Impact of Charcoal Briquettes from Rice Husk on the Environment in Comparison to Conventional Fuels

Ali Ahmad[1], Hafiz Muhammad Safdar Khan[1], Imran Shauket[1] and Muhammad Imran Khan[2]

https://doi.org/10.62345/jads.2026.15.1.15

Abstract

The rise in environmental, social, and economic issues associated with traditional fuels has driven the popularity of renewable and waste based energy sources. Rice husk is a significant agricultural waste in rice producing nations and it is usually disposed of by open burning or dumping, which causes air pollution and environmental degradation. The paper will be a critical review of the environmental impacts of rice husk charcoal briquettes over traditional fuels, including coal, wood charcoal, kerosene, diesel, and liquefied petroleum gas. The analysis is done using a life cycle approach that assesses sourcing of raw materials, manufacturing, combustion, greenhouse gas emissions, air pollutants, ash, land use, and socio economic aspects. According to the findings, rice husk briquettes are highly beneficial for the environment because they are a renewable, waste product. They have a lower net global warming potential than fossil fuels and less pressure on forest resources than wood charcoal. Though these factors, such as high ash content and energy requirements during carbonization, remain, they can be improved in terms of sustainability through technological advancements and policy frameworks. In general, rice husk briquettes are a potentially worthwhile avenue of cleaner energy transitions, rural incomes in developing economies, and environmental safeguards.

Keywords: Air Pollution, Biomass Energy, Environmental Impact, Greenhouse Gas Emissions, Renewable Fuel, Rice Husk Briquettes, Sustainable Energy, Waste Valorisation.

Introduction

The 21st century faces an uphill dual challenge: meeting the rising energy needs of a growing world population and swiftly curbing the rampant environmental degradation associated with the traditional energy system. The burning of fossil fuels, coal, oil, and natural gas is the most common cause of anthropogenic climate change, as it accounts for around 77% of the world's primary energy use and most of the carbon dioxide (CO2) emissions. At the same time, biomass fuels such as firewood and primitive charcoal remain the primary energy source for almost 2.4 billion people in most parts of the developing world. This reliance causes a wave of harmful effects: rapid deforestation and loss of carbon sinks, indoor air pollution that causes millions of premature deaths each year, and long-term and labour costs, especially among women and children, in collecting fuel (Kipngetich et al., 2023).

Such a complicated energy scenario requires a shift in paradigm that goes beyond renewable and low-carbon solutions to include available, affordable options that can help solve localized

[1]*Department of Structures and Environmental Engineering,University of Agriculture Faisalabad, Pakistan. *Corresponding Author Email: muhammad.safdar@uaf.edu.pk*

[2]*Institutes of Soil and Environmental Sciences, Faculty of Agricultural, University of Agriculture Faisalabad, Pakistan*

Compliance with ethical standards: There are no conflicts of interest (financial or non-financial). This study did not receive any funding.

environmental problems (Tanko et al., 2001). In this regard, the situation of transforming agricultural residues into solid biofuel is an interesting opportunity at the crossroads of waste disposal, renewable energy, and rural development. Among these residues, rice husk, a protective layer removed during rice milling, is particularly notable for its enormous global production and its inability to be properly disposed of (Unrean et al., 2018). Paddy rice is grown worldwide, producing more than 750 million metric tons each year, which yields about 150 million tons of rice husk. Considered a low value waste in historical times, it is typically disposed of either through open field burning, which results in the formation of dense clouds of particulate matter (PM), greenhouse gases and other impurities or uncontrolled dumping, which causes the production of methane and the development of leachates (Saeed et al., 2021).

Converting this problem residue into charcoal briquettes provides an avenue to convert environmental liability into a sustainable energy resource. Rice husk charcoal briquettes are made by carbonization (slow pyrolysis) and densification, which increases the power density of the final solid fuel and improves its uniformity of burning properties compared to raw husk (Ugwu et al., 2024). This process aligns with the principles of the circular bio-economy, which aim to derive the greatest benefits from biomass resources by cascading their use and reducing waste. The environmental benefits that can be achieved are multifaceted: the replacement of fossil fuels will decrease the net greenhouse gas emissions, the replacement of wood charcoal will decrease the strain on forest ecosystems, and the use of the waste stream will help reduce pollution caused by its open burning (Akolgo et al., 2021).

Nevertheless, the suggestion of the rice husk briquettes as an indisputably green alternative needs to be carefully examined at a system level. An actual examination of the environment should not only be conducted at the point of combustion but also throughout the whole life cycle (Kipngetich et al., 2023). The following are some key questions: Does the energy used in carbonization and briquetting counteract the carbon benefits? What is the comparison of emissions of non CO2 emissions, such as carbon monoxide (CO) and particulate matter ($PM_{2.5}$), when using conventional fuels in those cook stoves or heaters used in real-life scenarios? Implications of high silica ash generated and its inclusiveness in a circular model. Moreover, the socio-economic aspect is vital; for successful adoption, briquettes should be affordable, stable, and user-friendly for end users (Suryaningsih & Nurhilal, 2018).

Although there has been an increasing number of interesting studies, the current literature on the research subject is mostly fragmented. Research can be done individually on briquette engineering characteristics, combustion emissions under controlled laboratory settings, or life cycle assessments (LCAs) with different system boundaries. The urgent requirement is a synthesized critical review that would bring together existing information on the overall environmental effects of rice husk charcoal briquettes. This kind of review should put these impacts squarely against the alternative fuels they are intended to replace, namely fossil fuels such as coal and traditional biomass fuels such as wood charcoal.

The Central Focus and Structure of the Review

This review article thus attempts to present a more systematic and integrative review of the environmental impact of rice husk-derived charcoal briquettes (Yusuf et al., 2023). The main aim is to test this biofuel across a range of environmental indicators, including global warming potential, air pollutant emissions, ash management, and land-use change, and to compare its performance with that of conventional fuel (Dinesha et al., 2019). The analysis relies on techno-environmental analysis, life-cycle inventory studies, and actual emissions measurements to construct a balanced evidence base (Lubwama & Yiga, 2018).

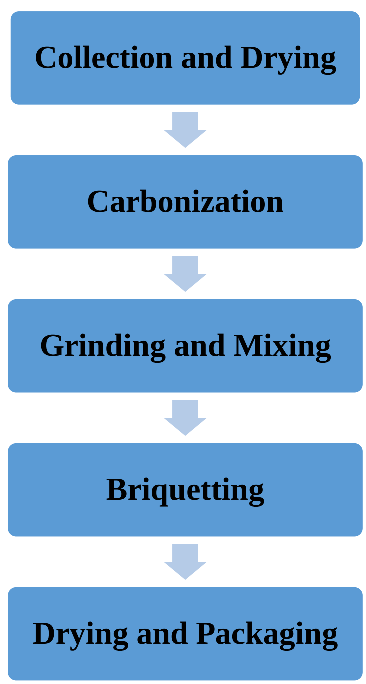
The paper is organized so that it initially defines the typical production processes involved in rice husk briquettes, as the technological decisions are inherently related to the final environmental performance downstream. Thereafter, it devotes a central part of its investigation to environmental effects and classifies them into greenhouse gas effects, atmospheric contaminants, and solid waste (ash) factors. The next section is the key part of the comparative study, in which rice husk briquettes are compared with wood charcoal, coal, and fossil-based substitutes such as LPG and kerosene across the following impact categories. As environmental viability is also conceived in the practical adoption, the socio-economic and policy dimensions relevant to it are also addressed in the review. Lastly, it identifies persistent knowledge gaps and suggests priority areas for future research to strengthen the sustainability of this promising biofuel system.

This review can enlighten policymakers, development practitioners, and researchers on the potential of rice husk charcoal briquettes, either by synthesizing disparate research or by providing a realistic assessment of the product's potential and limitations. The eventual goal is to be part of evidence-based solutions that utilize agricultural waste to generate sustainable energy, thereby addressing the interconnected problems of energy availability, climate change, and environmental health.

Briquettes of Rice Husks Production Process

Manufacturing rice husk briquettes involves a series of technical processes that directly affect fuel quality, combustion rates, and environmental attributes. The common production chain consists of the following steps:

Figure 1: Rice husk briquettes production process



Collection and Drying

Rice husk is collected at rice mills, where it is produced as a byproduct of paddy milling. Depending on storage conditions, fresh husk may contain 10-20% moisture. To minimize moisture content to an optimal level (typically less than 12 percent), proper drying (typically by sun drying or controlled-air drying) is required. Reduced moisture increases combustion efficiency and calorific value, and eliminates smoke formation during combustion (Brand et al., 2017). Sun drying is the cheapest in rural areas, but in large operations, mechanical drying can be used.

Carbonization

Rice husk is transformed into char by carbonization (slow pyrolysis) in low oxygen concentrations through kilns or reactors. This process adds fixed carbon levels, increases calorific value, and makes the briquettes denser in energy and less polluting to burn than the raw husk. Carbonization is also a method of reducing volatile substances that cause excessive smoke. Nonetheless, it requires additional energy and may produce emissions when used inadequately (Yank et al., 2016). The performance of the kiln (both traditional earth kilns and enhanced metal reactors) significantly influences environmental impact and product quality.

Grinding and Mixing

Once carbonized (and directly when non carbonized briquettes are used), the material is reduced to fine particles, typically 1-2 mm. Even particle size ensures high compaction and strength. An adhesive, such as starch, molasses, or clay, is then added to enhance cohesion and stability (Magnago et al., 2020). Binder content affects the mechanical strength, ash content, and combustion properties.

Briquetting (Densification)

The ready mixture is pressed into uniform shapes, such as cylindrical, pillow, or hexagonal forms, using manual, hydraulic, or screw presses (Suryaningsih et al., 2018). Densification also increases bulk density, enhances handling and transportation efficiency, and improves combustion stability. Mechanical presses usually produce smaller, stronger briquettes than manual systems, but they require electricity or mechanical energy.

Drying and Packaging

Newly made briquettes still contain water and must be dried before they can be stored and distributed. Drying may be done either under the sun or in dry chambers. Drying decreases the rate of cracking, enhances ignitability, and increases shelf life (Yank et al., 2016). The end product is then packaged or bundled for transportation and marketing.

Environmental Impacts of Rice Husk Briquettes

The production process significantly impacts the environmental footprint of rice husk briquettes. Conventional manual carbonization and briquetting systems can emit increased levels of carbon dioxide and PM. Mechanized systems, in contrast, have better control systems, such as wet scrubbers and kilns, that can significantly reduce emissions at the production stage. This underscores the importance of technology choice in reducing air pollution and improving overall sustainability. It is hence necessary to invest in cleaner, more efficient production technologies to ensure maximum gains on both environmental and socio-economic grounds.

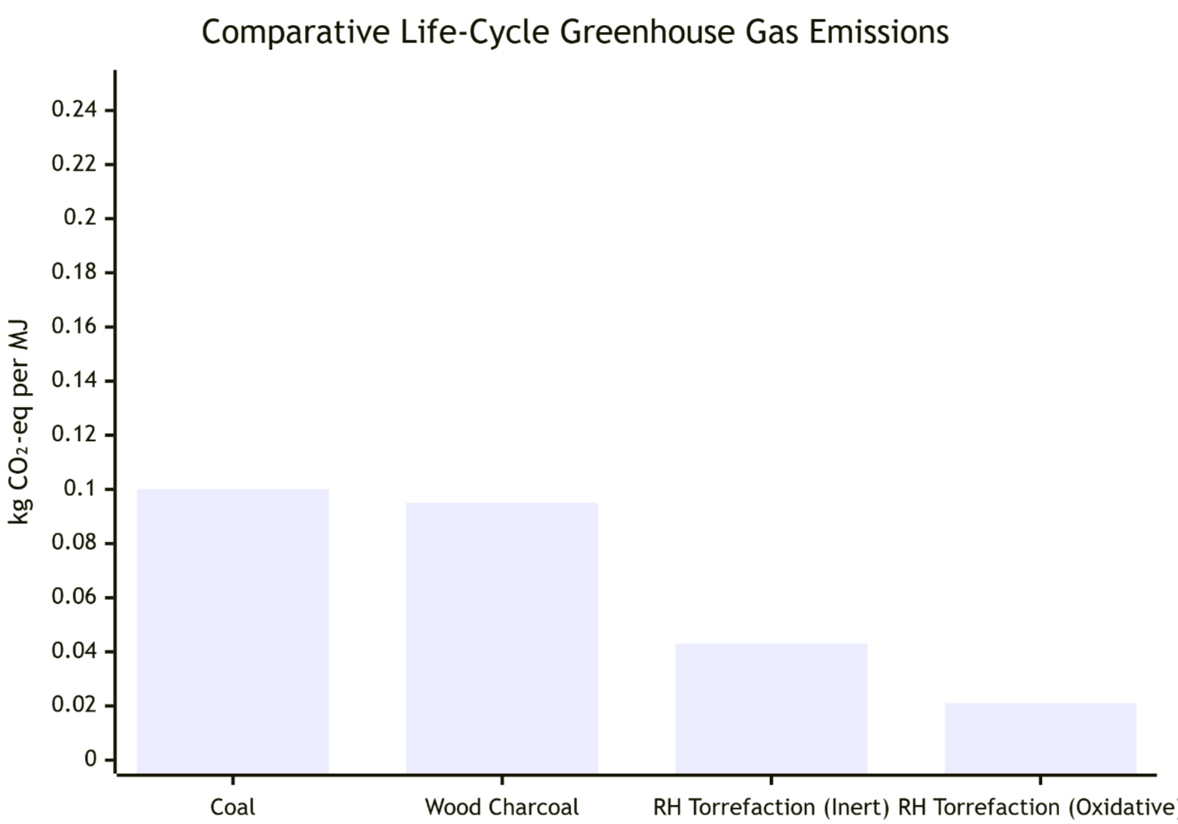
Greenhouse Gas Emissions across Fuels

Rice-husk briquettes are widely considered carbon neutral because the CO_2 released during combustion is roughly equivalent to the CO_2 absorbed by the rice plant during photosynthesis. Life cycle assessments that include biomass-carbon uptake show that the net global-warming potential (GWP) of rice-husk briquettes is far lower than that of fossil fuels (Rashif et al., 2025). For example, a study on biomass-briquette heating systems reported that substituting 100,000 tons of biomass briquettes for coal could avoid 335,679 tons of CO_2 equivalent emissions (Daniel et al., 2020).

The carbon neutrality assumption, however, requires sustainable harvesting and no land-use change. When rice husk is diverted (i.e., used as a soil amendment) or when more energy is consumed in carbonization and transportation, the balance of net GHG emissions would be unfavourable. The comparative LCAs of various biomass feedstocks show that corn-cob briquettes can be slightly less damaging to the environment than burnt rice-husk briquettes, indicating that feedstock choice and processing route are relevant (Muazu et al., 2022).

The following graph illustrates the Global Warming Potential (GWP) of different fuels based on life cycle assessment data.

Figure 2: Comparative Life Cycle Greenhouse Gas Emissions



When produced through an advanced oxidative torrefaction, rice husk (RH) briquettes alone have a much lower carbon footprint than traditional solid fuels. Rice husk torrefaction data is based on a life cycle analysis study; whereas the data of coal and charcoal is also generalized to make comparisons against the standard emission factors.

Ash Generation and Waste Management

Rice husk contains 15–20 % silica (SiO_2). Consequently, its briquettes produce a large volume of ash (20–40 % by weight) that is rich in amorphous silica (Sun et al., 2016). Disposal of this ash can be a challenge, but it also presents opportunities: rice-husk ash is used as a pozzolan in cement, as a filler in construction materials, and as a source of high-purity silica for industrial applications. Integrating ash utilization into the briquette value chain can mitigate waste and create additional revenue streams.

Land-Use and Deforestation

Rice husk briquettes instead of wood charcoal directly causes deforestation and loss of forests since the raw material is an agricultural residue that would otherwise go to waste. Replacing rice husk briquettes with wood charcoal can therefore ease the burden on forests, save biodiversity and preserve carbon sinks (Cai et al., 2024). It is a significant environmental advantage that is indirect in form of land use.

Air Pollutant Emissions

Burning of rice husk briquettes generates common biomass burning pollutants, including carbon monoxide (CO), particulate matter (PM), Nitrogen Oxides (NO_X), and volatile organic compounds (VOCs). The levels are dependent on combustion conditions, the design of the stove and the fuel properties.

Carbon monoxide: Manual briquetting methods have been associated with CO emissions averaging 220 ppm, whereas mechanized production with integrated wet scrubbers can reduce CO by about 39 % (Yuan et al., 2017).

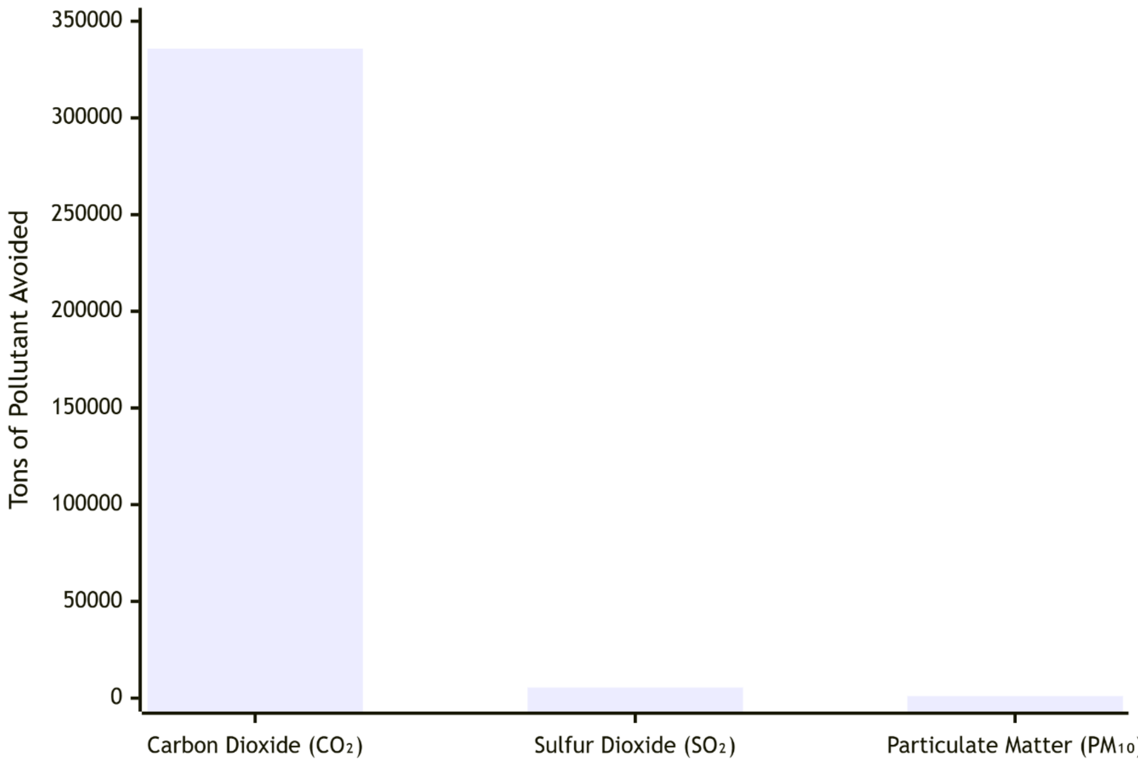
Particulate matter: Briquettes made from carbonized rice husk tend to have higher ash content, which can increase PM emissions (Liu et al., 2016). However, carbonization also improves fixed carbon content and reduces smoke, leading to “cleaner” flames. One techno-environmental assessment noted that $PM_{2.5}$ emissions from biomass briquettes generally comply with WHO safety thresholds, though some feedstocks (e.g., sawdust) may exceed limits.

Sulfur and nitrogen oxides: Rice husk contains negligible sulfur, so SO_2 emissions are minimal. NO_x formation is primarily thermal and can be controlled by optimizing combustion air supply (Fujii & Managi, 2016).

Air Pollutant Reduction from Fuel Substitution

This chart quantifies the avoided emissions when substituting coal with biomass briquettes in a heating system, based on a specific case study.

Figure 3: Air Pollutant Reduction from Fuel Substitution



Beyond CO_2, the switch to biomass briquettes drastically reduces emissions of sulphur dioxide (a cause of acid rain) and particulate matter (harmful to human health), as biomass contains negligible sulphur.

Comparison with Conventional Fuels

Wood Charcoal

Wood charcoal is a traditional fuel in most developing areas. It is produced through cutting trees, slow pyrolysis in earth mound kilns, and transportation. It is very inefficient (10-15% conversion efficiency) and produces high levels of CO, CH4, and PM. The production of charcoal through deforestation causes soil erosion, loss of watersheds, and reduced carbon absorption. By comparison, rice husk briquettes do not have these land use effects, and when burned in better stoves, they may produce less CO and PM (Zam et al., 2025).

Coal

Coal is a fuel with a high GHG emissions intensity (≈2.3 kg CO_2 per kg of coal). It is also a source of sulphur (0.5–5 %), which results in SO2 emissions that cause acid rain, and heavy metals (e.g., mercury, arsenic), which are harmful to health. Replacing coal with rice husk briquettes in industrial boilers and domestic heating systems can significantly reduce CO2, SO2, and PM emissions. One LCA estimated that replacing 63,558 tons of coal with biomass briquettes would avoid 5,460 tons of SO_2 and 1,012 tons of PM_{10} (Li et al., 2024).

Fossil Fuels (LPG, Diesel, Kerosene)

Liquefied petroleum gas (LPG), diesel, and kerosene are convenient but fossil-based. They emit CO_2, NO_x, and (for diesel) PM. While they burn more cleanly than solid biomass in well-maintained appliances, their life cycle GHG emissions are far higher than those of carbon-neutral rice-husk briquettes (Gomes et al., 2024). Moreover, fossil fuels are subject to price volatility and supply-chain disruptions, whereas rice husk is a locally available, renewable resource.

Economic and Social Aspects

The briquetting of rice husks provides valuable economic incentives to small landholders, rice millers and rural businesspeople, as it transforms large agricultural byproducts into a valuable commodity. The creation of small- or medium sized briquetting facilities in rice mills will enable local value addition, lower transportation costs, and additional sources of income in the countryside. The technology employed in production is relatively easy to implement and flexible, well suited to rural conditions, making decentralized energy production feasible with moderate capital expenditure. This not only provides employment in rural regions but also enhances local energy security and reduces reliance on traditional fossil fuels.

Socially, rice husk briquettes can enhance home air quality relative to conventional wood charcoal, especially when installed in better stoves, thereby lessening exposure to dangerous smoke and related health risks (Costa et al., 2024). Nonetheless, some constraints may influence user acceptability. The fact that it has a lower calorific value (around 1418 MJ/kg) than coal (around 25 MJ/kg) may necessitate more frequent refuelling, and its higher silica ash content means it will require regular cleaning. These practical issues can be addressed by improving briquette formulation, designing the stove, and educating users to achieve wider adoption and long-term economic success.

Policy Implications

Government intervention is a major factor that will facilitate the adoption of rice husk briquettes as a renewable energy source. The use of financial incentives, such as subsidies for briquetting equipment and tax exemptions for biofuel manufacturers, can reduce entry barriers and enable small-scale entrepreneurs to enter the market. This is equally important as regulatory support. The institutional environment for expansion can be conducive through the introduction of biomass briquettes into the national renewable energy portfolio and the development of more favourable emission standards for low-carbon fuels. Moreover, dedicated research and development resources are required to streamline carbonization methods, improve stove design to burn husks effectively, and develop value-added uses for rice husk ash.

Conclusion

Rice husk charcoal briquettes can be considered a viable alternative to traditional fuels, e.g., wood charcoal, coal, and liquid fossil fuels, in terms of environmental and sustainability aspects. In a similar manner to converting a large agricultural byproduct into useful energy, rice husk briquettes also help mitigate environmental issues associated with open burning and improper disposal. Rice husk briquettes are also eco-friendly in terms of greenhouse gas emissions, as much of the carbon dioxide produced by burning rice husks is wasted during rice cultivation. They can lower emissions of carbon dioxide, sulphur dioxide, and particulate matter compared to coal and wood charcoal, thereby improving air quality. They can also alleviate pressure on forest resources, as they do not require the extraction of wood; instead, they use agricultural residues. Even though emissions during carbonization and the comparatively elevated ash levels are issues of concern, their effects could be minimized through improved production technologies and the proper use of ashes. Briquettes made from rice husks also have social and health benefits, especially in areas that rely on traditional biomass fuels. When properly used in better stoves, they burn more efficiently, produce less smoke and carbon monoxide, and improve indoor air quality compared to unprocessed biomass.

In general, rice husk charcoal briquettes are a potential avenue for sustainable energy production in rice-producing countries like Pakistan. They can help protect the environment, develop rural areas, and support cleaner energy transitions in developing economies through appropriate technological improvements and policy support.

References

- Akolgo, G. A., Awafo, E. A., Essandoh, E. O., Owusu, P. A., Uba, F., & Adu-Poku, K. A. (2021). Assessment of the potential of charred briquettes of sawdust, rice and coconut husks: Using water boiling and user acceptability tests. *Scientific African, 12,* e00789.
- Brand, M. A., Jacinto, R. C., Antunes, R., & da Cunha, A. B. (2017). Production of briquettes as a tool to optimize the use of waste from rice cultivation and industrial processing. *Renewable Energy, 111,* 116–123.
- Cai, M., Javed, J., Wu, H., Zhou, Y., Liyang, H., Yang, C., Zhang, Q. (2024). Valorizing waste activated sludge incineration ash to S-doped Fe2+@Zeolite 4A catalyst for the treatment of emerging contaminants exemplified by sulfamethoxazole. *Journal of Environmental Management, 369*, 122382.
- Costa, L. J., de Castro, V. R., Trugilho, P. F., Lana, A. Q., Oliveira, A. C., Lima, M. D. R., de Paula, M. O. (2024). Physical–chemical properties and hygroscopicity of Brazilian metallurgical charcoal. *Wood Science and Technology*, *58*(2), 503–532.
- Daniel, K. K., Siagi, Z. O., & Ogola, J. O. (2020). Effect of formulation, binder and compaction pressure of rice husk-bagasse briquettes on thermal and physical properties. *Journal of Scientific Research and Reports*, *26*(10), 38–53.
- Dinesha, P., Kumar, S., & Rosen, M. A. (2019). Biomass briquettes as an alternative fuel: A comprehensive review. *Energy Technology, 7*(5), 1801011.
- Fujii, H., & Managi, S. (2016). Economic development and multiple air pollutant emissions from the industrial sector. *Environmental Science and Pollution Research, 23*(3), 2802–2812.
- Gomes, G. S. L., Oliveira, S. N. D., Carneiro, A. D. C. O., Lopes, L. S. D. S., Leite, H. G., & Caldeira, M. V. W. (2024). Influence of spacing between trees on wood and charcoal quality indicators. *Cerne, 30,* e-103270.
- Kipngetich, P., Kiplimo, R., Tanui, J. K., & Chisale, P. (2023). Effects of carbonization on the combustion of rice husks briquettes in a fixed bed. *Cleaner Engineering and Technology, 13,* 100608.
- Li, G., Gao, L., Liu, F., Qiu, M., & Dong, G. (2024). Quantitative studies on charcoalification: Physical and chemical changes of charring wood. *Fundamental Research, 4*(1), 113–122.
- Liu, J., Mauzerall, D. L., Chen, Q., Zhang, Q., Song, Y., Peng, W., Zhu, T. (2016). Air pollutant emissions from Chinese households: A major and underappreciated ambient pollution source. *Proceedings of the National Academy of Sciences, 113*(28), 7756–7761.
- Lubwama, M., & Yiga, V. A. (2018). Characteristics of briquettes developed from rice and coffee husks for domestic cooking applications in Uganda. *Renewable Energy, 118,* 43–55.

- Magnago, R. F., Costa, S. C., de Assunção Ezirio, M. J., de Godoy Saciloto, V., Parma, G. O. C., Gasparotto, E. S., Barcelos, R. L. (2020). Briquettes of citrus peel and rice husk. *Journal of Cleaner Production*, *276*, 123820.
- Muazu, R. I., Borrion, A. L., & Stegemann, J. A. (2022). Life cycle assessment model for biomass fuel briquetting. *Waste and Biomass Valorization*, *13*(4), 2461–2476.
- Rashif, M. N., Hartini, S., Sari, D. P., Ramadan, B. S., Matsumoto, T., & Balasbaneh, A. T. (2025). Life cycle assessment of biomass waste briquettes as renewable energy. *Global Journal of Environmental Science and Management*, *11*(1), 207–224.
- Saeed, A. A. H., Yub Harun, N., Bilad, M. R., Afzal, M. T., Parvez, A. M., Roslan, F. A. S., Afolabi, H. K. (2021). Moisture content impact on properties of briquette produced from rice husk waste. *Sustainability*, *13*(6), 3069.
- Sun, X., Li, J., Zhao, X., Zhu, B., & Zhang, G. (2016). A review on the management of municipal solid waste fly ash in America. *Procedia Environmental Sciences*, *31*, 535–540.
- Suryaningsih, S., & Nurhilal, O. (2018, May). Sustainable energy development of bio briquettes based on rice husk blended materials: An alternative energy source. In *Journal of Physics: Conference Series* (Vol. 1013, No. 1, p. 012184). IOP Publishing.
- Suryaningsih, S., Nurhilal, O., Yuliah, Y., & Salsabila, E. (2018, February). Fabrication and characterization of rice husk charcoal bio briquettes. In *AIP Conference Proceedings* (Vol. 1927, No. 1, p. 030044). AIP Publishing LLC.
- Tanko, J., Ahmadu, U., Sadiq, U., & Muazu, A. (2021). Characterization of rice husk and coconut shell briquette as an alternative solid fuel. *Advanced Energy Conversion Materials*, 1–12.
- Ugwu, K. E., Ezema, C. G., Ibeto, C. N., & Okafor, I. F. (2024). Properties of biocoal briquettes from mesoporous coals and rice husk and their effects on environmental pollution. *Discover Environment*, *2*(1), 106.
- Unrean, P., Fui, B. C. L., Rianawati, E., & Acda, M. (2018). Comparative techno-economic assessment and environmental impacts of rice husk-to-fuel conversion technologies. *Energy*, *151*, 581–593.
- Yank, A., Ngadi, M., & Kok, R. (2016). Physical properties of rice husk and bran briquettes under low pressure densification for rural applications. *Biomass and Bioenergy*, *84*, 22–30.
- Yuan, X., Zhang, M., Wang, Q., Wang, Y., & Zuo, J. (2017). Evolution analysis of environmental standards: Effectiveness on air pollutant emissions reduction. *Journal of Cleaner Production*, *149*, 511–520.
- Yusuf, M. A., Witdarko, Y., & Pamungkas, W. A. (2023). Characteristics of charcoal briquettes from rice husk waste with compaction pressure variations as an alternative fuel. *Journal of Ecological Engineering*, *24*(4).
- Zam, J. F., Biwole, A. B., Eyinga, J. J. B., Fongnzossie, E. F., Bessike, G. J., Mouangue, R., & Zobo, J. M. (2025). Determining the quality of wood charcoals as a bioenergy source in humid tropical regions of Central Africa: The effect of carbonized wood and storage time. *Biomass Conversion and Biorefinery*, *15*(5), 6971–6987.