



Evaluation of renewable energy from rice husk waste potential in Bali Island

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INFO ARTIKEL

Kata kunci:

Secam padi, energi terbarukan, biomassa, limbah pertanian

Keywords:

Rice husk, renewable energy, biomass, agricultural waste

Received: 21-12-2025

Revised: 19-01-2026

Online published: 30-03-2026

ABSTRAK

Studi ini mengevaluasi potensi limbah sekam padi sebagai sumber energi terbarukan di Pulau Bali. Berdasarkan data produksi sekam padi sebesar 127.095 ton per tahun dan nilai kalor rata-rata 14 MJ/kg, potensi energi diperkirakan mencapai 494.258.728,74 kWh per tahun. Jumlah ini cukup untuk memenuhi kebutuhan listrik sekitar 41.188 rumah tangga, dengan asumsi konsumsi rata-rata 100 kWh per bulan. Hasil evaluasi menunjukkan bahwa sekam padi memiliki nilai strategis sebagai sumber daya biomassa lokal yang dapat dimanfaatkan melalui berbagai teknologi, seperti pembakaran langsung, gasifikasi, dan pembriketan biomassa. Selain mengurangi ketergantungan pada bahan bakar fosil, pemanfaatan ini mendukung pengelolaan limbah pertanian berkelanjutan. Oleh karena itu, pendekatan terpadu yang melibatkan dukungan kebijakan, teknologi tepat guna, dan keterlibatan masyarakat sangat penting untuk menerapkan pemanfaatan energi dari limbah sekam padi secara efektif dan berkelanjutan di Bali dan wilayah pertanian lainnya di Indonesia.

ABSTRACT

This study evaluates the potential of rice husk waste as a renewable energy source in Bali Island. Based on rice husk production data of 127,095 tons per year and an average calorific value of 14 MJ/kg, the estimated energy potential reaches 494,258,728.74 kWh per year. This amount is sufficient to meet the electricity needs of approximately 41,188 households, assuming an average consumption of 100 kWh per month. The evaluation results indicate that rice husks have strategic value as a local biomass resource that can be utilized through various technologies, such as direct combustion, gasification, and biomass briquetting. In addition to reducing dependence on fossil fuels, this utilization supports sustainable agricultural waste management. Therefore, an integrated approach involving policy support, appropriate technology, and community engagement is essential to effectively and sustainably implement energy utilization from rice husk waste in Bali and other agricultural regions in Indonesia.

1. Introduction

As an agricultural country, Indonesia produces large amounts of agricultural waste, including rice husk. Bali has a fairly active agricultural sector as a province, especially in rice commodities, so it produces large amounts of rice husk. This potential has not been optimally utilized, even though its utilization can support clean energy policies and reduce carbon emissions. Every rice milling process produces waste in the form of rice husks, which are generally not optimally utilized. Rice husk contains chemical energy that can be converted into heat, electricity, or alternative fuels. Rice husk is a by-product of rice milling generally not utilized optimally. Rice husk has a fairly high energy content and has the potential to be an alternative fuel. Rice husk biomass waste has great potential for areas with rice as the main food source [1].

Rice husk, a by-product of rice processing, is still considered waste by farmers. Rice husk is a by-product of 20% of the weight of bulk grains from the rice processing industry

[2]. The rice milling industry generally produces 65% rice, 20% rice husks, and the rest is lost [3]. Based on data from the Central Statistics Agency, rice production in Bali in 2024 will be 635,473.4 tons of dry milled grain [4, 5]. The use of rice husks is limited to planting media and brick-burning processes, and most are considered waste and burned directly on farmers' land. On the other hand, rice husks have promising potential as a renewable and sustainable energy source because they will continue to be available as long as people consume rice as their staple food. Rice husk biomass has a calorific value equivalent to half the calorific value of coal and varies according to the results of several studies, namely 11-15.3 MJ/kg [6]; net calorific value 12-16 MJ/kg [7]; and 13-19 MJ/kg with an average of 18 MJ/kg [8]. Research conducted on rice husks through direct combustion processes and using a stove produced maximum temperatures of 560°C and 556.5°C °C, respectively; rice husks contain lignin, cellulose, and silica, so they are suitable for the use of heat energy [9, 10, 11].

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Biomass is a cleaner and more sustainable energy source due to the limited availability of coal and the high CO₂ emissions associated with coal combustion, but rice husk-based electricity generation is hampered by the absence of cogeneration facilities in rice mills [12].

The use of rice husks as a sustainable energy source has great potential as an alternative fuel for small farmers and power plants. Rice husks are theoretically cheap and easy to obtain because they are still considered waste. Rice husk biomass can be used as an energy source with direct or indirect methods. Rice husks are used directly through direct burning to produce heat, such as using a traditional stove as a substitute for firewood. The energy conversion process can utilize rice husks indirectly. The energy conversion process is carried out by applying a heat exchanger. The heat produced by this method is more optimal, and the dried product is not mixed with smoke from burning rice husks [13]. The process of converting rice husks into energy involves several methods, such as direct combustion, biomass gasification, anaerobic digestion, pyrolysis, pelletization, and co-burning, and the use of rice husks helps conserve natural resources and increase income for rice farmers through the sale of rice husks for power plants [14]. Rice husk shows stable fire, low emissions, and combustion efficiency reaching 99.2% based on test results conducted on a rectangular fluidized bed combustor [15].

This potential is relevant in the context of renewable energy development in Bali, which has been very dependent on fossil fuels and supplies from outside the island. By utilizing waste as an energy source, Bali can develop a more sustainable energy system based on local resources. This study aims to evaluate the energy potential of rice husks in Bali, including estimates of the amount of husk, calorific value, and projections of energy that can be produced.

2. Experimental Procedure

In this paper, an analysis of the potential of rice husk biomass produced on the island of Bali is carried out. Rice is the main product of rice and produces by-products in the form of bran, straw, and rice husks. The rice husk produced is approximately 20%, with its use by the community and small industry players limited to the needs of burning bricks, planting media, and being burned directly to clean the waste. On the other hand, the need for energy such as gas or oil for households and power plants continues to increase. Rice husk biomass, as agricultural waste that is abundantly available, has the potential to be developed as a sustainable energy source. The method in this report uses research results, field observations, and news. Analysis was conducted on the potential of rice husk energy based on the initial or theoretical potential. Economic aspects and raw material collection were not taken into account. Rice husk production based on conditions produced on the island of Bali, and calculations were based on rice production, namely dry milled grain. This study uses a quantitative descriptive approach with several stages. Estimation of rice husk production based on rice production data in Bali 2024 obtained from BPS. Assuming 20% of GKG becomes husk, the total estimate of rice husk can be calculated. Rice husk production and energy potential are calculated using Equations 1 and 2 [2, 16].

$$Rice\ husk\ potential\ (tons) = 0.2 \times rice\ production\ (dry\ milled\ grain) \quad (1)$$

The potential of rice husk in tons is converted into kg (1 ton = 1000 kg). The energy potential is based on rice husk production and the calorific value of rice husk. The calorific value of rice husk (Net Calorific Value/NCV) is taken from previous research results, which range from 13–15 MJ/kg [17]. The average value of 14 MJ/kg is used to calculate energy potential. The calorific value of rice husk is 3,350 kcal/kg [18]; when converted to Joules, it becomes 14 MJ. Energy in MJ units is converted to GWh (1 GWh = 3.6 × 10⁶ MJ).

$$Energy\ potential\ (MJ) = rice\ husk\ production \times calorific\ value\ of\ rice\ husk \quad (2)$$

3. Results and discussion

Bali Province in 2024, based on BPS data, produced a total rice production of 635,473.4 tons (GKG). If rice husks are 20% of dry milled rice (GKG), rice husk production reaches 127,095 tons or 127,095,000 kg for 2024. The results of rice husk production based on district/city can be seen in Figure 1, which presents the distribution of rice husk production in 2024 for districts and cities on the island of Bali. Fig. 1 shows the potential of rice and rice husks in each district or city in Bali. Tabanan Regency has a rice husk potential of 163,227 tons (dry milled grain) for one year (2024). Overall, in 2024, the potential of rice husks in Bali will reach 127,095 tons (dry milled grain) or 127,095,000 kg. This potential can theoretically produce a total energy of:

$$127,095,000\ kg \times 14\ MJ/kg = 1,779,325,380\ MJ$$

With 1 MWh equal to 3,600 MJ, 1 MJ is equal to $\frac{1}{3,600}$ MWh, So the electrical energy that can be produced in one year is:

$$\frac{1,779,325,380}{3,600} = 494,257\ MWh = 494.257\ GWh$$

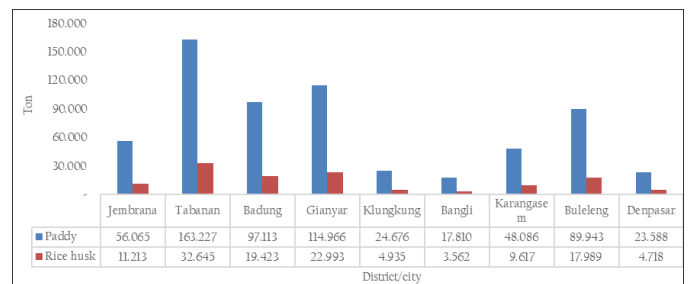


Fig. 1. Potential of rice husk on the island of Bali

The energy of 494.257 GWh is the total energy potential (theoretical) in one year, especially in 2024. The average calorific value of rice husk is 14 MJ/kg, and 1 MJ is equivalent to 0.277778 kWh, so 14 MJ/kg is 3.888892 kWh/kg. Therefore, one ton of rice husk produces energy of 1,000 kg × 3.888892 kWh = 3,888.8920 kWh/ton. The total energy from 127,095 tons of rice husk is:

$$127,095\ tons \times 3,888.8920\ kWh/ton = 494,258,728.74\ kWh\ per\ year$$

The calculation results show differences due to rounding numbers and unit conversions. If the average household needs

are 100 kWh per month, the energy potential is 494,258,728.74 kWh per year. Based on this, the annual electricity consumption per household is as follows.

$$\frac{100 \text{ kWh}}{\text{month}} \times 12 \text{ month} = 1,200 \text{ kWh /year}$$

Consumption of 1,200 kWh/year can serve the number of households of:

$$\frac{494,258,728.74 \frac{\text{kWh}}{\text{year}}}{1,200 \frac{\text{kWh}}{\text{year}} \text{ house}} = 411,882.27 \text{ house}$$

$$\approx 411,882 \text{ house}$$

This makes rice husks an important local energy source for Bali's energy security. The potential for utilizing rice husks as an alternative energy source is local wisdom, cheap, and environmentally friendly. When viewed for each district/city, the energy potential (theoretical) in one year, especially in 2024, is as shown in Fig. 2.

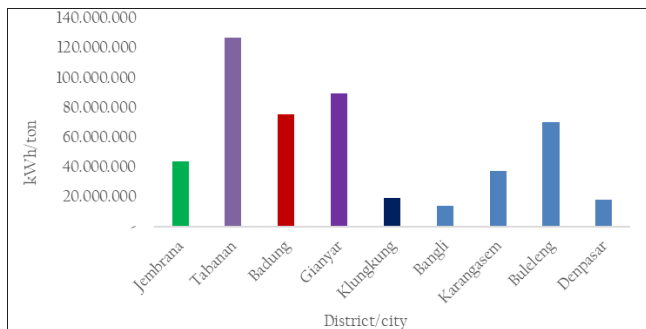


Fig. 2. Theoretical energy potential of rice husks in each district/city on the island of Bali

Table 1 presents the theoretical energy potential of rice husks in each regency/city on the island of Bali.

Table 1. Theoretical Energy Potential of Rice Husk in Each Regency/City

No.	Regency/city	kWh/year
1	Jembrana	43,606,053
2	Tabanan	126,954,264
3	Badung	75,532,674
4	Gianyar	89,418,118
5	Klungkung	19,192,203
6	Bangli	13,851,852
7	Karangasem	37,400,532
8	Buleleng	69,955,505
9	Denpasar	18,346,245

This potential is usually calculated based on the volume of rice husk waste that can be converted into energy. The kWh/year unit indicates the total electrical energy that can theoretically be produced in one year, if all waste or energy sources are available and utilized optimally. Conversion of rice husk biomass into energy is generally done by direct

combustion. All biomass can be burned directly to heat buildings and water, to provide industrial process heat, and to generate electricity in steam turbines [19]. Using biomass as an alternative energy source, such as for power plants, is a sustainable and environmentally friendly solution to increase energy independence and provide economic benefits to the community. In addition, more efficient, environmentally friendly infrastructure and technology development are needed, as well as support from the government and industry players [20]. The heat generated from applying rice husk biomass to produce energy can be done through direct combustion. The heat from biomass combustion in the boiler produces steam, which flows to the turbine and rotates it, driving the generator. The rotation of the turbine is converted into electrical energy through magnets in the generator [21]. The abundant potential of rice husk biomass can be used as a substitute for energy from fossils or coal.

Using rice husks as an alternative energy source will add value to waste and impact the emergence of economic growth. Rice husks have a fairly high energy content, making them a potential biomass energy source. Amidst the increasing need for energy and the high price of fossil fuels, using rice husks as an alternative fuel for household needs is very relevant, especially in rural areas and agricultural centers. Rice husk has great potential as a source of household energy, especially in rice-producing areas. Through simple technologies such as briquettes, biomass stoves, and conversion to bioenergy, rice husk can be an efficient, cheap, and sustainable renewable energy solution. Policy support and technological innovation must be provided to implement this utilization widely and sustainably.

4. Conclusions

The evaluation results show that rice husk waste in Bali Island has significant potential as a renewable energy source. With a total production reaching 127,095 tons per year and an average calorific value of 14 MJ/kg, rice husk can produce energy up to 494,258,728.74 kWh per year. This energy can theoretically meet the electricity needs of around 411,882 households with an average consumption of 100 kWh per month. Using rice husks through energy conversion technologies such as direct combustion, gasification, or biomass briquetting has proven feasible and can be a strategic solution for energy diversification, especially in agricultural areas. In addition to contributing to local energy security, this approach also positively impacts waste management and carbon emission reduction. For this potential to be utilized optimally, support for renewable energy policies, development of local-scale technology, and increased community capacity in biomass management are needed. With an integrated approach, rice husks can be an important part of the sustainable energy transition in Bali and other agrarian areas in Indonesia.

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