to renewable by 2030 and is committed to becoming a carbon-neutral economy by 2050. The Government has committed USD50 million in funding for six projects to boost the domestic green hydrogen industry. In 2023, the Chilean Development Office signed additional funding agreements with GNL Quintero, CAP, and Air Liquide for green hydrogen initiatives (*Holland Circular Hotspot, 2021; WEF, 2023*).
- **Peru**: the promotion of renewable energy is carried out through auctions. The Supervisory Agency for Energy and Mining Investment (OSINERGMIN) manages this process. The winning bidder will be given priority in supplying and selling electricity and will have access to the distribution and transmission networks. Long-term stable prices are determined through these auctions (*FIT LIMA,2020; WEF, 2023*)
- In the **U.S.**, over the past decade, federal incentives have been uniformly applied across all 50 states. These incentives are key to enhance the adoption of renewable energy systems. Many incentives include the Investment Tax Credit (ITC) for biomass and conventional CHP fuels, Production Tax Credit (PTC) for biomass systems, and accelerated depreciation. As the PTC expired at the end of 2020, the

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state-level incentives or the local Government incentives will play a crucial role in various regions (*USDA, 2020*).

4.4 Oceania

Governments have provided significant funding for renewable energy, some references are including:

- The **Australian** Federal Government has a long-term emission reduction strategy (*Australian Government, 2022*). This strategy was presented at the climate summit under the United Nations Framework Convention on Climate Change (UNFCCC), COP26 in Glasgow, 2021. The Government has committed USD3.5 billion through the Climate Solution Package to fulfill Australia's obligations under the Paris Agreement 2030, based on existing climate change mitigation policies and programs. The primary mechanism to support emission reduction in Australia is the Emission Reduction Fund (ERF). This fund incentivizes businesses to reduce GHG emission and store carbon. Participants can earn Australian Carbon Credit Units (ACCUs) for each ton of emission reduces or stored through a project. Businesses can sell ACCUs to generate revenue for the Government through auctions to other enterprises.

  Australia is reducing emissions by promoting renewable energy in a competitive manner, encouraging Government and corporate collaboration to develop action plans. Although Australia does not have a specific biofuel target, the Government aims to reduce $CO2$ emissions by 26-28% by 2030 compared to 2005. In October 2021, the federal Government announced a target to achieve a 100% reduction by 2050. This plan will be driven by technology rather than mandates. It will succeed if the cost of renewable energy is lower than that of fossil fuels. The plan is implemented through tools such as the Climate Solutions Fund, the Snowy Hydro 2.0, the Domestic Electric Vehicle Strategy, and ARENA's Bioenergy Roadmap (*Bert Annevelink & colleagues, 2022*).

- New Zealand: The Government requires suppliers to sell a minimum percentage of biofuel. Incentives for biofuel include exemptions from excise tax on bioethanol and R&D support for research organizations. The Government also provides funding through various types of grants such as Catalyst, Endeavour, Envirolink, Collaboration programs, Innovation partnerships, Domestic science challenges, PreSeed Accelerator Fund, Commercialization Partner Network, Strategic Science Investment Fund, RSI: Science and Talent Promotion, Advanced

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energy technology platforms, Callaghan Innovation R&D, and Future sustainable food and fiber contracts. Biomass energy from agricultural waste can participate in these support packages (*IEA Bioenergy, 2021*)

5. Problems and Challenges

The global economic output decreased by 3%, while APEC's decreased by 1.7% (measured by 2017 PPP in USD), resulting in APEC's annual energy supply decreasing by over 8,000 PJ (2.3%). All energy sources decreased except renewable energy, which increased by 1,8%. However, due to fossil fuel accounting for 86%, the increased in renewable energy has not had clear impact (*EGEDA, 2022*).

5.1 ASEAN region

If ASEAN member economies aim to achieve their goals, they must significantly reduce their consumption of fossil fuel and thoroughly research alternative renewable energy sources. The utilization of biomass as primary energy in ASEAN economies holds great potential due to abundant natural resources and a large agricultural sector. However, developing biomass resource requires a shift in bioenergy policies. The main challenges for the ASEAN economies include (*IRENA, 2020*):

- The economies have not clearly articulated specific goals and targets for biomass energy mostly due to low growth rate, lack of capital and insufficient foundation research.
- The greatest challenge in developing biomass energy is research, development, and technology transfer. The absence of appropriate technology undermines trust in the potential of biomass energy among Governments and rural communities.
- Basic technology transfer activities do not fully account for local conditions in operation, management, training for use, maintenance capabilities and supportive agreements.
- Most technologies are expensive and not suitable for farmers and local communities. For development to take place, technologies must be cost-effective yet efficient. Local agencies and research institutes should collaborate with international partners to develop technologies for farmers.
- Public and private sectors involvement remain uncertain due to the profitability and risks associated with using biomass energy. This type of energy has low density, large biomass volume requiring storage systems, high transportation cost, data reliability, while biomass technologies are underdeveloped, and there is a shortage of skilled local manpower.

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- Lack of dissemination of crucial and useful information about biomass locally. There is no dedicated system for information flow regarding research and development of biomass energy. This needs to be established and regularly updated
- Lack of comprehensive education and training program results in weak cooperation of locals to develop biomass energy. Mechanisms to encourage and stimulate the self-reliance of local communities are lacking.
- There is not enough support from the public sectors for biomass energy production due to various reasons. Some believe that bioenergy is a traditional commodity that is not financially and socially sustainable. Others argue that the initial cost of biomass energy production is relatively high, and the collection of agricultural wastes is inefficient.
- There have been organizations researching, producing, and utilizing biomass energy for commercial purposes, but they have not received adequate attention. As a result, the market developed slowly, with insufficient funding for research and development.
- Governments have not clearly defined policies and strategies for the development of biomass energy. There are only a few activities involving information exchange and sharing of experiences on bioenergy technologies among organizations.
- Lack of financial and human resource is one of the underlying causes of the above-mentioned problems.
- Seasonal variations on biomass feedstock supply and quality due to competing uses and prevailing practices. High upfront investments for energy projects and limited financial solutions for small-scale applications.
- Lack of policy incentives and regulatory environment that encourage sustainable practices. Limited awareness of the benefits of biomass energy and social acceptance.
- Survey results show some challenges in BAW production of some ASEAN economies.

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Table 16. Survey results on biomass energy challenges in ASEAN

No	Challenges	Economies		
		Malaysia	Thailand	Viet Nam
1	Seasonality in the supply of agricultural waste	x	x	
2	Using biomass energy is only suitable for small scale households		x	x
3	Removing agricultural waste from fields reduces the amount of organic fertilizer	x	x	x
4	Agricultural waste collection and transportation cost is high	x	x	x
5	Biomass energy competes with other renewable energy sources		x	x

[Source: Distributed Questionnaires]

Some challenges that Indonesia is facing currently in biomass production like lack of collaboration and integrated regulatory support across sectors, resulting in disharmonious implementation of policies related to biomass production and utilization; The development of biomass management technologies has not yet been fully adopted by farmers and/or industries; The absence of market certainty, leading to unsold products in the market *(Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, Ha Noi, 18 - 20 September 2024).*

5.2 East Asia and Far East

- The construction and operation cost of a bioenergy plant is more expensive than traditional forms of electricity generation.
- Transportation and processing costs of biomass materials are high due to their high moisture content and low energy density.
- The main barriers to maximizing the use of agricultural waste are financial constraints, operational factors, and environmental regulations. While the poorest households could benefit most from biogas digesters, the technology remains costly. Without significant Government and other support, it is challenging for these households to adopt it.
- The biomass supply from agricultural waste depends on seasonal agricultural

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production, which poses a potential challenge to the stability of biomass energy plants.

- Local air pollution control regulations must be followed because burning biomass fuel release various air pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), particulate matter, and volatile organic compounds (VOCs).

Table 17. Survey results on biomass energy challenges in East Asia

No	Challenges	Economies	
		Japan	Chinese Taipei
1	Seasonality in the supply of agricultural waste	N/A	x
2	Using biomass energy is only suitable for small scale households	N/A	
3	Removing agricultural waste from fields reduces the amount of organic fertilizer	N/A	
4	Agricultural waste collection and transportation cost is high	x	x
5	Biomass energy competes with other renewable energy sources	x	x

[Source: Distributed Questionnaires]

5.3 The Americas

- Expanding biomass production for non-food biofuel and bio product could impact food security. Although many biomass crops are not food crops, they may compete for agricultural land used for food crops or animal feed (*U.S. Department of Agriculture, 2024*).
- The increased demand for biomass could lead to higher commodity prices, thereby increasing global food prices. These impacts would affect low-income individuals the most, as they spend a larger portion of their income on food compared to higher-income individuals. This effect would be particularly pronounced on an international scale (*U.S. Department of Agriculture, 2024*).
- Increased demand for biomass requires higher crop yield, improved conversion efficiency, and more agricultural land, potentially leading to deforestation of land conversion. Advanced biofuel based on non-food feedstock may offer greater

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environmental benefits but is typically more expensive than first-generation biofuel.

- Most biofuel cannot be used in current equipment without being blended with conventional fuel (*Natural Resources Canada, 2024*). For instance, ethanol typically needs to be blended up to 10% by volume with gasoline.
- Storing biomass feedstock is easier compared to other renewable energy sources, but it typically has low density, higher moisture content, is dispersed, and varies seasonally. These characteristic lead to high costs for collection, transportation, and storage.
- Production facilities need to have sufficient biomass storage capacity. Testing sites must be able to accommodate various types of raw materials. Processing capacity is also limited because there are few large-scale facilities.
- Unclear or frequently changing policies create barriers to invest and long-term planning in the bioenergy production and biomass supply systems (*U.S. Department of Agriculture, 2024*).

Table 18. Survey results on biomass energy challenges in Canada

No	Challenges	Level of agreement		
		Disagree	Agree	Strongly agree
1	Seasonality in the supply of agricultural waste		x	
2	Using biomass energy is only suitable for small scale households	x		
3	Removing agricultural waste from fields reduces the amount of organic fertilizer		x	
4	Agricultural waste collection and transportation cost is high			x
5	Biomass energy competes with other renewable energy sources		x	

[Source: Distributed Questionnaires]

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5.4 Oceania

- There is not yet an adequate legal and institutional framework to support the sustainable production, use, distribution, supply and utilization of liquid biofuel.
- Biofuel is a key factor in reducing transport emissions but their cost cannot compete with oil.
- Economic viability is a major barrier to advanced biofuels. Initial policies supporting renewable energy technologies such as wind and solar power have resulted in technologies initially costing more than or equal to fossil fuel.
- Producing ethanol from corn typically reduces costs and carbon intensity, but it is actually petroleum that increases costs and carbon intensity, due to the recovery and refining involved in unconventional oil sources (*Australian Government, 2022*).

Table 19. Survey results on biomass energy challenges in Australia

No	Challenges	Level of agreement		
		Disagree	Agree	Strongly agree
1	Seasonality in the supply of agricultural waste		x	
2	Using biomass energy is only suitable for small scale households			
3	Removing agricultural waste from fields reduces the amount of organic fertilizer		x	
4	Agricultural waste collection and transportation cost is high		x	
5	Biomass energy competes with other renewable energy sources		x	

[Source: Distributed Questionnaires]

6. APEC cooperation mechanism to promote the development of biomass energy from agricultural wastes

APEC economic cooperation focuses on three priorities: open trade and investment opportunities; restoring connectivity across all aspects; and promoting balanced, sustainable, and inclusive growth. Particularly in 2022, APEC leaders endorsed the Bangkok Goals on Bio-Circular-Green (BCG) Economic Model. This event marked the first comprehensive environmental and climate goals set by APEC in the context of global

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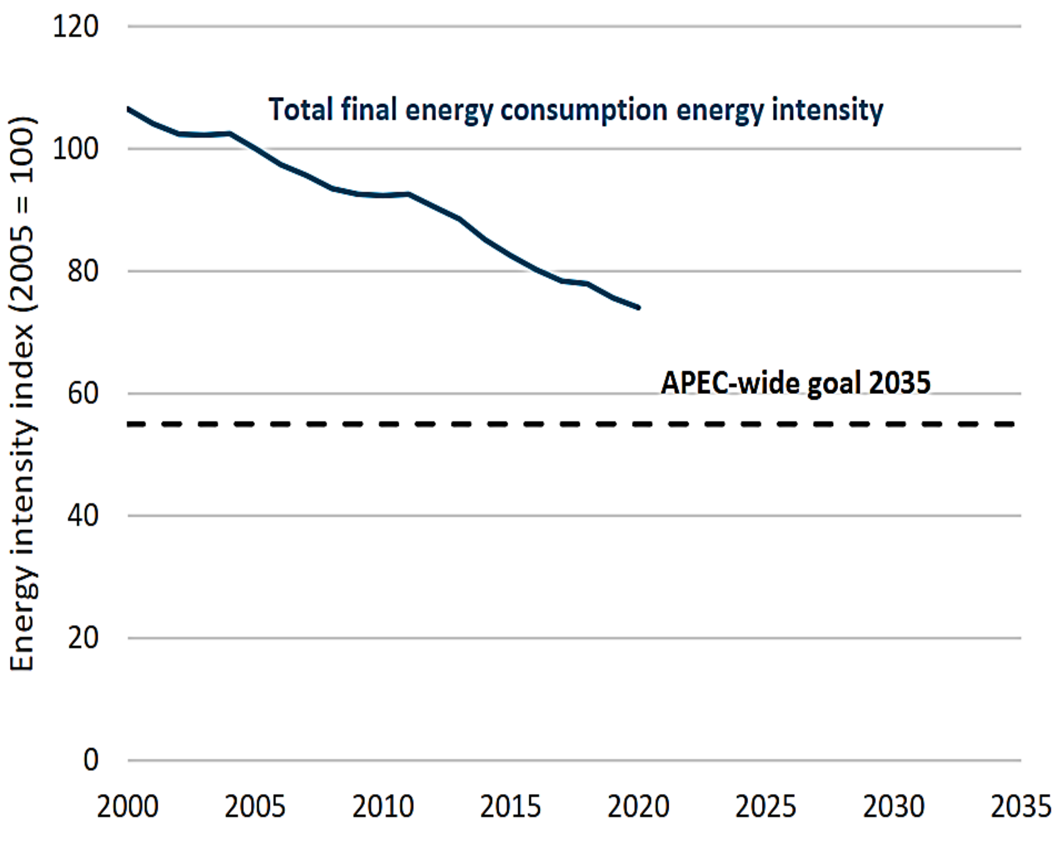
economic recovery.

According to forecasts from Science Direct, energy consumption in the APEC region is expected to continue increasing rapidly. To develop alternative energy sources and promote energy efficiency, proactive investment in traditional energy, nuclear energy, renewable energy, and other alternative sources is one of the key focuses of APEC's energy security strategy.

The APEC economies have agreed to meet and unify two energy goals: Improving energy intensity and doubling the share of modern renewable energy (*APEC, 2023*).

In 2011, APEC set a target to reduce energy intensity by 25%, and by 45% by 2035 (compared to 2005). As of 2020, the energy intensity in APEC had already improved by 26%, with an additional 19% improvement needed to meet the 2035 target. APEC is likely to achieve the first goal if it continues this trend (*APEC, 2023*).

Figure 10. APEC's energy consumption intensity index



[Source: EGEDA, 2022]

The second goal is to double the share of modern renewable energy in the APEC's energy mix by 2030 compared to 2010. While there are no specific targets set for individual economies, improvements made by each economy will contribute to achieving the overall goal.

Modern renewable energy does not include traditional biomass because the latter is often

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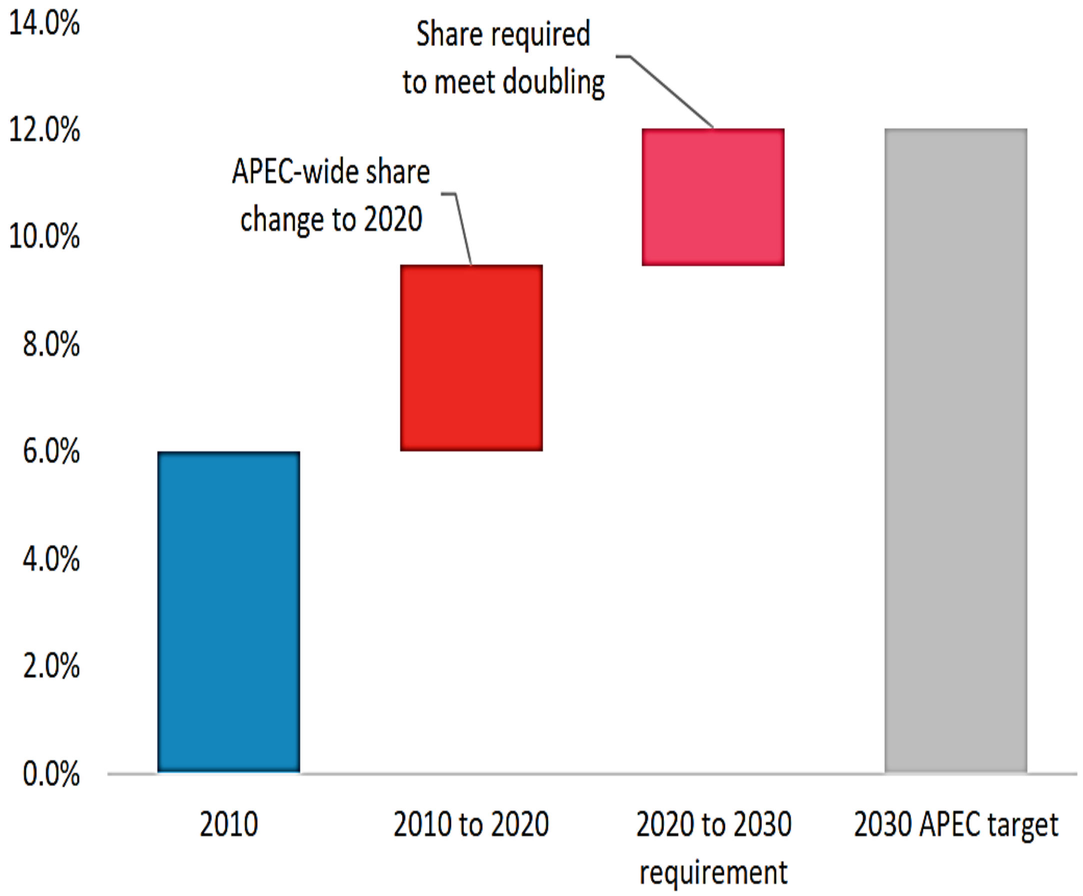
considered for use by emerging economies for household purposes and can have negative health impacts. To reduce traditional biomass consumption, APEC economies have policies to upgrade cooling stoves or switch to alternative fuel such as natural gas, liquefied petroleum gas (LPG), biogas, or electricity.

Figure 11. APEC's share of modern renewable energy



[Source: EGEDA, 2022]

Final consumption of modern renewable energy increased from 6.0% in 2010 to nearly 9.5% in 2020, marking a 57% improvement. This progress indicates that APEC is ahead of schedule to double the share of modern renewable energy by 2030. In 2020, renewable generation in APEC accounted for 24.7% of electricity output, an increase from 15.6% compaored to 2010.

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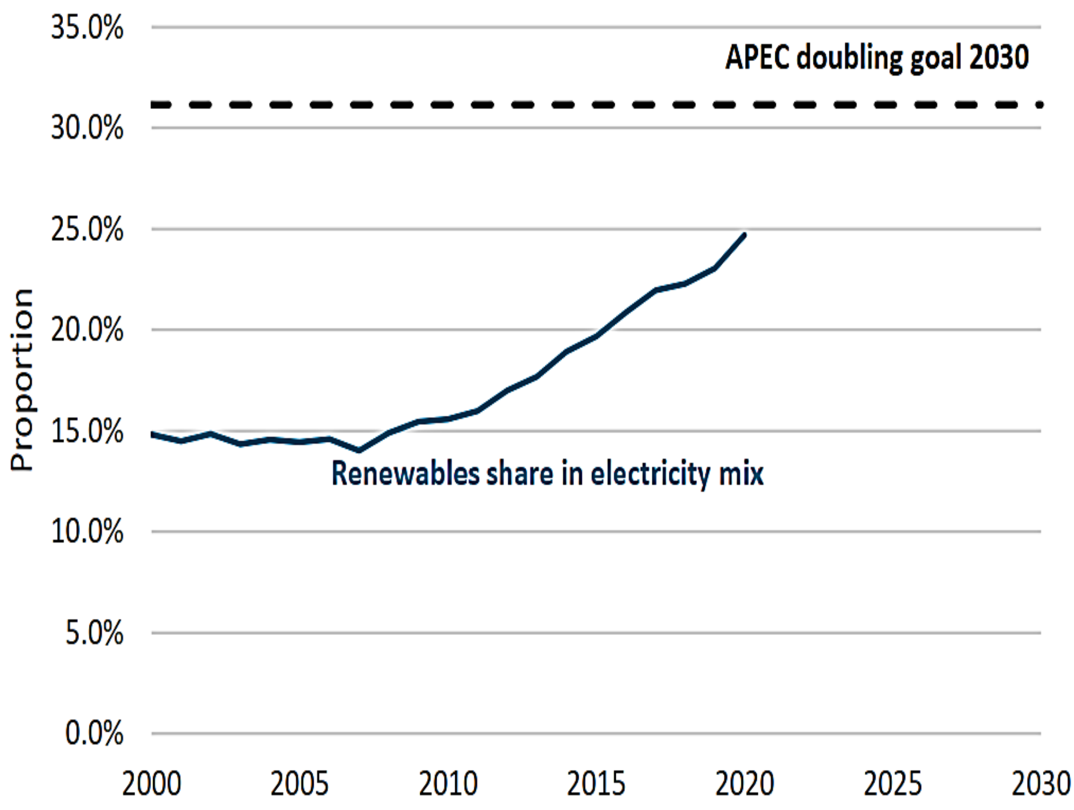
Figure 12. APEC's share of modern renewable energy in power source structure



[Source: EGEDA, 2022]

Modern renewable energy supply has increased from 4.8% in 2010 to 7.3% in 2020, an increase of nearly 53% halfway between 2010 and 2030.

In 2008, APEC collaborated on a biomass resource assessment and capacity involving 21 economies, sponsored by the United States Department of Energy (DOE). The survey provided biomass – related information related to diesel and ethanol production.

In 2009, APEC collaborated to assess borderland areas of member economies to evaluate biomass potential. They utilized the Food and Agriculture Organization's global agro-ecological zones system to determine biomass for 12 land types (*APEC, 2009*). The study estimated the total potential biomass annually from borderland areas to be approximately 1.3 billion metric tons, convertible into about 540 cubic kilometers of ethanol (equivalent to 260 million tons of gasoline). Compared to APEC's annual consumption to approximately 621 million tons of gasoline and 1.3 billion tons of imported crude oil, the ethanol potential from these areas could replace about 2/5 of gasoline and 1/5 of imported crude oil.

In 2021, APEC organized the event "Integrated Green Solutions in the APEC Region". The event included activities such as policy dialogues, workshops, online training programs based on projects, and on-site technical demonstrations (self-sponsored) with a practical meeting held in Chinese Taipei, and a virtual meeting on the Cisco WebEx

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platform from 18 – 21 December 2020 (*APEC, 2021*). The aim was to integrate renewable energy sources, enhance capabilities, recommend policies related to Integrated Green Solutions for public and private sectors of member economies, promote sustainable growth and address environmental issues.

In 2024, APEC cooperation is focusing on researching BAW, marking a new development in collaborative mechanisms within the context of climate change mitigation and sustainable agriculture development linked to renewable energy alternatives.

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III. BIOMASS ENERGY FROM WASTES OF SOME CROPS

1. Technologies for producing biomass energy from agricultural wastes

To produce biomass energy from agricultural wastes, economic, environmental, and social considerations must be taken into account, along with local conditions and the feasibility of technical solutions. Based on experiments, developed economies have multiple energy options derived from crop and animal wastes.

In general, there are two main technology groups for producing biomass energy as well as BAW: thermochemical and biochemical processes. Each group is further divided into several specific methods. The choice of which to use depends on the conditions and type of biomass available.

Table 20. Technologies for converting biomass into energy

Technologies	Procedures	Energy	Advantages	Disadvantages
Heat conversion	- Co-firing - Pyrolysis Torre faction	- Heat/steam - Oil and biochar - Biochar	- Biomass can be burned in power plants that currently use fossil fuel - Used for steam turbines to produce electricity - Can operate at optimal temperature range	- Specific temperature and control systems are required. - Can emit toxic gases
Chemical conversion	Direct conversion	Biodiesel	Advanced biofuel can be obtained	- Input materials for agriculture and animal feed decreased. - Large scale operations required.
Thermochemical conversion	- Carbonization pyrolysis - Hydrothermal	- Synthesis gas - Yet fuel - Diesel	- Cheap, easy to transport and to set up shop. - Can produce charcoal and	- Heat is required to produce synthesis gas. - High

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Technologies	Procedures	Energy	Advantages	Disadvantages
	conversion gasification - Liquid catalyst		related products in large quantities - Less processing required when sold on the market. - Quality product - Greater energy	investment cost - Many technical limitations
Biochemical conversion	- Anaerobic digestion - Fermentation	- Transportation fuel - Gasification energy	- Application of microbiological techniques. - Low GHG emission into the atmosphere - Utilizing the energy in the air - Reduce sludge volume - Medium competitive in economic	- Impact human and animal health

[Source: Ikram Mehrez & colleagues, 2022]

The Questionnaire Survey shows the technological status of some APEC economies.

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Table 21. Biomass energy production technology from agricultural wastes of some APEC economies

No	Technologies	Australia	Canada	Japan	Malaysia	Chinese Taipei	Thailand	Viet Nam
1	Burn to generate heat (furnaces, engines, machines) and electricity	x	x	N/A	x	x	x	x
2	Pyrolysis to produce oil, gas fuel and biochar		x	N/A	x	x	x	x
3	Gasification to create clean fuel (biodiesel, bio-oil)		x	N/A			x	
4	Fermentation to produce ethanol (bio-ethanol)	x	x	N/A			x	x
5	Anaerobic decomposition (biogas) to generate heat (cooking, furnace) and electricity	x	x	N/A		x	x	x

[Source: Distributed Questionnaires]

Thus, each economy has different choices, but combustion technology to generate heat (furnace, engines, machines) is the most chosen.

2. Biomass energy production from energy waste

2.1 Biomass energy production from rice straw

The primary waste from rice cultivation is straw. There are two main uses for straw: energy and non-energy (fertilizer, mushroom cultivation, soil cover). In theory, about 668 tons of straw can produce 187 gallons of bioethanol, but in reality, straw is often burned at the fields at an increasing rate, which is a significant waste.

In principle, there are five different energy conversion technologies applied to straw. To

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date, these technologies are still in use and undergoing further research and development. The operational principles of each technology are as follows:

- Combustions: Straw can be used alone or mixed with other biomass materials in direct combustion processes. In this technology, combustion furnaces are used in conjunction with steam turbines to produce electricity and heat. The energy content of straw is about 14 MJ/kg at 10% moisture content. In the thermal combustion process, air is injected into the combustion chamber to ensure that the biomass burns completely within the chamber.
- Fluidized Bed Technology: This is a method of direct combustion. Solid materials are burned in a fluidized state by injecting air into the combustion chamber to achieve complete combustion. An appropriate air-to-fuel is maintained because insufficient air supply can lead to numerous problems with the boiler's operation.

In the high-temperature combustion process of straw, potassium is converted and combines with other alkaline materials such as calcium. These compounds then react with silicate materials, leading to the formation of dense slag structures on the grate and furnace walls. Alkaline compounds also play a crucial role in forming slag and residue. This means that fuels with low alkaline content are easier to burn in the boiler. The by-products, including flying and bottom ash, also have economic value as they can be used in cement/or brick manufacturing industries, as well as in road construction and embankments

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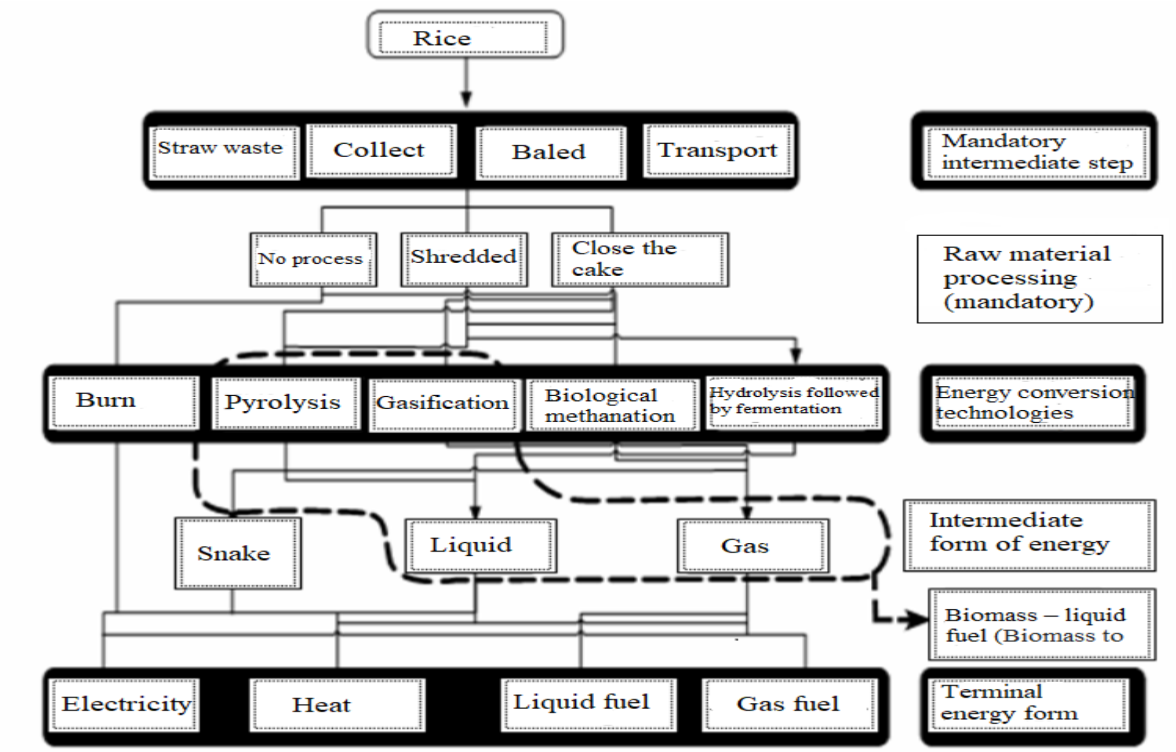
Figure 13. Energy conversion technology for straw



[Source: Domestic Agency for Science and Technology Information, 2010]

Specifically, for some cases:

(1) China

Each year, agriculture generates over 1.04 billion tons of waste, including 230 million tons of straw (*Liu & colleagues, 2021; Su & colleagues, 2021*). A significant amount of this waste is either discarded or burned, negatively impacting the environment, air quality, aquatic systems, and causing soil degradation (*Alengebawy & colleagues, 2022*). Utilizing straw to produce biogas is one of the most common methods in China. Biogas is used to generate heat, compressed gas, and electricity, while the wastes from anaerobic digestion is used to produce bio fertilizer (Ferrari & colleagues, 2021).

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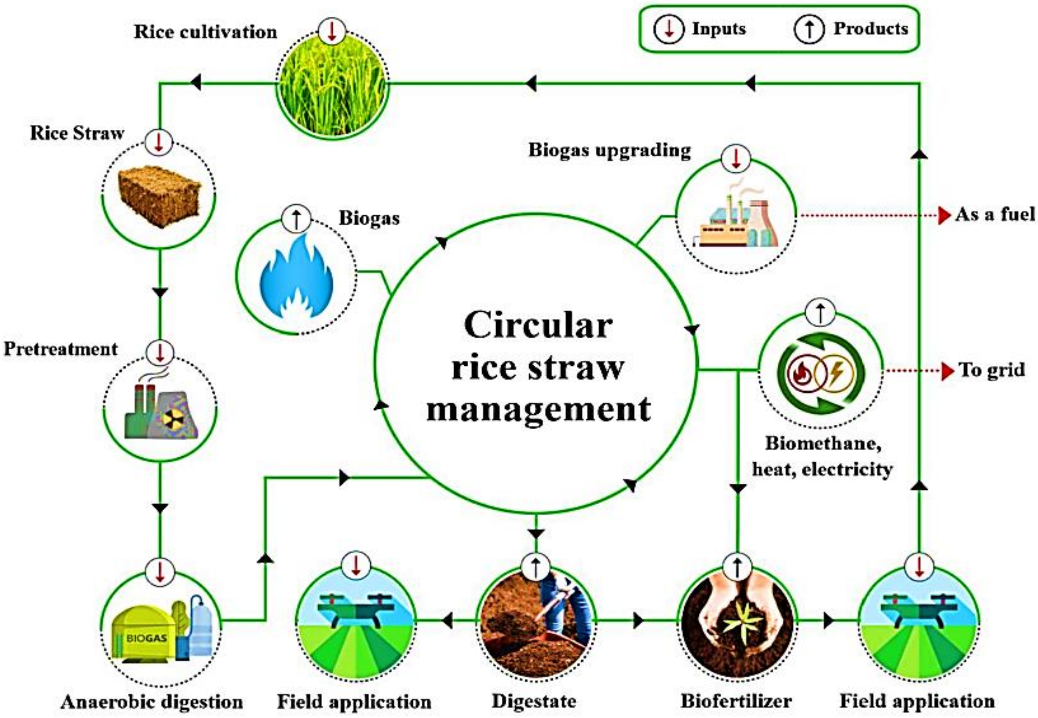
Figure 14. Straw management process to create a sustainable source for biomass energy



[Source: Ahmed Alengebawy, 2023]

Straw has a calorific value of more than 16 MJ/kg, so it has the potential to produce greater energy (*Alengebawy et al, 2023*).

Table 22. Analysis of some indicators of rice straw in China

Approximate analysis (% weight, dry matter)	**Value**	**Final analysis** (% weight, dry matter)	**Value**
Humidity	10.78	Hydro	6.03
Fixed carbon	13:85	Carbon	46.65
Ash	09/12	Oxygen	41.75
Lignin	18.83	Sulfur	0.23
Cellulose	38.44	Nitrogen	1.02
Hemicellulose	27.21	Lower heat value	15:35

Note: The characteristic value of straw varies from region to region due to climatic and soil conditions.

The physical and chemical properties of straw making it a strong competitor with other biomass sources in the production of biofuel. Straw has an average calorific value of 14-15 MJ/kg and a high volatile content of up to 60-70%, making it comparable to other types of biomasses (*Van Hung & Colleagues, 2020*).

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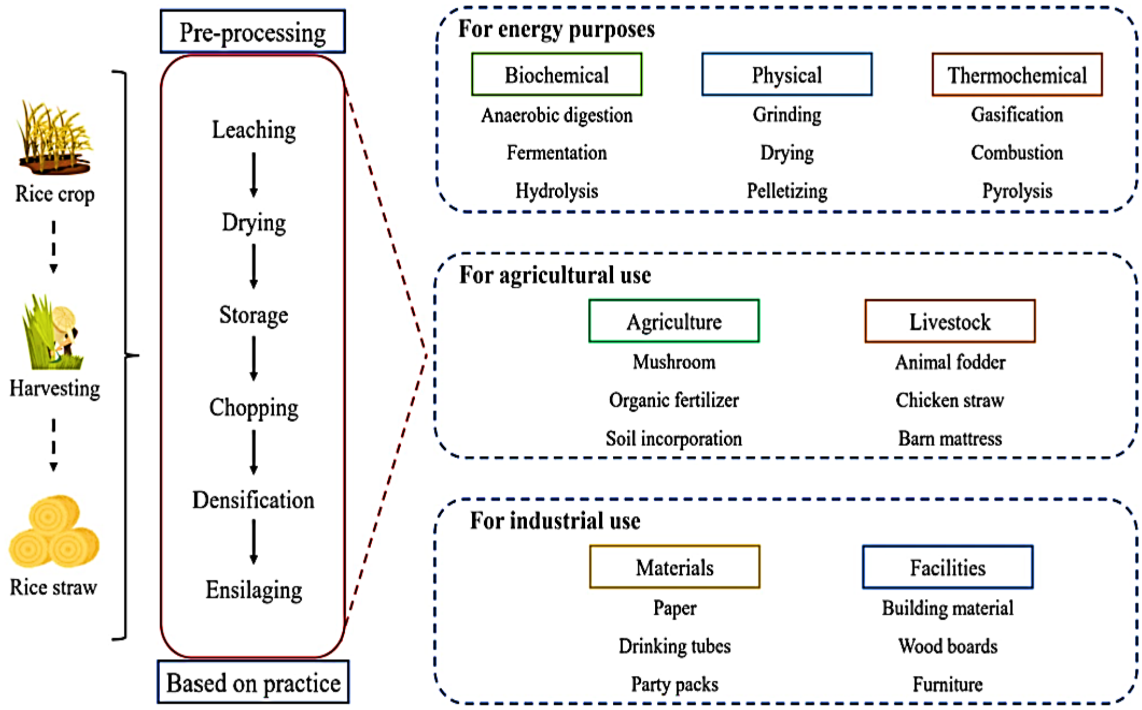
Figure 15. The most common methods of using straw



[Source: Ahmed Alengebawy, 2023]

Straw can be used for various purposes such as mushroom cultivation, fertilizer, animal feed, construction materials, and making paper. Effective management of straw is a concern in many economies like China and the Philippines (*Bhattacharyya & colleagues, 2021*). Biogas from straw can be a suitable alternative solution for managing straw to meet local energy needs, especially in rural areas (*Röder & colleagues, 2020*). Biogas is produced by the biological conversion of straw in an oxygen-free environment with the help of microorganisms (*Atelge & colleagues, 2020*). However, some pretreatment measures are necessary to enhance the digestibility of biomass and increase biogas productivity (*Ghimire & colleagues, 2021*).

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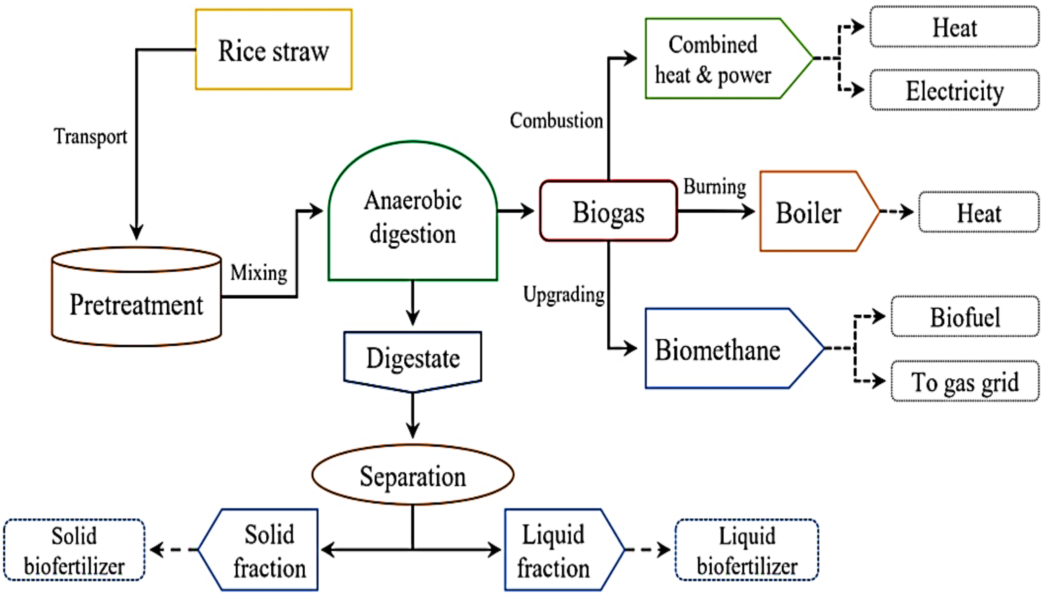
Figure 16. Biological recycling method from rice straw



One of the most common methods of utilizing straw in China is the production of biogas through anaerobic digestion for various purposes. The by-products from biogas production are then used as fertilizer (*Ferrari & colleagues, 2021*).

To maintain the stability of biogas production from straw and enhance biogas productivity, straw must be treated using various methods such as physical, chemical, biological, or a combination of these techniques (*Mothe & Polisett, 2021*).

Thus in theory, there are 5 technologies to produce energy from straw, but combustion technology has been commercialized and widely used, while the others are not significant.

(2) Malaysia

Rice Straw in Malaysia is now used as animal feed, straw paper handicraft and pulping materials 'which are used to produce bio-based packaging products, biodegradable erosion control products and biodegradable drinking straws. Straw management in the rice granary areas i.e. leaving the straw in the paddy field and ploughing it into the soil or removing the straw from the field using tractors; burn and leave it in the field as a carbon source. Straw. mulching helps reduce soil erosion, Suppress weed growth and conserve, Soil moisture. Future Rice Straw Used for mushroom cultivation, thermal insulation, using biochar for the purpose of carbon sequestration and nano cellulose production *(Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, Ha Noi, 18 - 20 September 2024. Presentation of Wan Mohd Rusydan Bin Wan Ibrahim et all)*

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(3) The United States

California has utilized hydrolysis technology followed by fermentation to process rice straw. Many companies are researching the biological conversion of straw (i.e., lignocellulose material) into ethanol. Colusa Biomass Energy Corporation (CBEC) is one of the companies currently advancing integrated bio refining to produce about 143,000 liters of ethanol per day. This process has been patented. It involves first hydrolyzing the straw with enzymes, acids, bases, and then fermenting it to produce ethanol. This technology can achieve 303-379 liters of ethanol per ton of straw. The by-products: ash and silica (silicon dioxide) also have commercial value. Each kilogram of straw contains 390 grams of cellulose, so theoretically, it can produce 220-283 milliliters of ethanol, but in reality, it only achieves 74% of this potential. Leading car manufacturer Honda has announced that the next generation of cars will run on fuel made from plant leaves and straw. Many research organizations around the world are currently focusing on this technology *(Nguyen Phuoc Tuyen, 2024)*.

(4) Viet Nam

The simplest technology used primarily is direct combustion of agricultural wastes to generate energy, which can be used directly in stoves or for burning in stoves or furnaces. Recently, research on pyrolysis technology to convert waste into charcoal of biofuel has begun. This requires investment in machinery, equipment, and finances, so it is still very limited.

In 2020, Viet Nam's rice cultivation area was approximately 7.3 million hectares, with a rice production of 42.7 million tons (*GSO, 2021*), generating about 8.5 million tons of rice husks and 42.7 million tons of straw (with 24.4 million tons from the Mekong Delta). Straw is used for various purposes, such as burning, burying, producing organic fertilizer, mushroom cultivation, growing crops (e.g., vegetables, flowers, and fruit trees), livestock feed, and industrial production (e.g., bioethanol, paper, building materials, and straw powder). Currently, in Viet Nam, straw is not used as a fuel source on an industrial scale. Most straw is either buried in fields to improve soil quality or burned openly in fields. Both of these practices lead to severe soil and air pollution.

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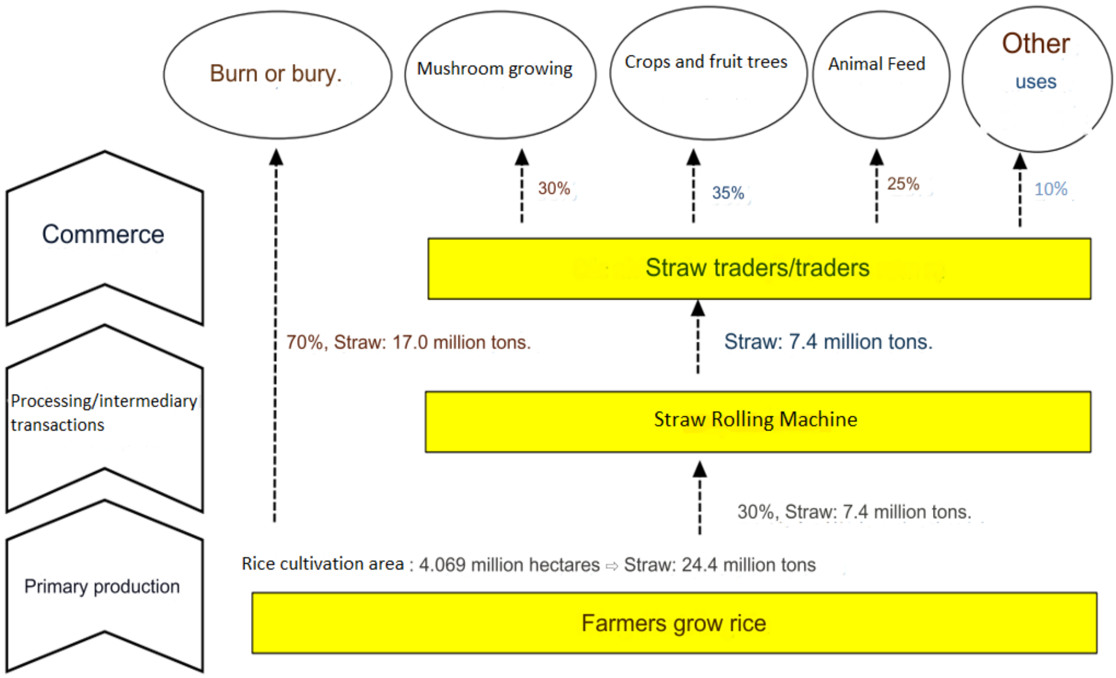
Figure 17. Straw Supply chain in Mekong Delta



[Source: Le Canh Dung et al., 2020]

The use of straw for small-scale or household bioenergy is more common during the dry season (the winter-spring crop) and less common during the rainy season (the summer-autumn and autumn-winter rice crops) due to challenges with rolling the straw and its quality. The ratio of straw usage for energy between the two seasons is about 70% in the dry season and 30% in the rainy season.

In recent years, straw is being collected using baling machines. It is anticipated that the demand for straw will increase in the future, especially during the rainy season, as it could be used more frequently for industrial purposes (e.g., ethanol, construction materials, and organic fertilizers). Recently, there have been some models converting straw into biochar. For example, the Agricultural Environment Institute has successfully developed a small-scale straw-to-biochar kiln, but the challenge remains in practical adoption. To date, there is no information on the implementation of this research outcome in practice.

2.2 Biomass energy production from rice husk

Rice production is widespread, year-round, milled both industrial and small-scale scales, therefore making rice husk a biomass fuel that is available in large quantities and easy to collect. Rice husk has been used as a fuel for over 100 years. By the end of the 20th century, the potential of rice husk was recognized worldwide, especially in developing economies.

Rice husk is a raw material for biomass production because it mainly consists of cellulose,

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hemicellulose, and lignin. These three compounds make lignocellulose biomass less biodegradable, as lignin encases the cellulose and hemicellulose.

Table 23. Characteristics of rice husk

Content	Ratio (%)
Cellulose	34.4
Hemicellulose	29.3
Lignin	19.2
Approximate analysis	
Fixed carbon	16.22
Volatiles	63.52
Ash	20.26
Final analysis	
Carbon	38.53
Hydrogen	4.75
Oxygen	35.47
Nitrogen	0.52
Sulfur	0.05
Heat value (MJ/kg)	15.84

[Source: Y.-F. Huang and S.-L. Lo, 2019]

Some specific cases:

(1) The Philippines

Rice is processed in rice mills, which produce rice (white rice), rice bran, and rice husk. The average proportions of these products are approximately 70% for white rice, 10% for rice bran, and 20% for rice husk. Typically, mills purchase wet rice, dry it, and then mill. About 30-50% of rice husk is used for combustion. The remaining 50-70% is either discarded of left to decompose naturally over time. In a few cases, husk is used as raw materials in cement production (*Ofero A. Caparino, Ph.D, 2018*)

(2) Thailand

Thailand is a major global producer of rice, sugarcane, and cassava. The Thai Government estimates that 40 million tons of unused biomass are generated annually. In 2021, Thai biomass power plants produced approximately 4.7 GW of electricity, while solar power contributes about 3 GW.

The gasification technology is applied to process rice husk to produce heat. Rice husk has been successfully used in gasifiers with liquefied beds for IC engines. However, there are

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still issues with the tar content in clean syngas.

Kamphaeng Phet Province, a leading cereal-producing region in Thailand, utilizes a large amount of rice husk as fuel for local rice mills. Japanese food company Ajinomoto, seeing the potential for stable rice husk supply, decided to install a biomass cogeneration system at their umami seasoning production plant in Kamphaeng Phet. Since 2016, Ajinomoto's Ayutthaya plant in Ayutthaya province has operated a rice husk cogeneration system. This is the second plant in Thailand to operate such a system [*Profile of Ajinomoto Co., (Thailand) Ltd.'s Kamphaeng Phet plan*].

(3) Viet Nam

Viet Nam's main biomass sources include rice husk, straw, bagasse, cassava, waste, and wood, primarily used for domestic cooking and furnaces burning (with wood and charcoal accounting for over 50%, rice husk 21%, and bagasse 9%). In 2020, the total installed capacity economy-wide was nearly 75,000 MW, but biomass electricity accounted for less than 1%, with grid-connected commercial electricity just over 0.1%. This is very small compared to the biomass electricity potential (*Workshop on experience in developing biomass electricity in Viet Nam, November, 25, 2020*)

Viet Nam is the fifth-largest rice producer in the world, with production concentrated in the red River Delta and the Mekong Delta (*Le Canh Dung & colleague, 2021*). The annual rice yield is estimated to be between 43 - 45 million tons. In 2020, with a rice cultivation area of approximately 7.3 million hectares, the production reached 42.7 million tons, generating around 8.5 million tons of rice husk and 42.7 million tons of straw. Rice husk is used as a raw material, with 80% of it being utilized in industry as pellets, briquettes … (*Nguyen Minh Nhut & colleagues, 2022*)

The Mekong Delta has great potential in producing biofuel from rice husk because it can reach nearly 5 million tons of rice husk annually.

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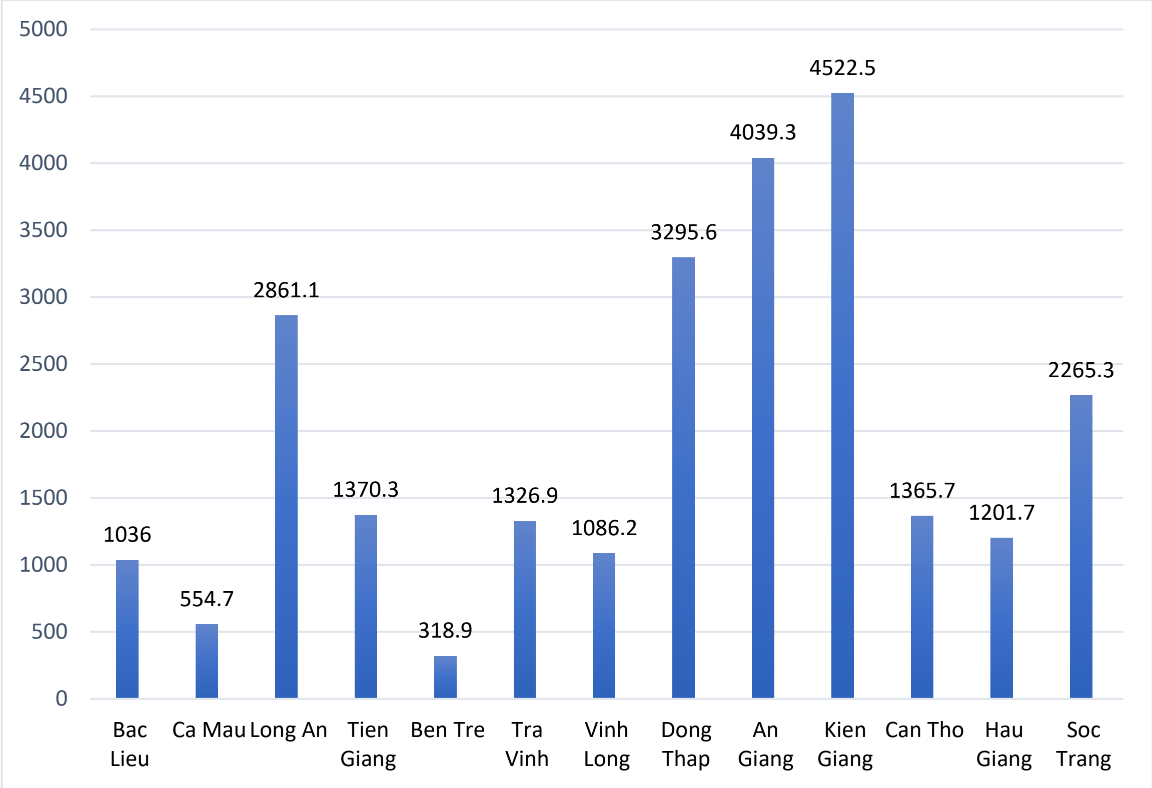
Figure 18. Distribution of rice husk in the Mekong Delta (ton/year)



In the Mekong Delta, rice husk is notably used as fuel for drying rice and fish meal dryers (accounting for about 49% of the total husk consumption), followed by industrial boilers (20%), producing compressed husk briquettes (16%), firing kilns (6%), and as compost for crops (9%) (Dung et al., 2020). After milling, husk is primarily transported by boat to drying facilities, industrial boiler or other locations where they are used for various purposes. The technology for producing biomass energy from husk in Viet Nam, particularly in the Mekong Delta, has significantly advanced from direct combustion to producing husk briquettes and biochar. For instance, Thien Phat Company in Can Tho city illustrates this progress. Initially, the company used husk to fuel their kilns for drying rice, with the remaining husk sold externally. Later, they adopted a Vietnamese technology to press husk into large briquettes, further improving the process to produce more convenient and cleaner briquettes. Currently, they are experimenting with Japanese small-scale machines to produce biochar for export to Japan and Korea (*Pham Thi My Dung and Vu Thi Thanh Nhu, field survey at Thien Phat Company on July 11,2024*)

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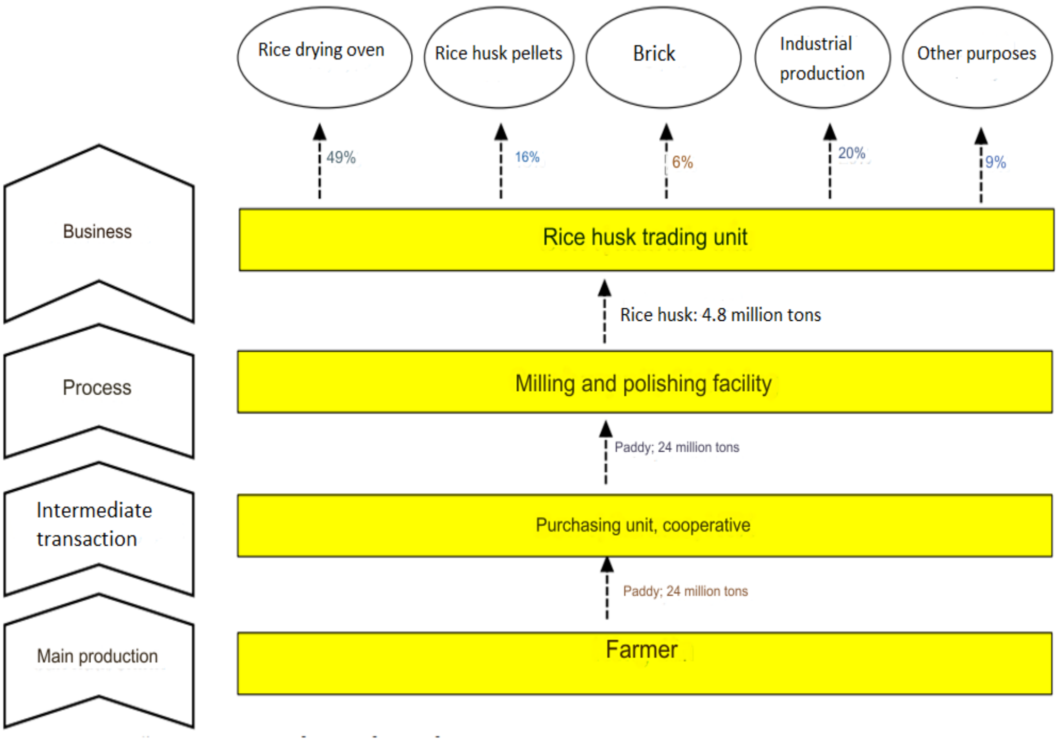
Figure 19. Husk supply chain in Mekong Del



[Source: Le Canh Dung et al., 2020]

An Giang province is a pioneer in rice husk power generation. Dong Thanh Investment and Import - Export Company, located in the An Thanh industrial cluster, Hoa An commune, Cho Moi district, has built a thermal power plant using fluidized bed boiler and steam turbine technology. The plant has a capacity of 10 MW and can process 120,000 tons of rice husk per year. Additionally, the province is supporting the construction of another rice husk thermal power plant in Thoai Son district. The Environmental Investment and Regeneration 1 Company has built a 10 MW rice husk power plant in Thai Giang commune, Thoai Son district, to supply electricity to local rice milling factories.

The development plant for biomass power in the Mekong Delta up to 2020, with a vision to 2030, focuses on using rice husk for electricity production. By 2020, the target was to install 140 MW of rice husk electricity, and 150 MW during the 2021-2030 period.

In the plan to build 20 rice husk thermal power plants economy-wide, the Mekong Delta is funded a total install capacity of 20 MW across five provinces: An Giang, Kien Giang, Hau Giang, Dong Thap, and Can Tho.

In other regions, there are several small-scale rice husk briquette production models operated by cooperatives or farmer households. They collect rice husk from milling

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facilities, invest in machinery, and produce rice husk briquettes for sale.

3. Biomass energy production from corn waste

The primary wastes are corn stalks, leaves, and cobs. In particular, corn cobs are used for producing heat, electricity, fuel, and various other chemicals. The technologies for generating energy from corn waste is similar to that used for rice. The main technologies are direct combustion, with a few other emerging technologies starting to show promise. Specifically:

(1) Indonesia

Various agro-wastes are produced from corn processing, such as corn husks and cobs, which have diverse uses through value addition. Various products with nutritional and industrial value, as well as other potential bio-product diversifications from corn processing, are listed below (*Workshop on Biomass Energy Promotion for Inclusive and Sustainable Agriculture Development in APEC Region, Ha Noi, 18 - 20 September 2024. Presentation of Sri Suhesti & Erlita Adriani).*

Figure 20. Utilization of Maize Waste Biomass

(2) United States

Corn is the staple grain in the United States, occupying approximately 30% of the total agricultural land (*USDA, 2019*). Corn is used primarily for animal feed, food, seeds, and various industrial purposes, including fuel.

The conversion of corn into energy is still mainly by traditional direct combustion. Some new technologies have been implemented, such as:

- Research on producing activated carbon from corn waste by the University of California:

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Most of corn waste is incinerated and rarely utilized for commercial or industrial purposes. Engineers from the University of California, Riverside (UC Riverside), led by assistant professor Kandis Leslie Abdul-Aziz, have discovered a way to utilize this resource to produce activated carbon for water pollution treatment with a filtration efficiency of 98%. Instead of using the traditional combustion method, the research employs hot compressed water, similar to hydrothermal carbonization. This method produces activated carbon with a higher surface area and larger pores. These features allow the carbon to absorb vanillin (a common water pollutant) up to 98%. The research findings were published in the latest issue of the ACS Omega, titled "Physicochemical properties of biochar and activated carbon from biomass residue: Effect of process conditions on absorption properties" (*Vnexpress.net, 2021; Mark Bustos, 2021*).

- Ethanol production from corn waste:

In the United States, the production of ethanol from corn biomass and corn waste is highly developed using "combined heat and power" technology. Combined heat and power (CHP) is an innovation that uses a single energy input to produce two or more energy output (in this case, thermal and electricity). Ethanol production facilities can improve their energy efficiency by implementing a CHP system that uses corn waste (*Susanne Retka Schill, 2021*).

CHP systems for ethanol production typically use natural gas or agricultural waste. In the process of burning corn stalks, steam is generated in a biomass boiler, and electricity is produced using a back-pressure turbine. These technologies are still being applied and continue to be researched and developed.

Most bioethanol production in the United States is from corn. In 2018, the US produced over 16 billion gallons of corn ethanol while consuming slightly less than that amount (*USDA, 2019*). The United States' corn ethanol production has steadily increased from 1.6 billion gallons in 2020 to 16 billion gallons in 2018. This level of production is expected to remain stable through 2030 (*IEA 2018 a, b, c; 2019 a, b, c, d, e, f; 2020 a, b, c*). The corn ethanol industry has a significant economic impact on rural communities in the US. According to the Renewable Fuels Association (RFA), in 2019, there were 68,684 direct jobs, 280,327 indirect and induced jobs, and USD23.3 billion in household income from ethanol-related industries (*RFA, 2020*). Ethanol is often blended with petroleum products, so corn ethanol has helped domestic and local energy security by reducing petroleum imports (*DOE, 2019*). RFA estimates that nearly 600 million barrels of imported oil would have been needed in 2018 if 16 billion gallons of ethanol has not been produced (*RFA, 2019*). If the blending ration exceeds 10%, the United States could further

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reduce their petroleum imports.

(3) Viet Nam

Each year, Viet Nam produces around 8-10 million tons of corn cobs, but only a small portion is processed into bio fertilizer, mushroom growing substrates, and manual fuel. Meanwhile, most corn drying facilities still use direct combustion of coal or corn cobs, leading to environmental pollution, GHG emission, and contamination of the dried products.

To address the limitations, the Research Institute of Agricultural Machinery (Ministry of Industry and Trade) received funding from the project "Development of Viet Nam's environmental industry by 2015, vision 2025" to research and test a corn cob drying oven. The Institute developed and applied a continuous corn cob gasification method on an industrial scale. Trials in Son La demonstrated that the drying system provided clean energy, was economically effective, improved product quality, and reduced environmental pollution. In 2015, the Institute was granted patent number 1-0012653-000 for "Downward continuous gasification equipment using corn cob fuel" and an industrial design patent for "Downward gasification equipment".

The cost of fuel is about one-third compared to direct combustion using coal. The equipment cost is approximately 40-45% of the price of similar equipment imported from China; India; Thailand; and the Philippines. Currently, the corn cob gasification system has been transferred to a processing company in Son La. Experience with the equipment shows that: The flame intensity when burning syngas is high and stable, with a flame height of approximately 1.5 to 2,0 meters; the temperature at the center of the flame ranges from 650°C to 760°C; the fuel supply rate is between 120 and 150 kg/h; the air supply flow rate is 235 to 310 m^3/h, the ash content after gasification is about 4% to 6%. The development of this equipment opens up new opportunities for utilizing agricultural waste, including corn cobs (*Tietkiemnangluong.com.vn, 2016*).

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IV. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

- The APEC region has a significant share of the world's agriculture and BAW. APEC produces a wide range of crops, with the most common being rice, wheat, corn, sugarcane, palm oil, and potatoes. These crops account for 43.5% of global production, and their waste constitutes 64.6% of the world's agricultural waste. The density of crop waste in the APEC region is higher than the global average because APEC covers about 52% of the world's total land area.
- Agricultural waste is used for two main purposes: biomass energy and non-energy (such as organic fertilized, mushroom cultivation, and soil cover). Utilizing agricultural waste for bioenergy is not as common as it using it for non-energy purposes.
- Although there is no official data on the general and specific usage rates of agricultural waste for biomass energy, various sources indicate that the rate of utilizing waste is very low compared to its potential. This results in wasted resources, environmental pollution, climate change, and reduced added value in agriculture. The proportion of agricultural waste used for energy is significantly lower than for non-energy uses.
- The most common method to treat crop waste is on-field processing such as burying or burning, which leads to various negative impacts on the ecosystem, the environment, and soil conservation. The most widely used technology for producing biomass energy from agricultural waste in APEC economies is direct combustion in household stoves, boilers, and drying ovens to generate heat.
- The economies have made considerable efforts and progress in developing new technologies for producing biomass energy from agricultural waste, but these technologies are not yet widespread, mostly remaining in research, experimentation, and transfer phases. While some developed economies have succeeded in commercializing this type of energy, it is still characterized by the specific approaches of individual companies and organizations.
- Despite the potential for developing biomass energy from agricultural waste, economies face numerous obstacles and challenges, including technological issues, resource limitations, perceptions, awareness, community involvement, and Government support. Without strong solutions, achieving significant results will be difficult.
- Each economy can process agricultural waste for biomass energy in unique ways

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depending their geography, natural resources, economic and political conditions, domestic and local energy policies.

- Some APEC economies with extensive capabilities have completed biomass resource assessments. However, these assessments are usually estimation and lack specificity. Additionally, economies do not have a clear understanding of the scope and methods used for assessing resources in other economies.
- APEC members are committed to utilizing agricultural waste for biomass energy. This commitment is evident through laws, policies, regulations, goals, and strategies at various stages. Even industrial and urban economies are considering renewable energy for energy security and supporting broader policies. This represents a significant opportunity for the APEC region to advance cooperation in this field.
- Each economy has policies on renewable energy and biomass energy at different levels, but very few have implemented direct and strong policies specifically for biomass energy from agricultural waste.
- Due to the unique characteristics of each agricultural sector, APEC members have different capabilities and experiences in producing biomass energy from agricultural waste, resulting in diverse sources of bioenergy. Some economies focus on rice straw, others on corn, some on industrial crops, and some on forestry products. Technologies for producing biomass energy from crop waste are much more varied compared to those from livestock waste. Conversely, biomass energy production from livestock waste is more common, as biogas systems from electricity and heat are widespread. Producing biomass energy from livestock waste is relatively easier, while from crop waste is more challenging due to the need for larger scale and more investment. Therefore, the choice to focus on crop waste in this research is justified.

2. Recommendations to promote APEC cooperation for sustainable development of biomass energy from agricultural wastes

First, building APEC cooperation mechanisms and principles to develop biomass energy from agricultural wastes.

To ensure a successful cooperative relationship, organizational management must be a topic of priority. Some activities for managing cooperation within a diverse APEC community could include:

- Organize a Task Force representing APEC to review past cooperative

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relationships regarding biomass energy from agricultural wastes. This review should assess results and limitations, identify causes, and make timely adjustments and improvements to enhance the cooperation.

- Develop regulations and principles for cooperation in biomass energy from agricultural wastes. These guidelines will serve as a basis for economies to decide whether to engage in cooperation, to join efforts across the entire APEC region, participate in smaller regional collaborations within APEC, or to cooperate bilaterally with individual economies.
- Regularly assess the outcomes of cooperation in the development of biomass energy from agricultural wastes, as well as the results of implementing the agreed - upon mechanisms and principles, in order to make appropriate adjustments.
- Add a sub-section on biomass energy from agricultural waste to the energy section of the APEC website to generate interest among members.
- To enhance development in food production, land, biomass energy in general, and biomass energy from agricultural waste specifically, APEC should propose training programs and guidelines for calculating land use conditions for food security, energy security, environmental protection and climate change mitigation.
- Explore ways to develop carbon markets and emissions trading schemes, as many APEC economies are working towards achieving their climate targets. Biochar's role as a carbon sink (sequestering carbon in soils) means it could be recognized under carbon trading or carbon offset schemes within APEC economies. APEC could support the integration of biochar projects into these markets, allowing farmers, energy producers, and other stakeholders to benefit financially from biochar's carbon sequestration abilities.
- Strengthening cross-region cooperation for sustainable biomass energy development through regional frameworks:

  (i) Joining with ASEAN Bioenergy Cooperation Framework which include programs on harmonizing policies and developing joint projects.

  (ii) Harnessing the benefit of aligning with existing ASEAN strategies such as the ASEAN Strategy for Carbon Neutrality and Guidelines for the Reduction of Crop Burning in ASEAN to achieve post 2025 sustainable, regenerative and circular agriculture in the region.

- Leveraging institutional support from development partners such as international organizations and private sectors for technical, funding and knowledge and tapping into climate finance mechanisms to support biomass energy projects that

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contribute to climate mitigation.

Second, APEC economies should collaborate to build a database on biomass energy from agricultural wastes to standardize perspectives, evaluations and promote bio-energy development.

To date, not only does the APEC region as a whole lack comprehensive information on biomass energy from agricultural wastes, but even individual economies do not have complete data on this subject. While economies are interested in renewable energy, including biomass energy from biomass plants, BAW receives very little attention. Therefore, it is challenging to find information to propose methods and focused areas for developing this type of energy. Some actions in building a regional database include:

- APEC should develop a policy to collaboratively build a shared database on biomass energy from agricultural waste, including all sectors such as crop cultivation, livestock, forestry, and fishery across all different stages.
- Regular surveys should be conducted to build a database from simple to complex. Initially, the database should focus on the main sources of agricultural waste in each economy, and then gradually expand over time as resources allow.
- There should be projects for investigation, surveys, and assessments of biomass energy from agricultural waste in a comparative research format to gather relatively consistent information that can be integrated into a common database.
- APEC members should propose to central statistical agencies or agricultural statistics bodies to include indicators for agricultural waste and the proportion of agricultural waste for biomass energy. It is best to conduct such statistical surveys annually, periodically, or as part of specialized agricultural investigations.
- Each APEC economy should analyze and evaluate in detail the quantity and quality of agricultural waste available for biomass energy production in key supply areas. It is necessary to assess the readiness in terms of logistics, technology, finance, and human resources for biomass exploitation to enable effective interventions.
- A comprehensive biomass resource map is required to serve as valuable tools for decision-making and the further development and adoption of bioenergy technologies.
- A standardized method for calculating agricultural biomass should be established so that the data collected from each economy can be comparable and easily accessible. All survey data should be compiled and stored in a uniformly formatted database. This approach will help APEC gain a clearer understanding

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of both common and specific conditions. Consequently, it will improve transparency regarding the production and supply of biomass energy within the region.

Third, enhance the sharing of information and practical results regarding biomass energy from agricultural waste within the APEC community.

Traditionally, APEC has had many activities for sharing information and research results. Which has greatly contributed to the collective development of the region. However, in the area of biomass energy from agricultural waste, such activities are still very limited. Information sharing on the matter should be enhance through activities such as:

- Regularly organize dialogues, conferences, workshops, and visits to exchange information, experiences, policies, and address collaborative issues.
- Develop communication products such as videos, brochures, articles, and short films to widely disseminate information to the general public, especially rural and agricultural communities.
- Organize innovative contests in the production and use of biomass energy from agricultural waste to attract public interest, especially among youngsters.
- Engage in dialogue with policy-making agencies and educational institutions to incorporate the topic of bioenergy from agricultural waste into experiential education programs for high school students, helping them to start career orientation early.

Fourth, strengthen scientific research and technology transfer cooperation on biomass energy from agricultural wastes.

- Identify new and urgent topics on theory and practice in the development of programs, projects, and policies related to biomass energy from agricultural waste. This involves cooperating on research, providing policy advice, and supporting Government initiatives through a comparative research approach. This can be achieved through research projects, specific studies, and research teams from scientific institutions and practical expert groups.
- APEC should connect scientific organizations from each economy involved in research related to biomass energy from agricultural waste. Leverage human resources from educational and research institutions, businesses, and interested organizations. Utilize financial resources from science ministries, science departments, domestic science funds, corporate science funds, protocol programs, matching funds, and public-private partnerships.

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- Some research results and technology transfers have been published and utilized, bringing benefits (as evidenced by this review report). However, in practice, many valuable results remain unpunished. Therefore, APEC should collaborate to gather both published and unpublished works, thereby creating a more comprehensive information resource
- To elevate APEC more rapidly, developed economies or sponsors should provide increased support to developing members in scientific research and technology transfer. Essential support includes training, guidance, experimentation, and technology transfer to enhance capabilities in developing economies. Financial support, if possible, should be direct or linked with various sources. The financial support mechanism should be based on principles or voluntarism, mutual benefit, and self-reliance, with support primarily serving as seed funding.
- Research and transfer technologies to production and residential areas. Focus on small scale applications, particularly for rural communities, small and medium enterprises, and craft villages.

Fifth, using agricultural waste for biomass energy needs to be balanced with other purposes.

Agricultural waste is increasing, and its uses are becoming more diverse, which can lead to competition among them. Therefore, it is important to consider several points:

- A strategy is needed to manage the competition between using agricultural waste for energy and non-energy purposes. While both approaches serve circular agriculture, they can be mutually competitive. Using waste for energy purposes may reduce the availability of waste for non-energy uses. The management of this competition should be based on the characteristics of the waste and the stages of its decomposition. Waste from high fiber (cellulose) crops, long-term crops, and forestry products is more suitable for energy applications, whereas waste with high organic content, such as fruit peels, leaves, stems, should be for non-energy uses. Each crop type requires guidance on which waste should focus on which purpose. For example, rice husk should be prioritized for energy uses, while straw should be for non-energy. Corn cobs are more suitable for energy purposes than corn stalks. As for sugarcane, bagasse is suitable for energy and the roots are better for non-energy application.
- In developed economies, most agricultural waste is generated on a large scale and associated with processing industries, making it primarily used for energy in the form of biochar or electricity. In developing member economies, agriculture is

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small scale, dispersed, and the income of rural population is low. Therefore, agricultural waste is mainly used for household cooking and heating, as well as non-energy purposes like livestock feed, fertilizer, and soil covering. To choose the energy direction, it is necessary to have small collection equipment, identify suitable types of waste, and consider households that do not require its use.

- Selecting a reasonable agricultural structure can adjust the competition between the two uses of agricultural waste. The energy direction should focus on using the same type of waste during machine operation, while the non-energy direction should combine various types of waste from crop cultivation, livestock, and organic household waste.
- Crop waste is limited by seasonality, so it is necessary to have flexible methods to stabilize biomass energy production capacity. Addressing seasonality can be achieved by arranging crop planting.

Sixth, a comprehensive perspective is needed when producing biomass energy from agricultural wastes.

Biomass energy from agricultural waste involves various aspects such as agriculture, the environment, energy, and the market. Therefore, addressing it requires coordination among multiple parties. Specifically:

- APEC economies need to increase agricultural productivity and sustainable food production, thereby increasing the supply of agricultural waste. Solutions to enhance agricultural productivity are also to increase agricultural waste through promoting the development of agricultural biotechnology; facilitating agricultural extension services and technology transfer; accelerating the transformation and upgrading of the agricultural sector; and promoting sustainable agricultural development.
- Producing biomass energy from agricultural waste needs to be considered in terms of both benefits and risks, advantages and disadvantages, with a balanced understanding of the trade-offs to ensure sustainability and increase consumer trust. Economies should avoid producing biomass energy from agricultural waste in ways that harm the environment, as thermochemical and gasification technologies can impact the environment through smoke, dust, and gas emission. It is crucial to monitor, certify, and assess the environmental impact when producing biomass energy from agricultural wastes.
- To commercialize the biomass energy market from agricultural waste, it is essential to research, develop, and utilize technologies to overcome technical

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barriers and increase competitiveness with other energy sources. Additionally, it is important to integrate the biomass energy system from agricultural waste into a sustainable management system and to monitor costs from raw materials.

- Enhance coordination among APEC economies to optimize the use and distribution of biomass energy from agricultural waste, taking advantage of the proximity of neighboring economies. Collaborate to establish conditions for transfer, transportation, and develop regional standards for the quality of agricultural waste.
- The APEC region has a diverse range of biomass resources, with economies like China; Indonesia; Malaysia; and the United States having significant potential for biofuel production from agricultural wastes. However, there are regional variations in resource availability, technologies and utilization, which need to be addressed through integrated biomass management strategies and efficient conversion technologies.
- Compiling biomass energy technologies for transferring and adoptation (regional scale). Mainstreaming biomass energy into NDC implementation, develop carbon credit for renewable energy technology; Increase investment for biomass energy project among APEC; and Enhance technology level for member economic through R & D cooperation.

Seventh, strong Government support is needed through individual economy policies and APEC's overall policies.

- The development of biomass energy is linked to many issues, making macroeconomic policies crucial. APEC should have a common policy, but the most important policies are those specific to each economy. Reviews indicate that most economies have related policies, though their levels and effectiveness vary, and no APEC economy has a direct, specific policy for biomass energy from agricultural wastes.
- Direct policies for biomass energy from agricultural waste are need to achieve multiple objectives: environmental protection, circular economy, increased income for farmers, and enhancing the value of food supply chains from farm to table. APEC economies should be encouraged to establish specific, direct policies for biomass energy from agricultural waste. This requires discussion, debate, and demonstration of the effectiveness of these direct policies. The direct policies for biomass energy from agricultural should focus on: supporting technology for collecting and transporting agricultural waste to centralized, small scale biomass

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production facilities for processing and consumption; Implementing pricing policies for biomass electricity; establishing policies for direct electricity sales from agricultural waste without going through common grid systems; tax incentives for renewable energy plants with high agricultural waste utilization rates; policies for land, production facilities, and infrastructure for storage, collection, and initial processing of agricultural waste for biomass energy.

- Policies related to biomass energy from agricultural waste often cover a wide range of areas, but the most relevant ones that need to be leveraged include: environmental policies; renewable energy policies; sustainable agricultural development policies; ecological agriculture policies; organic agriculture policies; safe energy consumption policies; renewable energy transition policies.

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APPENDIX

QUESTIONNAIRES FOR DATA COLLECTION ON PRODUCTION AND USE OF BIOMASS IN THE APEC REGION

(Use for the Project "Promoting APEC Cooperation for Sustainable Biomass Energy from Agriculture Wastes")

Dear APEC Member Economies,

Excessive use of fossil fuels has led to increased greenhouse gas emissions, leading to climate change and negatively impacting the environment. Therefore, it is necessary to gradually replace fossil fuels with renewable energy sources. One of which is biomass energy (BE) produced from agricultural waste (AW). Economies in the APEC region have developed methods to produce biomass energy from agricultural waste but there is in lack of regional summarization, sharing, and dissemination. Therefore, Viet Nam has developed the Project "Promoting APEC Cooperation for Sustainable Biomass Energy from Agricultural Waste" to enhance rural community ability through sharing advanced technologies for producing biomass energy from agricultural waste; and providing recommendations for promoting cooperation within the APEC region on enhancing the production and utilization of biomass energy from agricultural waste. The Project consists of two activities: Overview of the production and utilization of biomass energy from agricultural waste; and Organize a workshop for information and experience sharing within the APEC region. Therefore, we would appreciate it very much if APEC Economies would offer support by filling out this Questionnaire and send back to us by 20 May 2024**.**

We sincerely thank all APEC Economies for your support.

I. GENERAL INFORMATION

APEC Economies' name: ……………………………………………………………..

Name: ………………………………………………………. ………………………..

Organization: …………………………………………………………….……………

Position: ………………………………………………………………………........

Email…………………………………………………………………………………..

II. QUESTIONAIRES

Question 1. Related documents

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1. Have your economy developed renewable energy development strategies?

[ ] Yes [ ] No [ ] no information

1.1. If yes, have those strategies addressed the issue of biomass energy?

[ ] Yes [ ] No [ ] no information

1.2. If yes, can you please share the strategies by providing the documents.

2. Does your economy have Programs/Projects for developing biomass energy from agricultural waste?

[ ] Yes [ ] No [ ] no information

2.1. If yes, which products you focus on to use the wastes converting to biomass:

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………………………………………………………………

2.2. What percentage of renewable energy will biomass energy from agricultural waste account for the end of the Program/Project? ....%

Question 2. Implementation

1. Which agencies are mainly responsible for guiding the production of biomass energy from agricultural waste in your economy?

[ ] Yes [ ] No [ ] no information

If yes, please indicate the source. (Example: Official Government Websites)

…………………………………………………………………………………………
…………………………………………………………………………………………
……………………………………………………………………………

2. Does your economy have the multiple stakeholder's platform regarding biomass energy from agricultural waste, including the public sector (e.g. public-private partnerships)?

[ ] Yes [ ] No [ ] no information

If yes, please indicate the name of the platform and provide its web link (if available)

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………………………………………………………………………………….

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3. Does your economy receive support from foreign organizations for the development of biomass energy from agricultural waste?

[ ] Yes [ ] No [ ] no information

If yes, please specify the names of those organizations and their main activities?

Agencies/Organizations	Roles	Main Activities
1.		
2.		
3.		

Question 3. Does your economy have communication programs regarding the production of biomass energy from agricultural waste?

[ ] Yes [ ] No [ ] no information

If yes, which of the following programs are included?

[ ] TV

[ ] Broadcasting

[ ] Newspapers

[ ] Social Media

[ ] Others, ………………………………………………………………………….

Question 4. What methods have your economy used to support the development of biomass energy from agricultural waste?

[ ] Project development from Government budget

[ ] Land support

[ ] Tax incentives

[ ] Electricity price preference

[ ] Training for knowledge improvement

[ ] Encourage innovative technologies

[ ] Credit support

[ ] Others, ……………………………

Question 5. Does your economy have an estimation of the volume of agricultural waste and treatment methods?

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[ ] Yes [ ] No [ ] no information

If yes, please fill in the following table

No	Crops	Area (Hectares)	Production (Tons)	Waste	
				Tons	Used for energy (%)
1	Rice				
2	Coffee				
3	Corn				
4	Sugar Cane				
5	Others………				

Question 6. Technologies for producing biomass energy from agricultural waste

1. Which of the following technologies is your economy using?

a. Burning for heat (furnace, engines, machinery) and electricity

b. Pyrolysis for oil, gas fuel, and biochar

c. Gasification for clean fuel production (biodiesel, bio-oil)

d. Fermentation to produce Ethanol (Bioethanol)

e. Anaerobic decomposition (biogas) creates heat (cooking, furnace) and electricity

2. Among the technologies used in your economy, which one is the most common?

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Question 7. Does your economy have biomass power plants?

[ ] Yes [ ] No [ ] no information

If yes, how many? …………..…………..…………..…………..…………..

Among them, how many use agricultural waste?

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Question 8. What are the challenges of producing biomass energy from agricultural waste in your economy?

No	Challenge	Level of agreement		
		Disagree	Agree	Strongly agree
1	Seasonality in providing agricultural waste			
2	Biomass energy is only suitable for small-scale, household use			
3	Removing agricultural waste from fields reduces on-site organic fertilizer			
4	High costs for agricultural waste collection and transportation			
5	Biomass energy struggles to compete with other renewable energy sources			

Question 9. Does your economy participate in the commitments, vision, and cooperation for Sustainable Biomass Energy from Agricultural waste?

[ ] Yes [ ] No [ ] no information

If yes, can you please share:

……………………………………………………………………………………..……

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Question 10. What opportunities do you see for further development or expansion of biomass utilization in the APEC region?

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Please use this space to provide any additional comments, insights, or suggestions related for Sustainable Biomass Energy from Agricultural waste in the APEC region:

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