

## Bibliometric Analysis of Rice Husk Biomass Potential as an Environmentally Friendly Alternative Fuel

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### ABSTRACT

The increasing global energy demand and environmental concerns have intensified the search for sustainable alternative fuels. Rice husk, an abundant agricultural by-product in rice-producing countries, has attracted growing attention as a promising biomass resource. However, previous studies have mainly focused on technical conversion processes, while limited research has systematically examined publication trends and thematic developments in this field. Therefore, this study aims to analyze global research trends on rice husk biomass as an environmentally friendly alternative fuel using a bibliometric approach. Data were collected from the Scopus database covering publications from 2020 to 2026 using relevant keywords related to rice husk biomass and renewable energy. The data were analyzed using VOSviewer and Microsoft Excel to identify publication growth, dominant journals, collaboration networks, and keyword trends. The results show a significant increase in publications, reaching a peak in 2024, with Renewable Energy as the leading publication source. Keyword co-occurrence analysis revealed major themes such as biofuels, pyrolysis, combustion, and emission control. Thematic mapping indicates that combustion efficiency and thermal performance remain core research topics, while pelletizing and environmental assessment are emerging themes. This study provides insights into research directions and highlights the importance of technological innovation, efficiency improvement, and sustainability assessment to enhance rice husk utilization as a renewable energy source.

## 1. INTRODUCTION

The global energy crisis, rising fossil fuel prices, and increasing environmental concerns have encouraged many countries to accelerate the transition toward renewable energy sources. Fossil fuel dependence not only threatens long-term energy security but also contributes significantly to greenhouse

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gas emissions and climate change (Harahap, Nasution, and ... 2020). Therefore, developing sustainable and environmentally friendly alternative energy sources has become a global priority (Mesin et al. 2021).

Among renewable energy resources, biomass has gained considerable attention due to its abundance, renewability, and relatively carbon-neutral characteristics (Hasrudy Siregar et al. 2022; Madhubashani et al. 2021). In agricultural countries such as Indonesia, agricultural residues represent an important biomass resource with significant energy potential. One of the most abundant agricultural wastes is rice husk, a by-product of rice milling that accounts for approximately 20–30% of total rice grain weight (Surahmanto et al. 2023).

Indonesia is one of the largest rice-producing countries in the world, generating millions of tons of rice husk annually. However, a large portion of this residue remains underutilized or is disposed of through open burning, causing environmental pollution and wasting potential energy resources. This condition creates opportunities to convert rice husk into value-added renewable fuel products (Budiyono et al. 2023).

Rice husk possesses favorable fuel characteristics, including lignocellulosic composition, wide availability, and calorific values ranging from 13–16 MJ/kg. It can be converted into useful energy through combustion, gasification, pyrolysis, briquetting, and pelletizing technologies (Siregar, Siregar, and Effendi 2021). However, several challenges remain, such as high ash content, low bulk density, conversion efficiency limitations, and emission concerns.

Previous studies have primarily focused on technical performance and conversion technologies. However, limited studies have comprehensively mapped global research trends, publication growth, collaboration networks, and emerging themes related to rice husk biomass utilization. This indicates a research gap in understanding the scientific development of this topic from a bibliometric perspective (Khamis et al. 2026).

Therefore, this study aims to conduct a bibliometric analysis of rice husk biomass research published in the Scopus database from 2020 to 2026. This study contributes by identifying publication trends, leading journals, collaboration patterns, and future research opportunities to support sustainable biomass energy development.

## 2. METHOD

The research method used in this study is a bibliometric method with a quantitative descriptive approach. This approach was chosen to systematically analyze the development of scientific publications related to the potential of rice husk biomass as an environmentally friendly alternative fuel. The bibliometric method allows for the identification of research patterns, scientific collaborations, and topic trends based on quantitative data from the scientific literature (Duque-Acevedo et al. 2022; Khamis et al. 2026). The primary data source was obtained from the Scopus database, an internationally reputable database with extensive coverage of scientific publications. The data used was limited to journal articles published between 2020 and 2026 to ensure the novelty and relevance of the research. The search process was conducted using a combination of keywords such as "biomass," "rice husk," "renewable energy," "bioenergy," and "agricultural waste" with the help of Boolean operators (AND, OR) to obtain specific and focused results.

The data collection technique involved several stages: identification, screening, and selection of articles. In the identification stage, all documents relevant to the keywords were collected from Scopus. Next, a screening process was conducted based on inclusion criteria, including document type (journal article), language (English), and topic relevance to the research focus. Duplicate or irrelevant articles were eliminated to maintain data validity. After the selection process, the data was exported in CSV or RIS format to facilitate further analysis. This study used VOSviewer software to visualize the bibliometric network and Microsoft Excel to process descriptive data, such as publication distribution, keyword frequency, and author and institutional contributions.

Data analysis was conducted using several key techniques: co-authorship analysis to identify collaboration patterns among researchers, keyword co-occurrence analysis to uncover dominant themes and interrelationships between topics, and citation analysis to assess the influence and contribution of publications in the field. Furthermore, research trend analysis was conducted to observe the development

of the number of publications and the evolution of topics over time. The overall research process included keyword selection, data collection from Scopus, article screening and selection, data extraction, analysis using VOSviewer and Excel, and network visualization and interpretation of results. This process ensures that the research results provide a comprehensive overview of the development of rice husk biomass research as an alternative energy source.

### 3. RESULTS AND DISCUSSION

#### 1. Most Relevant Sources

To understand how scientific publication trends in rice husk biomass are evolving, it is important to first identify the most active and influential journal sources. This analysis provides an overview of the primary channels for research dissemination and identifies the dominant scientific centers in the field of biomass-based renewable energy (Geethakarathi 2021).

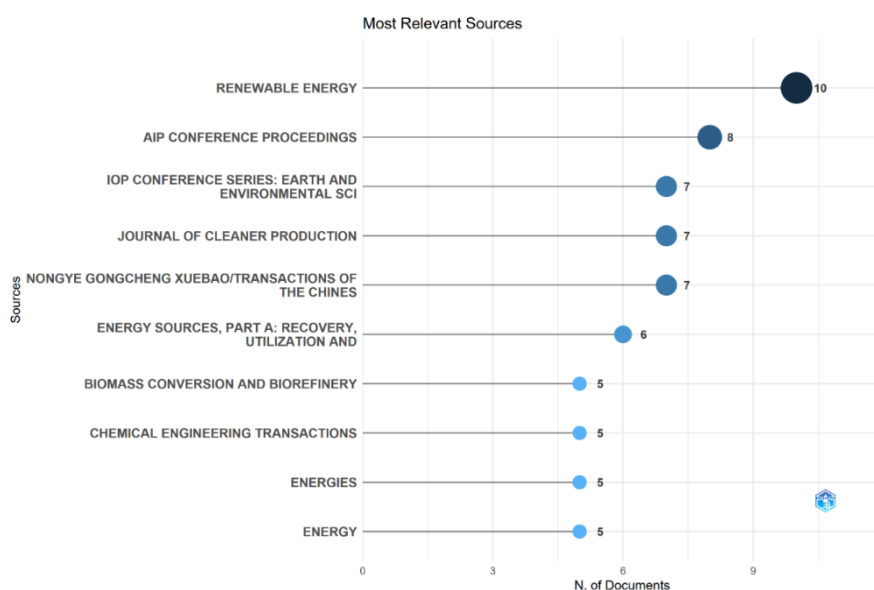


Figure 1. Most Relevant Sources

Based on this visualization, the Renewable Energy journal is the most dominant publication source with the highest number of documents (Sasongko et al. 2024). This indicates that the journal has a strong focus on renewable energy issues, including biomass. Furthermore, the presence of proceedings such as the AIP Conference Proceedings and the IOP Conference Series indicates that research developments are also frequently presented in scientific forums. Other journals, such as the Journal of Cleaner Production, indicate the link between biomass and environmental sustainability issues. This distribution demonstrates that biomass research is interdisciplinary and spread across various reputable scientific platforms (Cho et al. 2025).

To gain a more comprehensive understanding of the distribution of scientific publications in the field of rice husk biomass, it is necessary to identify the most active and significantly contributing journal sources (Stefanelli et al. 2023). This analysis is essential for identifying centers of knowledge dissemination and journals with a strong focus on biomass-based renewable energy development. The results of the data processing are then presented in the following table.

Table 1. Top Publication Sources on Rice Husk Biomass Research

NO	Journal Source	Number of Documents
1	Renewable Energy	10
2	AIP Conference Proceedings	6

3	IOP Conference Series: Earth and Environmental Science	5
4	Journal of Cleaner Production	4
5	Energy Sources, Part A: Recovery, Utilization and Environmental Effects	3
6	Biomass and Bioenergy	3
7	Sustainability (Switzerland)	2
8	Energy Reports	2
9	Renewable and Sustainable Energy Reviews	2
10	Materials Today: Proceedings	2

The following table shows that the Renewable Energy journal is the most dominant publication source with the highest number of documents. This indicates that the journal plays a strategic role in disseminating research related to renewable energy, particularly biomass (Jagnade and Panwar 2024). Furthermore, the presence of proceedings such as the AIP Conference Proceedings and the IOP Conference Series indicates that research development is also encouraged through international scientific forums. Journals such as the Journal of Cleaner Production and Biomass and Bioenergy reflect the integration of energy and environmental sustainability. Overall, this distribution demonstrates that rice husk biomass research is developing multidisciplinary and is spread across various reputable scientific platforms (Srivastava et al. 2023).

## 2. Documents by Year

In addition to publication sources, the dynamics of research development can also be observed through trends in the number of publications over time. This analysis is important to determine the extent to which the topic of rice husk biomass is gaining or losing attention in the global scientific community.

Documents by year

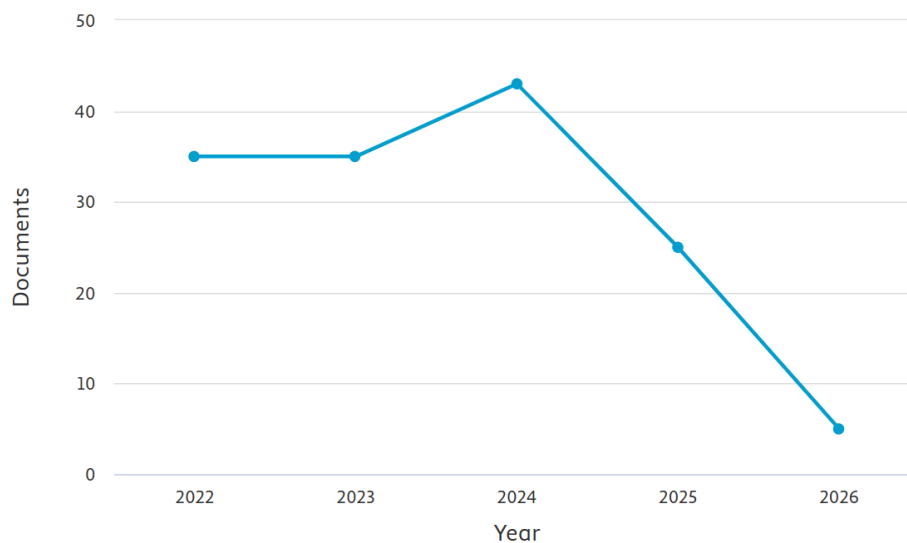


Figure 2. Annual Publication Trends (2022–2026)

The graph shows an increase in the number of publications from 2022 to a peak in 2024. This reflects growing interest in biomass energy as an alternative solution amid the global energy crisis. However, after this period, there is a decline in 2025 and 2026, likely influenced by limited recent data or a change in research focus (Wu et al. 2025). Overall, this trend confirms that biomass research is still in its developing phase and remains relevant for further study.

## 3. Network Visualization (Co-occurrence Keywords)

To gain a deeper understanding of the scientific structure of biomass research, an analysis of the relationships between the concepts used by researchers is necessary (Xu et al. 2026). These relationships can be identified through the appearance of associated keywords in various scientific publications.

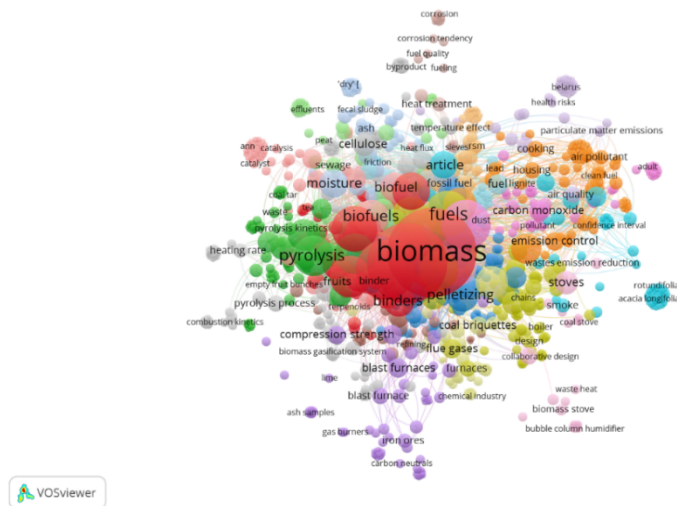


Figure 3. Keyword Co-occurrence Network

The visualization shows that "biomass" is the main hub in the research network, with strong links to keywords such as "biofuels," "pyrolysis," and "fuels." This indicates that the primary research focus lies on biomass energy conversion processes. Furthermore, links to keywords such as "emission control" and "air quality" indicate a concern for environmental impacts. The resulting clusters reflect the existence of several research subfields developing in parallel, such as conversion technology and environmental aspects (Przybyla and Nadaleti 2023; Siregar et al. 2024).

To understand the conceptual structure of rice husk biomass research, an analysis of the interrelationships between keywords used in scientific publications is necessary. This analysis aims to identify key themes and the relationships between emerging research topics. The results of the co-occurrence analysis are then summarized in the following table to provide a more structured overview.

Table 2. Most Frequent Keywords in Rice Husk Biomass Research

No	Keywords	Frequency (Occurrence)	Description
1	Biomass	High	Main research topic
2	Biofuels	High	Biomass energy conversion
3	Pyrolysis	High	Biomass processing technology
4	Fuels	Medium	Energy application
5	Pelletizing	Medium	Fuel quality improvement
6	Combustion	Medium	Combustion process
7	Emission Control	Medium	Environmental impact
8	Air Quality	Low-Medium	Environmental quality
9	Carbon Monoxide	Low	Gas emissions
10	Agricultural Waste	Medium	Biomass source

The table above shows that the keyword "biomass" is the primary focus of research, indicating that the focus of studies is still oriented towards the use of biomass as an energy source (Le et al. 2022). The strong association with keywords such as "biofuels" and "pyrolysis" indicates that much research is directed at energy conversion technologies. Furthermore, the emergence of keywords such as "emission control"

and "air quality" indicates a growing concern about the environmental impacts of biomass use. Therefore, it can be concluded that research in this field focuses not only on technical aspects but also encompasses broader sustainability and environmental dimensions(Przybyla and Nadaleti 2023).

#### 4. Country Collaboration Map

Research development is inseparable from contributions and collaboration between countries. Therefore, analyzing geographic distribution is crucial for identifying countries that are actively participating and patterns of international cooperation in biomass research.

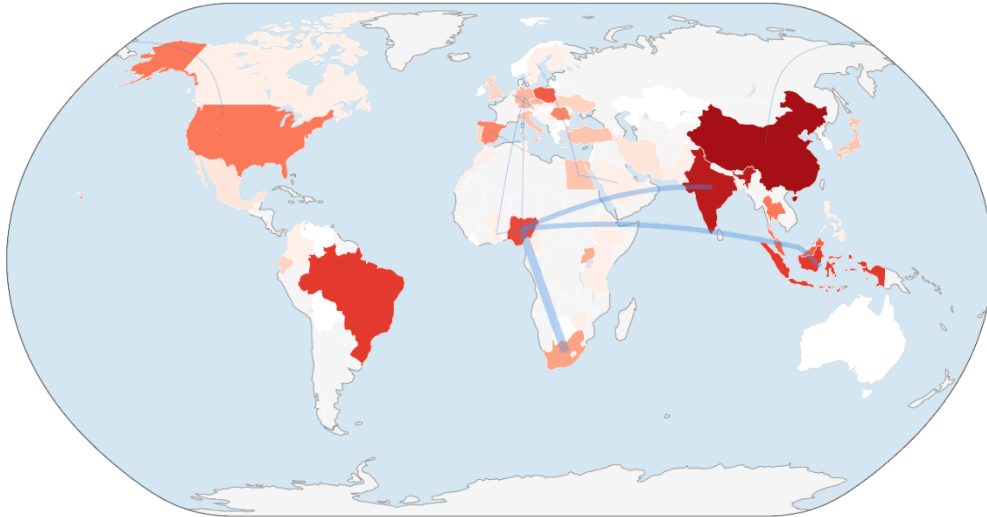


Figure 4. Country Collaboration Map

The map shows that countries such as China, India, and Indonesia have made significant contributions to biomass research. This is closely related to the availability of biomass resources in these countries. Furthermore, cross-regional collaboration is evident, particularly between Asia, Europe, and Africa. This collaboration reflects the fact that biomass research is a global issue that requires synergy between countries in technology development and implementation(Pueyo 2026).

#### 5. Thematic Map

To understand the direction and position of the development of research topics, a thematic mapping is needed that is able to group the main issues based on their level of importance and maturity in the scientific literature.

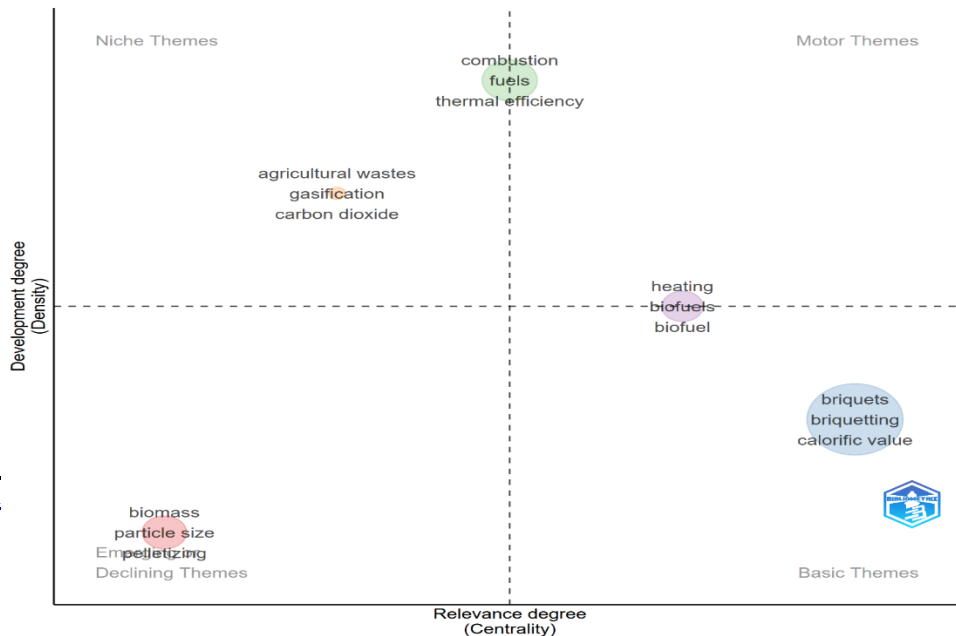


Figure 5. Thematic Map of Research Topics

The thematic map shows that topics like "combustion" and "thermal efficiency" fall into the motor themes category, meaning they are highly developed and play a significant role in research. Meanwhile, "briquettes" and "calorific value" fall into the basic themes category, which serve as the foundation for research but still require further development. Themes like "gasification" fall into the niche themes category, which are specific but well-developed. Meanwhile, "biomass" and "pelletizing" fall into the emerging or declining themes category, indicating potential new trends or declining interest. This mapping provides a strategic overview of the future direction of biomass research(Kole et al. 2022).

#### 4. CONCLUSION

This study analyzed the development of global research on rice husk biomass as an environmentally friendly alternative fuel using a bibliometric approach. The results indicate a significant increase in scientific publications, particularly during the 2022–2024 period, reflecting the growing international interest in renewable energy solutions based on agricultural biomass. Renewable Energy was identified as the most dominant publication source, showing that this topic has gained strong attention within the field of sustainable energy research.

Furthermore, keyword network analysis revealed that the major research focus is concentrated on biomass conversion technologies such as pyrolysis, combustion, and biofuels, along with increasing attention to environmental aspects such as emission control and air quality. Thematic mapping also showed that combustion efficiency and thermal performance remain central themes, while pelletizing, briquetting, and environmental assessment have emerged as promising future research areas. International collaboration among countries such as China, India, and Indonesia demonstrates that rice husk biomass research has broad global relevance, particularly in countries with strong agricultural sectors.

The scientific contribution of this study lies in providing a comprehensive overview of publication trends, research hotspots, collaboration patterns, and thematic evolution in rice husk biomass studies. These findings can serve as a strategic reference for researchers, policymakers, and industry stakeholders in developing sustainable biomass energy programs. Future studies are recommended to focus on techno-economic feasibility analysis, life cycle assessment, emission reduction technologies, supply chain optimization, and pilot-scale implementation to enhance the practical utilization of rice husk biomass as a competitive renewable energy source.

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