Journal of Global Sustainable Agriculture, 5(3): 361-367, Desember 2025 E-ISSN: 2775-3514
DOI:10.32502/jgsa.v5i3.1266 P-ISSN: 2775-3522

Dari Limbah Menjadi Energi: Penilaian Keberlanjutan Pembangkit Listrik Biomassa Sekam Padi

From Waste to Energy: Sustainability Assessment of Rice Husk Biomass Power Generation

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Received 10 October 2025, Accepted 30 December 2025, Published 31 December 2025

ABSTRAK

Penelitian ini bertujuan untuk mengevaluasi status keberlanjutan pengolahan sekam padi sebagai bahan bakar Pembangkit Listrik Biomassa (PLTBm) di PT Buyung Putra Pangan. Penelitian ini dilakukan di Kabupaten Ogan Ilir, Provinsi Sumatera Selatan, dari Januari hingga Mei 2023. Pendekatan yang digunakan adalah pendekatan preferensi ahli melalui Diskusi Kelompok Fokus (FGD) yang melibatkan berbagai pemangku kepentingan. Data dianalisis menggunakan metode Multidimensional Scaling (MDS) yang terintegrasi ke dalam perangkat lunak RAPFISH, dengan fokus pada tiga dimensi keberlanjutan: sosial, ekonomi, dan lingkungan. Hasil penelitian menunjukkan bahwa dimensi ekonomi dikategorikan sebagai cukup berkelanjutan (indeks 61,21), sedangkan dimensi sosial (45,92) dan lingkungan (38,56) dikategorikan sebagai kurang berkelanjutan. Indeks keberlanjutan rata-rata sebesar 48,56 menunjukkan bahwa pengolahan sekam padi di PT Buyung Putra Pangan secara umum berada dalam status kurang berkelanjutan. Temuan ini menyoroti perlunya peningkatan atribut sensitif, khususnya dalam pengelolaan dampak lingkungan dan peningkatan penyuluhan masyarakat, untuk memastikan bahwa pengolahan sekam padi selaras dengan prinsip-prinsip pembangunan berkelanjutan.

Kata kunci: Energi Biomassa; Pembangkit Listrik Biomassa; Sekam Padi; Keberlanjutan

ABSTRACT

This study aimed to evaluate the sustainability status of rice husk waste processing as fuel for Biomass Power Plant (PLTBm) at PT Buyung Putra Pangan. The research was conducted in Ogan Ilir Regency, South Sumatra Province, from January to May 2023. The approach used was an expert preference approach through Focus Group Discussions (FGDs) involving various stakeholders. Data were analyzed using the Multidimensional Scaling (MDS) method integrated into the RAPFISH software, focusing on three sustainability dimensions: social, economic, and environmental. The results showed that the economic dimension was categorized as moderately sustainable (index 61.21), while the social (45.92) and environmental (38.56) dimensions were categorized as less sustainable. The average sustainability index of 48.56 indicates that the rice husk waste processing at PT Buyung Putra Pangan is generally in a less sustainable status. These findings highlight the need for improvements in sensitive attributes, particularly in managing environmental impacts and enhancing community outreach, to ensure that the rice husk processing aligns with sustainable development principles.

Keywords: *Biomass Energy; Biomass Power Plant; Rice Husk; Sustainability*

INTRODUCTION

Energy has become a fundamental need, and energy consumption continues to increase every year. However, most of the energy demand is still supplied by fossil fuels such as petroleum, coal, and natural gas (Suganal & Hudaya, 2019). On the other hand, according to Government Regulation of the Republic of Indonesia Number 79 of 2014 Concerning National Energy Policy, the utilization of New and Renewable Energy (NRE) in the national energy mix must reach at least 23% by 2025 and 31% by 2050. Therefore, the development of new and renewable energy is continuously being promoted, including biomass as a source of renewable energy (Udjianto et al., 2021).

Biomass refers to all organic materials derived from plant or animal sources, such as agricultural residues, wood waste, straw, food waste, and various other types of organic waste (Sulasminingsih et al., 2024). Biomass can be used directly as fuel or through combustion processes. In addition, biomass can also serve as fuel for electricity generation (Mulyana, 2016). Rice husks are one of the most abundant types of biomass in Indonesia, including in Ogan Ilir Regency, South Sumatra. Rice husk is the hard protective layer of rice grains that is separated from paddy grains as a byproduct during the milling process. Typically, the milling process yields approximately 20–30% husk, 8–12% bran, and 50–63.5% milled rice from the initial weight of the paddy PU(Pujotomo, 2017).

According to data from the Statistics Indonesia (2023), in 2021 Ogan Ilir Regency produced approximately 78,146 tons of paddy (dry unhusked rice). At this level of production, it is estimated that

more than 15,000 tons of rice husk are generated annually. However, the utilization of rice husk waste to reduce the environmental impact of rice production remains very limited. In fact, agricultural waste that undergoes natural decomposition tends to do so slowly, leading to environmental pollution and potential adverse effects on human health (Listiana et al., 2021).

PT Buyung Putra Pangan, located in Ogan Ilir Regency, South Sumatra, is a company primarily engaged in the production and trade of rice under its main brands HOKI and Topi Koki. Previously, the rice husk waste generated daily was merely piled up around the milling plant. This aligns with the findings of Fahmi & Nurfalah (2016), who state that most producers only use rice husk as organic fertilizer, with a significant portion being burned or discarded, thus wasting its potential. The burning of rice husk piles not only lacks economic value but also poses environmental hazards.

To address the negative environmental impacts, PT Buyung Putra Pangan has initiated the use of rice husk waste as a fuel source for a biomass power plant, which is capable of converting 4 tons of rice husk into 3 MW of electricity per hour. Moreover, the construction of this rice husk-fueled biomass power plant by PT Buyung Putra Pangan serves as a noteworthy example of environmentally friendly renewable energy development and implementation, and it deserves serious attention.

The establishment of a biomass power plant fueled by rice husks is a novel initiative for the local community. As such, the development of large-scale infrastructure is likely to generate both positive and negative impacts. Therefore, such infrastructure development should consider the concept of sustainable development in order to minimize its negative consequences (Adharani, 2017).

Sustainable development is a strategy for utilizing natural resources in a manner that does not compromise their functional capacity, thus ensuring long-term benefits for humanity (Sompotan, 2016). Good development practices should demonstrate positive outcomes in environmental, social, and economic aspects. This is in accordance with Law of the Republic of Indonesia Number 32 of 2009 Concerning Environmental Protection and Management, which states that sustainable development is a conscious and planned effort that integrates environmental, social, and economic aspects into development strategies to ensure the integrity of the environment, as well as the safety, capability, welfare, and quality of life of both present and future generations.

Thus, assessing the sustainability of rice husk waste processing as a fuel for the biomass power plant at PT Buyung Putra Pangan is of significant interest. Such assessment is essential to ensure that the processing of rice husk waste for energy production aligns with the principles of sustainable development.

RESEARCH METODOLOGY

Time and Location

This research was conducted from January to May 2023. The study was carried out at PT Buyung Putra Pangan and within the Ogan Ilir Regency, South Sumatra Province. PT Buyung Putra Pangan is a large-scale rice milling industry that utilizes rice husk waste as a fuel source for a biomass power plant.

Population and Sample

The population of this study includes all parties with competence, experience, and relevance to rice husk waste management and its utilization as biomass power plant fuel. The sample was selected purposively based on the following criteria (Marimin, 2004):

a) individuals with experience and expertise in the relevant field,
b) individuals with a reputation or position relevant to the research topic,
c) individuals with high credibility who are willing to provide information,
d) individuals residing or working within the research area.

The expert respondents involved include:

a) Operational Supervisor of the Biomass Power Plant at PT Buyung Putra Pangan
b) Representative from the Environmental Office of Ogan Ilir Regency
c) Representative from the Agriculture and Food Security Office of Ogan Ilir Regency
d) Representative from PT PLN (Persero)
e) Activist from WALHI (Indonesian Forum for the Environment), South Sumatra Chapter
f) Village Heads of Pegayut and Harapan Villages

Types and Methods of Data Collection

This study employed both primary and secondary data:

a) Primary data were collected through Focus Group Discussions (FGDs) with experts to obtain preference scores for sustainability attributes.
b) Secondary data were obtained from regulatory documents, literature, and institutional reports, such as Law of the Republic of Indonesia Number 32 of 2009 Concerning Environmental Protection and Management and Presidential Regulation No. 59 of 2017 on the Implementation of Sustainable Development Goals.

Data Analysis

The sustainability assessment of rice husk waste processing as biomass power plant fuel was conducted using the Multidimensional Scaling (MDS) approach, integrated into the RAPFISH (Rapid Appraisal for Fisheries) software, developed by the Fisheries Centre, University of British Columbia (Pitcher & Preikshot, 2001). Although originally

E-ISSN: 2775-3514
P-ISSN: 2775-3522

designed for the fisheries sector, this method has been widely applied to assess sustainability in various other sectors.

The assessment focused on three main sustainability dimensions: social, economic, and environmental—each consisting of six attributes. Scores for each attribute were assigned by experts using a scale of 0–2, representing the condition of the attribute from poor to good.

The results of the MDS analysis will indicate the sustainability status of each dimension and serve as a foundation for developing policy improvement recommendations. Dimensions with lower sustainability scores will be identified as priority areas for improvement to enhance the sustainability of rice husk waste utilization as biomass power plant fuel at PT Buyung Putra Pangan.

The sustainability analysis used in this study refers to Susilo (2003) as cited in Hamdan (2007), which classifies sustainability status into four (4) categories, namely: (1) unsustainable, (2) less sustainable, (3) moderately sustainable, and (4) sustainable. The complete classification is presented in Table 1.

Table 1. Sustainability Index of Rice Husk Waste Management as Biomass Fuel

Index Value	Category
0.00 – 25.00	Unsustainable
25.01 – 50.00	Less sustainable
50.01 – 75.00	Moderately sustainable
75.01 – 100.00	Sustainable

RESULTS AND DISCUSSION

The sustainability assessment of rice husk waste management as fuel for the biomass power plant at PT Buyung Putra Pangan was carried out by analyzing three sustainability dimensions (social, economic, and environmental) as evaluated by expert respondents. Following the expert assessments, the RAPFISH method was applied to generate sustainability indices for each dimension. The results of the analysis are presented as follows.

Social Dimension

Based on the analysis using the RAPFISH software, the sustainability index for the social dimension was found to be 45.92 (Figure 1). This value falls within the range of 25.01–50.00, indicating that, according to the sustainability status criteria, the social dimension of rice husk waste management for biomass power plant at PT Buyung Putra Pangan is categorized as less sustainable.

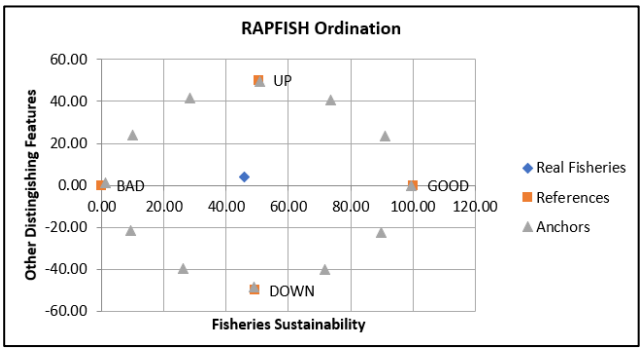

Figure 1. RAPFISH Ordination Results: Social Dimension

The leverage analysis (leverage of attributes) using RAPFISH identified the main leverage factor in the social dimension as the provision of information and/or environmental damage disclosure to the community, which scored 3.92. This indicates that the development and operation of the rice husk-fueled biomass power plant at PT Buyung Putra Pangan have not been accompanied by adequate information dissemination or public education regarding potential environmental impacts to nearby communities.

This is particularly significant considering that the utilization of rice husk waste at PT Buyung Putra Pangan directly affects the surrounding communities, especially residents of Pegayut and Harapan Village, which are located in proximity to the biomass power plant facility. Both village heads confirmed that no public consultation or socialization had been conducted regarding the operation of the biomass power plant. Furthermore, local residents reported learning about the waste-to-energy initiative only through informal channels within the community.

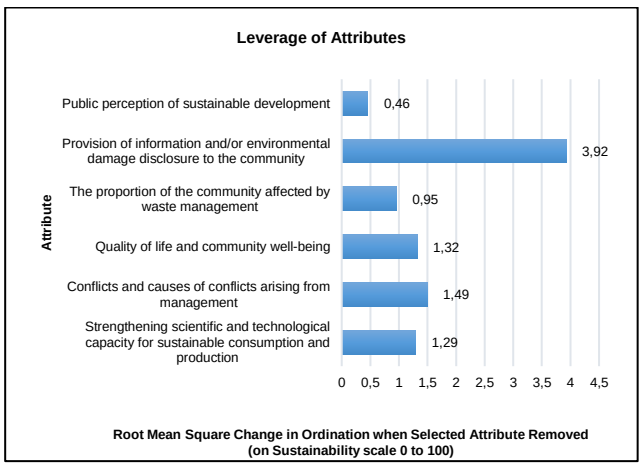

Figure 2. Leverage of Attributes Analysis Results for the Social Dimension

The lack of communication regarding the biomass power plant development and operation could potentially lead to social conflicts. This is evidenced by the conflict and conflict-triggering factors attribute, which scored 1.49. During the initial operation phase of the biomass power plant, there were public protests due to excessive noise from the machinery and airborne ash and smoke from the

E-ISSN: 2775-3514
P-ISSN: 2775-3522

combustion process, which significantly disrupted daily activities and posed health risks to nearby residents. In response, the company addressed the issue by installing soundproofing equipment and scrubbers on the smokestacks to reduce emissions and ash dispersion.

This aligns with the findings of (Putri, 2019), who emphasized that power plants should be equipped with adequate emission control technologies, such as sound dampeners and smokestack scrubbers, to reduce the air pollution they produce. Proper emission control can help mitigate the negative impacts of air pollution on human health and the environment.

The lowest-scoring attribute in the social dimension was public perception of sustainable development, with a score of 0.46. This attribute was considered to have minimal influence, as the local farmers' and residents' understanding of sustainable development did not significantly affect the rice husk waste management process for biomass power plant at PT Buyung Putra Pangan. Other attributes with relatively low scores include strengthening scientific and technological capacity for sustainable consumption and production, which scored 1.29, and the proportion of the community affected by waste management, which scored 0.95.

Economic Dimension

The sustainability index for rice husk waste management as fuel for the biomass power plant at PT Buyung Putra Pangan from the economic dimension was calculated at 61.21 (Figure 3), which falls under the category of moderately sustainable. This index value indicates that the rice husk waste processing activities for biomass power plant at PT Buyung Putra Pangan deliver a satisfactory economic performance and contribute tangible benefits to both the company and the local economy.

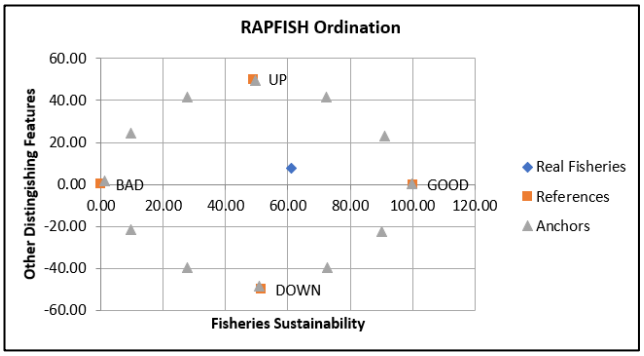

Figure 3. RAPFISH Ordination Results: Economic Dimension

The main leverage attribute in the economic dimension, as shown in Figure 4, is sustainable management and efficient utilization of natural resources, with a score of 6.35. The management and utilization of rice husk as a biomass fuel at PT Buyung Putra Pangan are considered effective and appropriate solutions to address the problem of rice husk waste, which was previously either piled up around Pegayut and Harapan villages or burned without treatment.

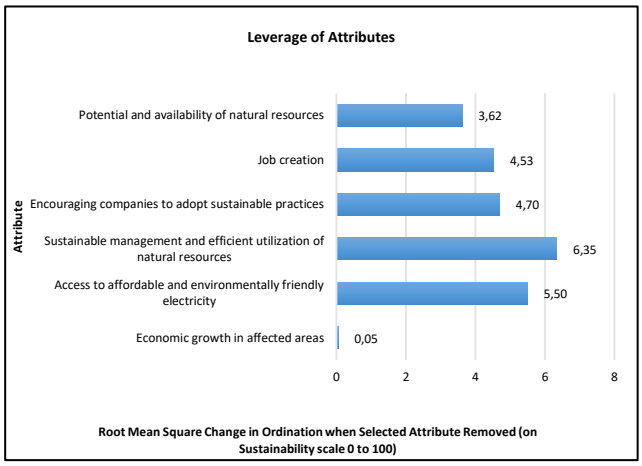

Figure 4. Leverage of Attributes Analysis Results for the Economic Dimension

This finding is consistent with Sulistyaningsih (2019), who noted that the utilization of rice husk waste can reduce environmental pollution. Prior to the development of the biomass power plant, PT Buyung Putra Pangan lacked proper regulation and procedures for handling the large amounts of rice husk generated during the milling process. With a milling capacity of 400 tons per day, the plant produces approximately 80 tons of rice husk waste daily. Given this volume, processing and reusing the husk as fuel is clearly more economically advantageous than allowing it to accumulate or go to waste.

The rice husk waste generated from the rice milling machines is directly channeled into the feeder tank of the biomass power plant, eliminating the need for transportation costs. Additionally, the ash residue from combustion is reused as fertilizer on the paddy fields owned by PT Buyung Putra Pangan. Rice husk ash (RHA) can serve as a substitute for inorganic fertilizers or be combined with them to enhance plant growth (Saranya et al., 2018).

Currently, the biomass power plant is not yet able to operate 24 hours a day due to a lack of skilled personnel to manage the power generation system and insufficient supply of rice husk waste. These constraints have resulted in suboptimal operational performance of the biomass power plant.

Another leverage attribute, with a score of 5.50, is access to affordable and environmentally friendly electricity. The electricity generated by the biomass power plant is utilized to meet the internal electricity needs of the company. Although it does not yet cover 100% of the company's electricity consumption, the biomass power plant has significantly reduced reliance on electricity from PT PLN (Persero) and contributed to lower energy costs. Moreover, the utilization of rice husk waste for energy production represents an eco-friendly alternative to managing agricultural waste generated by the

E-ISSN: 2775-3514
P-ISSN: 2775-3522

company.

On the other hand, the attribute with the lowest score in the economic dimension is economic growth in affected areas. The development and operation of the biomass power plant are perceived to have no significant economic impact on the surrounding communities. Economic impact in this context refers to the indirect influence of the biomass power plant project on the number and types of economic activities in the vicinity of PT Buyung Putra Pangan. Other attributes assessed in the economic dimension include potential and availability of natural resources, with a score of 3.62, job creation, with a score of 4.53, and encouraging companies to adopt sustainable practices, with a score of 4.70.

Enviromental Dimension

The analysis using the RAPFISH method on six attributes within the environmental dimension resulted in a sustainability index score of 38.56 (Figure 5). This score indicates that the sustainability of rice husk waste management as biomass fuel for the biomass power plant at PT Buyung Putra Pangan falls within the less sustainable category.

Further analysis of the leverage of attributes, as shown in Figure 6, identified two key attributes as particularly sensitive to the sustainability level of rice husk waste utilization for biomass power plant are the first attribute is the location of the power plant, with a leverage value of 10.80 and the second is the sustainability of environmental processes and functions, with a score of 10.72. Changes in these two leverage factors are likely to significantly influence the rise or fall of the environmental sustainability index.

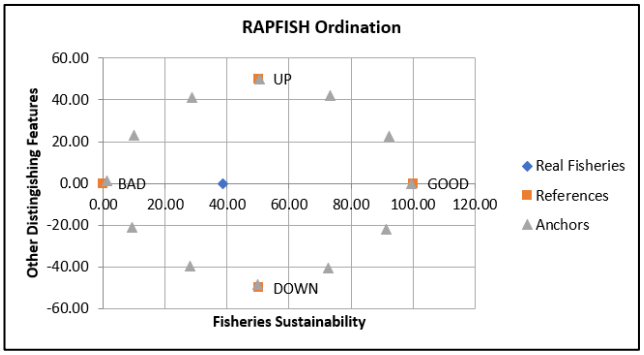

Figure 5. RAPFISH Ordination Results: Enviromental Dimension

The leverage analysis results suggest that the location of the biomass power plant requires particular attention. Although the biomass power plant was built near the rice milling facility to reduce transportation costs of rice husk, it is located in the middle of residential areas, namely Pegayut and Harapan Villages. This proximity has led to negative impacts, including noise pollution, air pollution, environmental degradation, and a decline in the residents' quality of life, particularly in terms of comfort and health. According to Pramanik et al. (2020), biomass power plants should not be located too close to residential areas, in order to prevent direct exposure of communities to the negative externalities of the plant's operations.

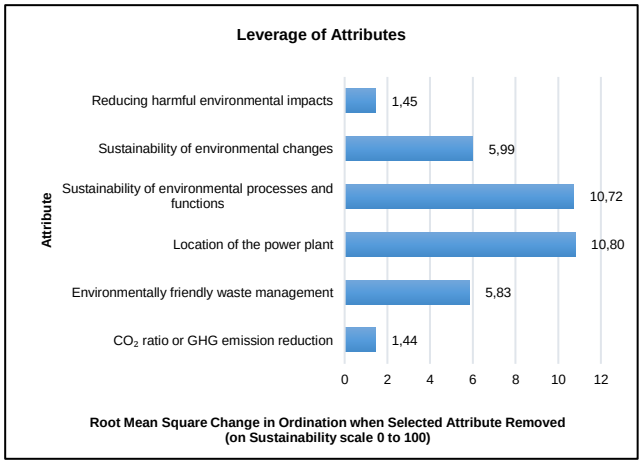

Figure 6. Leverage of Attributes Analysis Results for the Enviromental Dimension

This finding aligns with the second major leverage attribute, namely the sustainability of environmental processes and functions. Ideally, the biomass power plant should contribute to the continuous maintenance of environmental systems that support human life. However, the analysis indicates that the positive contributions of the biomass power plant are outweighed by the negative impacts experienced by the surrounding community.

One such impact is the suspected increase in greenhouse gas (GHG) emissions in the vicinity of the power plant. GHG emissions are air pollutants released into the atmosphere from the combustion processes of the biomass power plant. Although globally, biomass power plants can reduce GHG emissions by more than 95% per year compared to coal-fired power plants (Udjianto et al., 2021), the location of this biomass power plant within residential zones means that local communities still suffer from its direct environmental effects.

As a result, the lowest-scoring attribute in the environmental dimension is the CO_2 ratio or GHG emission reduction, reflecting the plant's limited perceived contribution to global emission reduction efforts. Another low-scoring attribute is reducing harmful environmental impacts, which scored 1.45. This attribute is deemed to have minimal influence on the determination of the overall environmental sustainability status of rice husk waste management at PT Buyung Putra Pangan.

Two other attributes with moderate leverage values include sustainability of environmental changes, with a score of 5.99, and environmentally friendly waste management, with a score of 5.83, each contributing to the environmental dimension of sustainability at corresponding levels.

Multidimensional Sustainability Status

The results of the RAPFISH analysis on the

sustainability status of rice husk waste management as biomass fuel at PT Buyung Putra Pangan yielded a sustainability index score of 48.56, which falls under the category of less sustainable. This score was obtained based on assessments of 18 attributes across three sustainability dimensions (social, economic, and environmental) as presented in Table 2.

Table 2. Sustainability Status of Rice Husk Waste Management as Biomass Fuel

Sustainability Dimension	Index Score	Stress Value	R^2 Value	Sustainability Status
Social	45,92	0.16	0.94	Less sustainable
Economic	61,21	0.16	0.94	Moderately sustainable
Enviromental	38,56	0.15	0.93	Less sustainable
Average	48,56			Less sustainable

Source: Primary Data Analysis, 2023

The RAPFISH analysis further shows that the evaluation of all attributes related to the sustainability status of rice husk waste utilization for biomass power plant at PT Buyung Putra Pangan is considered statistically reliable. This is supported by a stress value below 25%, specifically ranging from 0.15 to 0.16, and a coefficient of determination (R^2) close to 1, between 0.93 and 0.94. These values indicate that the attributes used to assess the sustainability status across the three dimensions are appropriate and sufficiently robust.

The index scores from each of the three dimensions, which serve as indicators for determining the overall sustainability status of the rice husk waste management for biomass power plant at PT Buyung Putra Pangan, are illustrated in a kite diagram shown in Figure 4.

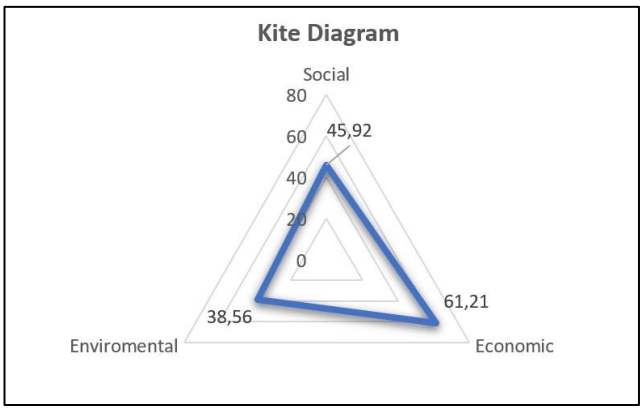

Figure 4. Kite Diagram of Sustainability Status

The scores for each dimension are as follows: the economic dimension scored 61.21, the social dimension scored 45.92, and the environmental dimension scored 38.56. Among these, both the social and environmental dimensions fall within the less sustainable category, highlighting critical areas requiring attention and improvement.

Based on the leverage of attributes analysis, six key attributes across the three dimensions were identified as sensitive contributors to the overall multidimensional sustainability index. This indicates that targeted improvements in these leverage attributes are necessary in order to enhance the overall sustainability of rice husk waste management as biomass fuel at PT Buyung Putra Pangan.

CONCLUSION

The multidimensional sustainability status of rice husk waste management as biomass fuel at PT Buyung Putra Pangan is categorized as less sustainable, with an average sustainability index of 48.56. The economic dimension is considered moderately sustainable, with a score of 61.21, while the social and environmental dimensions are categorized as less sustainable, with scores of 45.92 and 38.56, respectively. Statistical tests indicate that the RAPFISH analysis is an appropriate tool for evaluating the sustainability of rice husk waste management for biomass fuel at PT Buyung Putra Pangan in a quantitative and rapid manner. Efforts to improve the sustainability index should focus on enhancing the performance of key leverage attributes.

ACKNOWLEDGEMENTS

The author would like to express sincere gratitude to the leadership and staff of PT Buyung Putra Pangan (especially Mr. Candra), the Environmental Office of Ogan Ilir Regency, the Food Security and Agriculture Office of Ogan Ilir Regency, the Statistics Indonesia (BPS) Office of Ogan Ilir Regency, WALHI South Sumatra, PT PLN (Persero) UP3 Ogan Ilir, as well as the Heads of Harapan and Pegayut Villages for their support, information, and participation in the implementation of this research.

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