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Review Article: Potential of Rice (*Oryza sativa* L.) as Renewable Biomass Energy in The Agricultural Sector

(*Potensi Padi (*Oryza sativa* L.) sebagai Energi Terbarukan Biomassa di Sektor Pertanian)*

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ABSTRACT

The decline in fossil fuels, combined with increased fuel consumption and its negative effects on the environment, has necessitated the search for renewable energy alternatives. Among renewable energy sources, biomass is a dependable source because it is constantly available in nature. Indonesia has approximately 49,810 MW of potential plant-based biomass resources. The abundant availability of agricultural waste and biomass conversion techniques allow agricultural biomass, including rice, to be converted into an important renewable energy source. Investments in renewable energy derived from biomass can be made if supplies remain abundant and consistent in the future. Rice husks and straw, which are the primary waste products of rice production, have recently received a lot of attention as a renewable energy resource. The cost of rice husks and straw is lower and has no impact on food prices, and there is no conflict between food and fuel. This paper examines renewable energy derived from agricultural biomass, rice plant waste as a renewable energy source, and the conversion of rice plant waste into energy.
Keywords: *biomass; renewable energy; rice husk; rice straw*

ABSTRAK

Berkurangnya bahan bakar fosil bersamaan dengan kenaikan bahan bakar dan efek merugikan terhadap lingkungan menyebabkan perlu dicarinya alternatif energi terbarukan. Di antara sumber energi terbarukan, biomassa merupakan sumber yang dapat diandalkan karena selalu tersedia di alam. Potensi sumberdaya biomassa Indonesia yang berasal dari tumbuhan berkisar 49.810 MW. Ketersediaan limbah pertanian yang berlimpah dan teknik konversi biomassa memungkinkan biomassa pertanian, termasuk industri beras, dapat dikonversi menjadi sumber energi terbarukan yang penting. Investasi energi terbarukan bersumber biomassa dapat dilakukan jika persediaan berlimpah dan selalu tersedia di masa mendatang. Akhir-akhir ini limbah pertanian seperti sekam dan jerami padi sebagai limbah utama beras banyak diperhatikan sebagai sumber energi terbarukan. Harga sekam dan jerami padi lebih murah dan tidak mempengaruhi harga makanan serta tidak kontroversi antara bahan pangan dan bahan bakar. Paper ini mereview energi terbarukan dari biomassa pertanian, limbah tanaman padi sebagai sumber energi terbarukan dan proses konversi limbah tanaman padi menjadi energi.
Kata kunci: *biomassa; energi terbarukan; jerami padi; sekam padi*

INTRODUCTION

Most emerging countries, including Indonesia, rely largely on energy to propel socioeconomic growth. Fossil fuels are still the primary source of world energy use. The widespread usage of fossil fuels drives rapid economic growth in developed and industrialized countries. The usage of fossil fuels raises atmospheric carbon dioxide levels. Aside from this, the usage of fossil fuels contributes significantly to global warming and climate change. As a result, in the future, fossil fuels must be replaced with alternative energy sources that have no detrimental influence on human life or the environment (Kasmaniar *et al*., 2023).

Indonesia has a significant potential for renewable energy resources, as do other Southeast Asian countries. The renewable energy under consideration includes biomass, geothermal energy, solar energy, hydropower, wind energy, and others. Currently, renewable energy has a lower potential use than fossil and mineral energy. Renewable energy has the potential to improve Indonesia's sustainable development. Indonesia has been unable to meet its energy supply requirements due to an average annual increase in energy consumption of 3.46%. Currently, the government is attempting to develop various renewable energy sources with the goal of increasing energy security, protecting the environment, increasing energy access, and encouraging investment (Radhiana *et al*., 2023).

Biomass is a renewable energy resource, and the best biomass for use as an energy source is biomass that has a low cost. The most suitable type of biomass for use is one that has lost its primary product. Agricultural, plantation, forest, and livestock waste are all sources of potential biomass for generating electricity. In 2011, biomass energy accounted for approximately 12.41% of total renewable energy consumption. Biomass has the potential to be an alternative source of renewable energy because the majority of biomass is still underutilized. Furthermore, biomass has the characteristics of being renewable and sustainable, can be stored, replaced, and transported, has a high level of availability, and produces non-polluting CO_2 through its combustion (Radhiana *et al*., 2023).

This review focused on renewable energy derived from agricultural biomass, rice plant waste as a renewable energy source, and the conversion of rice plant waste into energy. The importance of considering the rice plant waste as renewable energy resources is emphasized because this biomass is renewable and sustainable.

BIOMASS AS BIODIVERSITY AND RENEWABLE ENERGY SOURCE

Biomass is an alternative renewable energy source with significant potential for meeting energy needs and overcoming the global primary energy supply crisis. Some of the characteristics of biomass as an alternative renewable energy source include its renewable nature, the ability to be produced in a decentralized manner, carbon neutrality, and contribution to climate change mitigation. The technical potential of biomass sources in Indonesia is 49,810 MW, but their utilization remains relatively low, at around 302 MW. Biomass-based renewable energy has the potential to significantly reduce reliance on fossil fuels. The availability of biomass raw materials as a renewable energy source is still very abundant in nature and this energy source can be renewed all the time.

Biomass is made up of various organic materials produced by organisms capable of photosynthesis, such as plants with vessels and other groups of organisms with pigments such as algae. Photosynthesis is the process by which water and carbon dioxide are converted into carbohydrates and oxygen using sunlight or other light. Solar energy or other light sources are converted into chemical energy used in photosynthesis. This carbohydrate is an organic material that serves as a biomass source for alternative renewable energy. There are three types of biomass: biomass from wood, biomass from non-wood, and biomass as a secondary fuel.

Currently, biomass is a vital energy source in countries around the world and has the potential to become a significant source of renewable energy in the future. The potential distribution of biomass as a renewable energy source in ASEAN countries is limited to Malaysia, Myanmar, Brunei, Cambodia, Laos, and Vietnam. Thailand and the Philippines have renewable energy potential sourced from wind and water (Radhiana *et al*., 2023).

BENEFITS OF BIOMASS AS A RENEWABLE ENERGY SOURCE

Agricultural wastes that can be converted into energy include rice straw, rice husks, wheat, potatoes, and fruit processing residues. ASEAN member countries have an abundance of biomass resources; however, they are not allocated equally. Malaysia, for example, as one of the world's biggest palm oil producers, has the potential to contribute the most to bioenergy. Other biomass-rich countries include Cambodia, Myanmar, and Laos. Due to limited budget and delayed technological progress, agricultural waste in these nations is often eliminated through open-air fire, and its energy potential is unrealized.

Some of the advantages of biomass-based renewable energy sources are as follows:

1. Renewable energy source
   Renewable energy sourced from biomass never runs out, such as food crops, livestock waste, and waste which is produced continuously by humans.
2. Neutral carbon
   The use of biomass in energy-producing industries basically follows the principles of a carbon neutral cycle. Therefore, there is no contribution to greenhouse gas emissions when biomass-sourced fuel is burned at a power plant.
3. Cost-effective
   Biomass energy is cheaper compared to other sources that produce renewable energy. Utilizing 70% of rice husk waste can produce 1328 GWh of electrical energy every year. The price of each unit of electricity produced from rice husks is 47.36 cents/kWh compared to 55.22 cents/kWh for each unit of electricity produced from coal.
4. Ability for small-scale electric power production
   Electrical energy production can be carried out on a small scale, especially in rural areas, using the gratuity method.
5. Variety of raw materials
   Biomass-sourced electricity can come from various raw materials such as rice straw, rice husks, wood pellets, bagasse, and others.
6. Methane gas residue
   The decomposition process of organic material indirectly releases methane gas, and burning biomass to produce energy can control the release of methane gas (Mofijur *et al*., 2019).

RENEWABLE ENERGY FROM AGRICULTURAL BIOMASS

Renewable energy, also known as new and renewable energy, is energy derived from renewable natural resources, which include sunshine, wind, rain, tides, geothermal heat, and biomass. Biomass is Indonesia's oldest traditional energy source, and it is commonly utilized for cooking in rural regions. Biomass waste is used to meet heat needs throughout the production process, as well as other energy needs in agriculture, plantations, and forestry (Kasmaniar *et al*., 2023).

The Indonesian government has campaigned for the adoption of renewable energy sources to alleviate the country's energy shortage. Biomass is a promising source of renewable energy in Indonesia; however, its use is not yet optimal. Biomass, which is used in Indonesia as a renewable energy source such as fuel, is waste that has previously been used for its primary output and hence has minimal economic value. Plants, trees, grass, tubers, agricultural waste (including food crop waste), forest waste, dung, and livestock manure are some of the natural resources utilized to generate renewable energy from biomass. Indonesia's biomass-based renewable energy potential is estimated to reach 49,810 MW(Kasmaniar *et al*., 2023).

The use of biomass as a renewable energy source, which is a long-term program in the future, faces several obstacles, namely the exploitation of biomass raw materials as a renewable energy source due to the increase in energy demand that must be met. Therefore, the use of biomass as a source of raw materials for energy, food, and other industrial requirements needs to be regulated by the government. Regulation and coordination by the government is intended to ensure the availability of biomass as raw material for renewable energy in the future (Kasmaniar *et al*., 2023).

Agricultural biomass must be effectively managed to meet people's needs while also conserving these natural resources so that they are available in the ecosystem. A broad number of agricultural plants can be used to generate renewable energy from agricultural biomass. The evaluation of plant types that qualify as raw materials for renewable energy must consider the following criteria:

1. Food source plants are available in excessive quantities,
2. Productivity of crop output from biofuel,
3. Energy source plants with various benefits,
4. Level of readiness for crop production development,
5. Public policy regarding land for cultivating crops that does not compete with land for food crops or marginal land that is suitable for cultivating plants that will be used as a source of renewable energy (Kasmaniar *et al*., 2023).

Because it contains oil or fat, starch or sugar, and lignocellulose, agricultural biomass can be used to produce biofuels such as biodiesel, bioethanol, and bioavtur. Biofuels can be derived from both wood and non-wood biomass. Trees and shrubs produce woody biomass, whereas plant residues and other vegetation produce non-woody biomass. Rice, corn, cassava, and bananas are examples of food crops with potential for use as agricultural biomass energy sources. These food plants' high starch and sugar content make them capable of producing bioethanol. Because these food plants are still used as a primary source of food, plant waste can be utilized (Radhiana *et al*., 2023; Kasmaniar *et al*., 2023).

Despite the advantages of using agricultural biomass as a source of renewable energy, there are several barriers to its use. These include the following:

1. There is still a lack of knowledge about the use of agricultural biomass as a renewable energy source among human resources, such as farmers and other community members who live near agricultural land.
2. There are still few human resources with sufficient levels of knowledge and expertise regarding the conversion of agricultural biomass into renewable energy; and
3. The agricultural tools used are still outdated and limited.

There are at least three ways to get around the challenges listed above:

1. Educating farmers and surrounding communities about agricultural biomass processing technology that produces renewable energy.
2. Establishment farm institutions to develop agro-industry; and
3. Establishment of an integrated agricultural area in the central area for the development of an integrated food system (Kasmaniar *et al*., 2023).

RICE PLANT WASTE AS A RENEWABLE ENERGY SOURCE

Agro-industry and agricultural waste are potential biomass raw materials for renewable energy production. Agricultural waste from planting, maintenance, and harvesting, such as stems and leaves, can be used as biomass raw materials. The use of agricultural waste as a biomass raw material will not degrade environmental quality or disrupt community activities. Rice is an agricultural biomass source with an energy potential of 66,412 million GJ/year, based on an annual production of 12,148 million tons. Rice residue in the form of husks (13.6 million tons/year in 2007-2008) has a technical energy potential of approximately 150 GJ per year, so it is estimated that it has the potential to become the main biomass energy source in Indonesia (Radhiana *et al*., 2023).

Rice (*Oryza sativa* L.) is an extremely important plant for humanity because it provides food for more than half of the world's population (Utama, 2015). Rice is important in Indonesian people's lives because it provides the primary source of energy in the form of carbohydrates. Indonesia is the third-largest rice producer (Radhiana *et al*., 2023). As the population grows, so does the demand for rice as a staple food. Rice is a renewable natural resource due to its ability to reproduce and multiply. Technological advancements enable rice plants to be more productive in meeting basic food needs.

Agricultural waste is biomass residue that can be divided into two categories: plant residues and agro-industrial residues. Furthermore, plant residues can be classified into two types, such as rice husks and straw. Rice husks are the outer layers of rice grains that are removed from the grain as a byproduct during milling. Rice straw is composed of rice stems and leaves that are left on agricultural land as a waste product after the rice grains have been harvested. Rice straw is formed when rice plants are harvested for grain. Rice straw accounts for nearly 50% of the net weight of the rice plant, with weights ranging from 40% to60% depending on the harvesting method (Mofijur *et al*., 2019).

Each harvest generates a significant amount of rice waste in the form of straw, with at least 1.35 tons of straw for every ton of rice produced. In 2017, Indonesia ranked third in rice, straw, and rice husk production. Indonesia produced 81.38 million tons of rice, 16.28 million tons of rice husks, and 81.38 million tons of rice straw, yielding an energy potential of 244.15 PJ. Rice straw waste accounts for around 62% of rice production in China, and not all of it is used to generate energy. In 2017, approximately 0.0563 million tons of wet and dry rice straw were wasted on 9,375 acres of agricultural land in Taiwan and about 38,862 acres of agricultural land yielded up to 0.233 million tons of rice straw (Mofijur *et al*., 2019). Several researchers reported variations in the ratio of rice straw and rice husk waste from 1.0-3.96 and 0.2-0.33, respectively. **Table 1** shows the production of rice, rice straw, and rice husks from the 20 largest rice-producing countries in the world. In general, 769.75 million tons of rice straw and 153.95 million tons of rice husks was produced in 2017, which can be used to produce 638.03 PJ of energy.

Table 1. The production of rice, rice straw, and rice husks from the 20 largest rice-producing countries in the world

Countries	Rice Crop (million tons)	Predicted Rice Husk [a]	Predicted Rice Straw [b]	Energy Potential (PJ)
China, mainland	212.68	42.54	212.68	638.03
India	168.50	33.70	168.50	505.50
Indonesia	81.38	16.28	81.38	244.15
Bangladesh	48.98	9.80	48.98	146.94
Vietnam	42.76	8.55	42.76	128.29
Thailand	33.38	6.68	33.38	100.15
Myanmar	25.62	5.12	25.62	76.87
Philippines	19.28	3.86	19.28	57.83
Brazil	12.47	2.49	12.47	37.41
Pakistan	11.17	2.23	11.17	33.52
Cambodia	10.35	2.07	10.35	31.05
Nigeria	9.86	1.97	9.86	29.59
Japan	9.78	1.96	9.78	29.34
USA	8.08	1.62	8.08	24.25
Egypt	6.38	1.28	6.38	19.14
Republic of Korea	5.28	1.06	5.28	15.85
Nepal	5.23	1.05	5.23	15.69
Lao People's Democratic Republic	4.04	0.81	4.04	12.12
Madagascar	3.10	0.62	3.10	9.30
World total	**769.75**	**153.95**	**769.75**	**638.03**

[a] Predicted residue ratio of 0.2 and [b] predicted residue ratio of 1.0.

(http://www.fao.org/statistics/en/)

Rice husks and straw have the potential to generate energy. Rice husk can be used as both an energy and non-energy source (**Figure 1**). Rice husk can be used as an energy source to generate heat, electricity, and fuel. Heat/electric power can be used for a variety of purposes, including household use, drying/production, electricity, and industrial boilers. Fuels can be solid (briquettes, pellets), liquid (ethanol, butanol, biodiesel, hydrogen), or syngas (refinery). Rice husk is a non-energy source that can be used in agriculture, industry, and other applications. Rice husk can be used in agriculture to produce animal bedding and fodder, as well as for carbonization (biochar). Industrial and other applications include building materials (fiberboard, brick) as well as high-end materials like silica and biofiber (**Figure 1a**). Rice straw can also go through pretreatment and processing stages (thermoprocessing and bioprocessing). Thermoprocessing includes combustion, gasification, and pyrolysis. This process generates heat, gas, liquid fuel, and char. Anaerobic digestion and fermentation are two bioprocessing steps that produce biogas, ethanol, butanol, and hydrogen. These two processes produce energy sources for heat, electricity, syngas, and biofuel (**Figure 1b**).

Rice plant waste contains numerous properties that can be assessed using proximal analysis, ultimate analysis, and element analysis. Rice straw and husks have high heating values (HHV) of 15.84 MJ/kg and 15.09 MJ/kg, showing their energy content and potential as an energy source, respectively. **Table 2** outlines the main properties of rice plant waste. The qualities of rice waste affect the quality of combustion during energy production. For example, the features of the extractive content determine a higher high heating value (HHV) and a lower ash concentration. The inclusion of Na, K, and P lowers the melting point of rice husks and straw, which can result in fouling and corrosion (Mofijur *et al*., 2019).

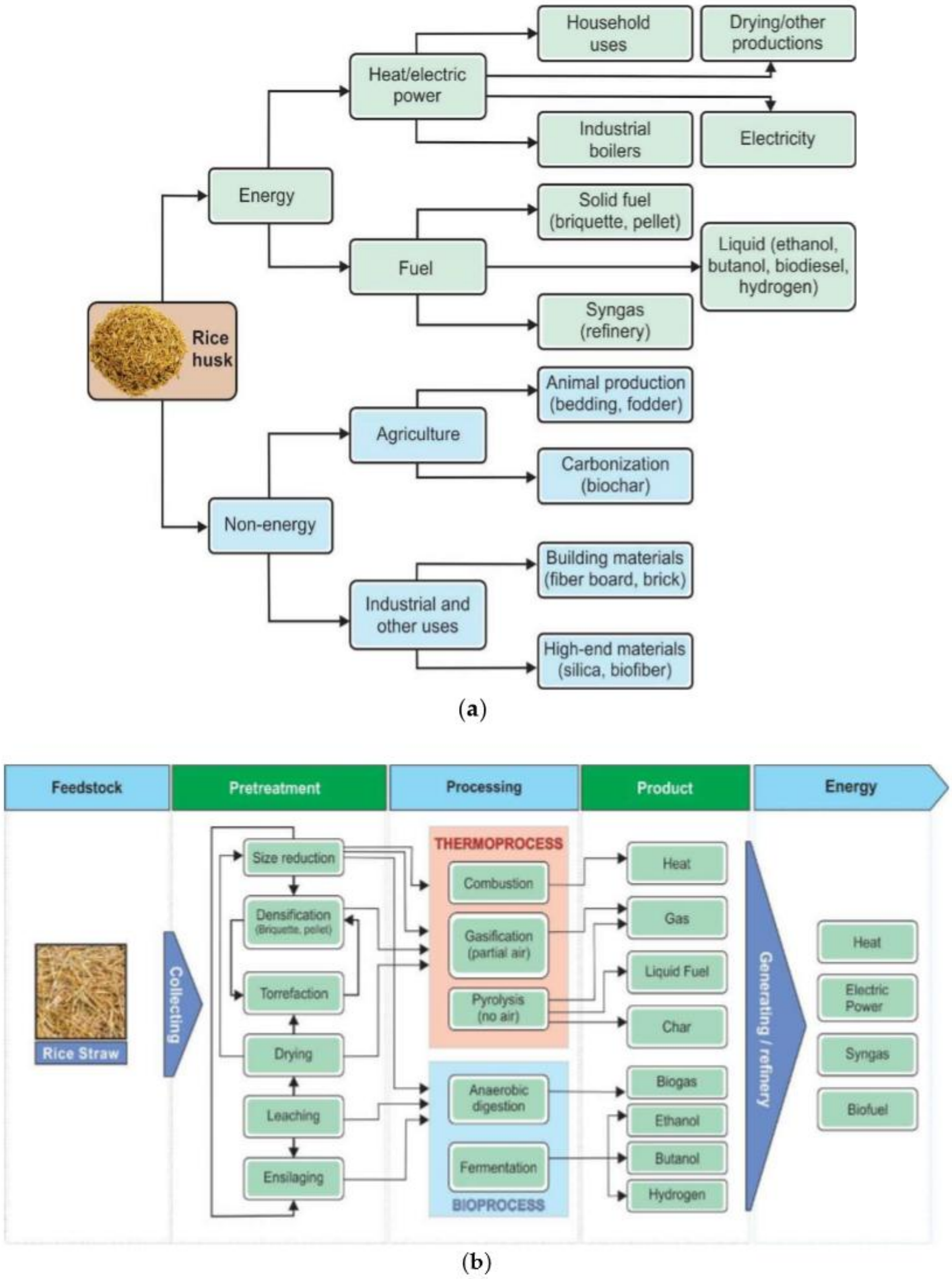

Figure 1. Potential of rice husks (a) and straw (b) to produce fuel and energy (Mofijur *et al*., 2019).

Table 2. Characteristics of Rice Plant Waste

Analysis	Properties	Rice Husk	Rice Straw
Constant volume	HHV MJ/kg	15.84	15.09
Proximate analysis (% dry fuel)	FC	16.22	15.86
	VM	63.52	65.47
	AC	20.26	18.67
Ultimate analysis (% dry fuel)	C	38.83	38.24
	H	4.75	5.20
	O_2	35.47	36.26
	N	0.52	0.87
	S	0.05	0.18
	Cl	0.12	0.58
	AC	20.26	18.67
Elemental analysis of ash (%)	SiO_2	91.42	74.67
	Al_2O3	0.78	1.04
	TiO_2	0.02	0.09
	Fe_2O_3	0.14	0.85
	CaO	3.21	3.01
	MgO	<0.01	1.75
	Na_2O	0.21	0.96
	K_2O	3.71	12.30
	SO_3	0.72	1.24
	P_2O_5	0.43	1.41

(Lim *et al*., 2012; Dizaji *et al.*, 2019; Mofijur *et al*., 2019).

1. Process of converting rice plant waste into energy

Rice straw contains three main components: silica, a high cellulose content, and a long decomposition period. Rice straw is widely used for animal feed as well as the production of non-wood fiber, which is used to make newspapers and corrugated packaging. Rice straw can be converted into bioethanol, a clean fuel that requires a costly chemical conversion process. Slagging and fouling occur during the boiling and burning processes. Rice straw produces energy through two processes: thermodynamics and biochemistry. The type and quantity of biomass feedstock, the desired form of energy (e.g., end user needs), environmental standards, economic conditions, and project-specific factors all influence which conversion process is used. **Figure 2** shows an energy factory made from rice husks. Details of the thermochemical and biochemical processes are described below.

a. Thermochemical Processes

Thermochemical conversion processes are divided into two categories: direct conversion of biomass into energy products and conversion of biomass into other forms that can then be used to generate energy. Thermochemical processes include direct combustion, gasification, and pyrolysis.

1) Direct burning

In this process the chemical energy stored as biomass is converted into heat, electricity, or other mechanical energy by burning the biomass in the open air. For proper energy production, biomass with a water content of less than 50% is needed. This process has several disadvantages, as follows:

• In most cases, it is important to pre-treat the biomass before burning.

• The pre-treatment referred to is drying, chopping, and grinding.
• Pretreatment processes increase costs and energy requirements.

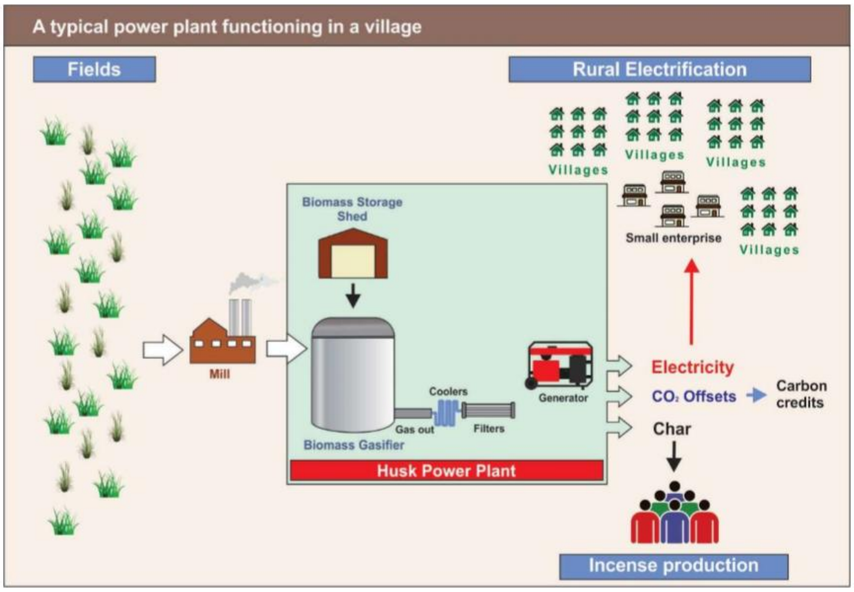

Figure 2. Energy factory made from rice husks (Mofijur *et al*., 2019).

Combustion is the most widely used thermochemical process, particularly in developing countries, accounting for 97% of all bioenergy consumed worldwide. The indirect combustion process demonstrates the use of biomass as a fuel source in the boiler, which supports steam production in the presence of oxygen in the boiler. A turbine converts steam into both heat and electricity (Mofijur *et al*., 2019).

2) Gasification

Biomass heated to high temperatures (800-900ºC) with insufficient air supply (partial oxidation) produces a flammable gas mixture. Rice husk gasification for energy production is widely used in Asia, including China, Indonesia, India, Thailand, Cambodia, and the Philippines. Gasification has the advantage of producing gas that can be used in gas engines, gas turbines, and fuel cells to generate electricity with high efficiency. Pode (2016) reported that 1 ton of rice husks can generate 800 kWh of electricity and save approximately 1 ton of CO_2 emissions when compared to current use. According to Prasara-A and Gheewala (2017), the ideal gasification process yields non-condensable gas and ash residue. Susastriawan *et al.* (2019) studied the suitability of downflow gas generators using various raw materials such as rice husks, sawdust, and their mixtures. The maximum balance ratio for gas generators is 3.13 for rice husks, 2.69 for sawdust, and 0.35 MJ/Nm^3 for the mixture. The potential for electricity production in rural areas using gasification systems has been discussed by Abe *et al*. (2007), but tree planting is required to provide long-term biomass for gasification.

3) Pyrolysis

Pyrolysis is the process by which biomass decomposes under high temperatures in the absence of air. The pyrolysis process operates at temperatures ranging from 350ºC to 550ºC . The process's operating conditions determine the ratio of pyrolysis products, which comprise gaseous residue, liquid, and carbon-rich residue. Bridgwater and Peacocke (2000) illustrated the importance of the fast pyrolysis process, which includes both the core reaction system and the processes that occur concurrently with the liquid product. Pyrolysis processes are categorized into three types based on temperature, heating rate, and residence time: slow, fast, and flash pyrolysis. The major product of slow pyrolysis is charcoal, coupled with a tiny amount of oil and steam. The primary product of the fast pyrolysis process is pyrolysis oil, whereas the main product of flash pyrolysis is gas. Fukuda (2015) discovered that the fast pyrolysis method employing rice husk as a raw material could provide a maximum oil product of 50% by weight of pyrolysis. According to Bridgwater *et al.* (2002), the quick pyrolysis process using dry feed raw materials produced around 75% of the weight of pyrolysis oil.

b. Biochemical Processes

Various useful products can be obtained through biomass conversion using the following biochemical processes.

1) Anaerobic digestion

Anaerobic digestion is the process by which microorganisms convert biomass into biogas (a mixture of carbon dioxide and methane). Biogas is a fuel used to produce heat and energy. Anaerobic digestion using rice straw as a raw material is not a new concept, but the potential for renewable energy generation using this raw material has almost never been examined. According to Mussoline *et al.* (2013), under ideal digestion conditions (pH 6.5-8.0; temperature 35-40ºC; nutrients with a C:N ratio of 25-35), volatile components can produce 92-280 L/kg of methane. Matin and Hadiyanto (2018) explored the development of biogas production from rice husks using solid-state anaerobic digestion (SSAD) and discovered that lignin was difficult to degrade with bacteria. This researcher also found that SSAD produced more biogas than liquid anaerobic digestion (LAD). Haryanto *et al.* (2018) investigated the effect of adding urea to biogas products produced by co-digesting rice straw and cow feces in a semi-continuous anaerobic digester and determined that adding urea improved product quantity and quality.

2) Fermentation

Bioethanol produced from lignocellulosic biomass generally involves three main stages, namely pretreatment, enzymatic hydrolysis, and fermentation. The first stage (pretreatment) involves screening and pelletizing, which is essential for the reduction of transportation costs and handling costs. The second stage, i.e., enzymatic hydrolysis, involves the transformation of cellulose and hemicellulose biomass into glucose, pentoses, and hexoses (Taherzadeh and Niklasson, 2004). During the third stage (fermentation), chosen bacteria convert glucose into ethanol. However, rice straw and husks can be converted using multiple processes that occur concurrently, including saccharification and fermentation (SF), as well as independent enzymatic hydrolysis and fermentation processes. According to Binod *et al*. (2010), the high ash and silica concentration of rice straw suggests that it can be used for bioethanol synthesis, despite being an inferior feedstock. Awoyale *et al*. (2018) employed rice and wheat straw for bioethanol production and discovered that the lignin, ash, and silica levels of rice straw necessitated an appropriate pretreatment method. However, some studies discovered that ethanol production from rice straw can reach 83.1% (Ko *et al*., 2009).

CONCLUSIONS

This paper examines rice's potential as a renewable energy source derived from agricultural biomass, considering that rice is the predominant food source in most Asian countries, including Indonesia. Indonesia is the world's third-largest producer of rice, specifically husks and straw. Rice husks and straw can be used as an energy source due to their high heating value of 15-16 MJ/kg. The technical energy potential of rice waste is around 150 GJ per year. Rice waste can be transformed into energy using both thermochemical and biological processes. Thermochemical processes include direct combustion, gasification, and pyrolysis, while biochemical processes include anaerobic digestion and fermentation. Rice waste can be transformed into energy using both thermochemical and biological processes. Thermochemical processes include direct combustion, gasification, and pyrolysis, while biochemical processes include anaerobic digestion and fermentation. Rice husk and rice straw have the potential to be a source of renewable energy if problems with their properties (ash content and water content) and logistics (distance between paddy field and power plant) are addressed.

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