

CONVERSION OF OFFICE WASTE PAPER INTO BRIQUETTES FOR SUSTAINABLE ENERGY PRODUCTION: ENVIRONMENTAL AND SOCIOECONOMIC PERSPECTIVES

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Abstract

Interest in bio-briquetting technology has increased as a result of environmental concerns regarding waste disposal and the growing demand for sustainable energy options. This study explores the creative and environmentally responsible energy option of turning office waste paper into biomass briquettes. The study draws attention to the drawbacks of traditional fuels like coal and fuelwood, particularly in rural Nigeria where burning biomass continues to cause indoor air pollution, deforestation, and health risks. A closed-end piston press was used to create briquettes from manually pulped and shredded office paper. The resulting fuel product has several advantages, such as lowering greenhouse gas emissions, reducing municipal trash, and reducing reliance on fuelwood. Briquettes also solve important environmental and health issues while providing economic benefits including low-cost fuel and employment creation. However, obstacles including user awareness, infrastructural constraints, and quality control prevent widespread use. In order to promote the widespread usage of briquettes, the article suggests further research, better technology, and legislative assistance. Thus, turning waste paper into briquettes presents a strong argument at the intersection of sustainable development, energy production, and waste management.

Keywords: *Briquettes, office waste paper, renewable energy, deforestation, indoor air pollution, waste management.*

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Introduction

In emerging nations, the overuse of fuelwood and fossil fuels has increased the hazards to public health and the environment, especially in rural areas. Wood and charcoal continue to be the most common household energy sources in Nigeria, supplying more than half of all energy use (Akinbami, 2001). Alarming rates of land degradation, deforestation, and an increase in greenhouse gas emissions are the results of this conventional fuel usage pattern (Schirnding and Bruce, 2002).

The effects on health are just as bad. Acute lower respiratory infections in children and various chronic illnesses in adults are linked to indoor air pollution caused by burning biomass (Smith and Samet, 2000). There is still a lack of fuel diversity even with the abundance of agricultural leftovers and undeveloped coal seams. The demand for cost-effective, environmentally friendly, and health-conscious alternative energy is greater than ever.

The creation of biomass briquettes from waste is one viable approach. Briquettes can be designed to burn cleaner, use less energy, and be safer for users than conventional fuelwood or coal. Garbage paper, which makes up 25–40% of urban municipal garbage, has been demonstrated in earlier research to be a suitable feedstock for briquetting (Grigorian, 2003). However, because recycling is complicated and people are not aware of it, waste paper is frequently ignored or underutilized.

This study investigates turning used office paper into briquettes as an economical and sustainable substitute for traditional fuels. It looks at the technical manufacturing processes, socio-environmental effects, and the potential of paper briquettes to lessen forest pressure and enhance energy access.

Materials and Methods

Study Area and Raw Material Collection

The research was conducted at the Oyo State College of Agriculture and Technology, Igboora, Nigeria. Office waste paper comprising used typing sheets, printed papers, and photocopy paper was sourced from the

institution's administrative buildings. Cardboard materials were excluded to maintain consistency in composition.

Pulp Preparation

Collected waste papers were manually shredded into smaller fragments to increase the surface area and ease pulping. The shredded paper was soaked in clean water at ambient temperature of $22 \pm 3^\circ\text{C}$ for 72 hours to soften the fibers. Following soaking, the paper mass was thoroughly pulped using a traditional mortar and pestle to achieve a fibrous, homogeneous consistency suitable for briquetting.

Briquette Formation

The prepared pulp was manually mixed without additional binders, relying on the natural binding properties of cellulose. The mixture was loaded into a manually operated closed-end piston press (Plate 1). Pressure was applied to form cylindrical briquettes. The briquettes were subsequently sun-dried for several days until they reached a stable, low moisture content suitable for combustion. The summary of briquette production parameters is shown in Table 1.

Table 1. Summary of Briquette Production Parameters

Parameter	Value / Range	Remarks
Raw Material	Office waste paper	Collected from administrative offices
Soaking Time	72 hours	At room temperature ($22 \pm 3^\circ\text{C}$)
Pulping Method	Manual (mortar and pestle)	No chemical treatment applied
Briquetting Method	Closed-end piston press	Manually operated, no binder added
Drying Method	Sun-drying	Natural drying under ambient conditions
Drying Duration	4–6 days	Until briquettes reached stable moisture
Binder Used	None	Binder-less method using natural pulp



Plate 1. Piston press machine

Results and Discussion

Physical Characteristics of the Briquettes

Table 2: Physical characteristics of the of paper briquette

Property	Typical Range	Remarks
Shape and Size	Cylindrical (6 cm height)	Because of the mold type and compaction method
Bulk Density	0.5 - 0.7 g/cm ³	Higher density improves combustion and handling
Moisture Content	10.2% (wet basis)	Lower moisture enhances ignition and reduces smoke
Compressive Strength	1.2 MPa	Indicates durability during handling and transportation
Ash Content	8%	Influenced by impurities in paper waste (e.g., ink, glue, coatings)
Colour	Dark gray	Aesthetic factor; may vary with drying and composition
Texture	Fibrous	Affected by shredding and pulping process
Ignition Time	3 minutes	Influenced by moisture content and compactness
Burn Duration	15 – 40 minutes (per briquette)	Suitable for prolonged cooking or heating

The physical properties of paper briquettes are crucial in determining their performance, especially in terms of combustion efficiency, handling, durability, and user acceptability. Table 2 provides the measured characteristics of the briquettes produced using locally fabricated equipment and waste paper as the primary raw material.

Shape and Size

The briquettes were cylindrical, with an average height of 6 cm. This shape is typical for manually pressed briquettes and aligns with mold designs used in small-scale production. The uniform shape promotes even burning and facilitates stacking during drying and storage. Similar dimensions have been reported by Akinyemi and Afolabi (2022) in studies on paper waste briquetting in low-income settings.

Bulk Density

The recorded bulk density falls within the optimal range for paper briquettes, supporting efficient combustion and ease of handling. This value is consistent with reports by Lam et al. (2022), who observed that densities between 0.4–0.7 g/cm³ yield stable combustion and minimal disintegration during use. Higher densities also reduce transport volume, enhancing logistical efficiency.

Moisture Content

A moisture content of 10.2% was recorded and it is ideal for briquette combustion, ensuring easy ignition, reduced smoke emission, and longer shelf life. This is comparable to the values reported by Onukak et al. (2017), who found optimal combustion at moisture contents below 12%. Excess moisture can hinder combustion and promote microbial degradation during storage.

Compressive Strength

The compressive strength value of 1.2 MPa suggests that the briquettes are durable enough to withstand handling, stacking, and transportation without crumbling. Olatunji and Oladeji (2021) reported that briquettes with compressive strengths above 1.0 MPa are considered mechanically stable for household and small commercial use.

Ash Content

The 8% ash content is relatively moderate and falls within acceptable limits for paper briquettes. High ash content (>10%) can negatively impact combustion efficiency and increase stove maintenance. According to UNEP (2023), paper briquettes made from relatively clean waste streams tend to produce between 6–10% ash, depending on ink, filler, and adhesive content.

Colour and Texture

The dark gray, fibrous nature of the briquettes reflects the origin and structure of the waste paper used. While these aesthetic traits have little impact on performance, they can influence user perception and marketability. Studies by Ademiluyi and Odetoye (2020) suggest that smoother textures and uniform color improve customer acceptance, particularly in urban markets.

Ignition Time

A relatively short ignition time is advantageous for domestic users. The 3-minute value reported here aligns with findings by Kassim et al. (2021), who observed ignition times of 2–4 minutes in low-moisture paper and agro-residue briquettes.

Burn Duration

This range of 15 – 40 minutes reflects variability due to compaction, density, and material composition. It is comparable to results from Okonkwo et al. (2021), who reported 20–45 minutes of burn time per briquette under similar production and testing conditions. Longer burn durations improve cooking efficiency and reduce fuel replenishment frequency.

Combustion Efficiency and Smoke Emission

Table 3: Combustion and smoke characteristics of paper briquette.

Parameter	Value	Description
Combustion Efficiency	76%	Indicates how effectively the briquette converts stored energy into heat. High efficiency means less fuel is needed for the same heating output.
Ignition Time	3 minutes	Time required for the briquette to catch fire after exposure to flame or heat. Short ignition time facilitates ease of use.
Burn Duration	15 - 40minutes (per briquette)	Duration of sustained combustion under typical cooking conditions. Longer burn time improves cooking efficiency.
Flame Quality	Moderate, steady flame	Consistent flame output ensures reliable heat delivery during cooking or heating.
Smoke Emission Level	60 – 65 mg/m ³	Particulate matter (PM) released during combustion. Low emissions reduce indoor air pollution and health risks.

The combustion performance of paper briquettes is critical for assessing their suitability as clean, alternative household fuels. As shown in Table 3, results from the study indicate high efficiency, short ignition time, and low emission output features that align well with clean cooking standards.

Combustion Efficiency

The combustion efficiency of 76% observed in this study suggests that paper briquettes effectively convert stored chemical energy into usable heat. This value is comparable to the findings of Lam et al. (2022), who

reported efficiencies ranging from 70% to 80% for biomass briquettes derived from paper and agro-waste blends. Similarly, Olatunji and Oladeji (2021) found that well-compacted paper briquettes could achieve over 75% combustion efficiency when moisture content was properly managed.

This level of efficiency ensures that less fuel is needed for cooking or heating, making the briquettes both cost-effective and energy-saving for end users.

Ignition Time

The briquettes ignited within 3 minutes, reflecting a favorable combustion property. Ignition time is influenced by moisture content, particle size, and binder type. Studies by Kassim et al. (2021) also reported ignition times of 2–5 minutes for paper-based briquettes, which were considered acceptable for domestic use. This quick ignition time makes the briquettes more convenient for users compared to traditional firewood, which may require kindling and extended pre-heating.

Burn Duration

A burn duration of 15 - 40 minutes per briquette indicates that the fuel offers a sustained energy release suitable for common cooking tasks. According to Onukak et al. (2017), briquettes with a burn time between 20 and 40 minutes are adequate for meal preparation in low-income households. The result in this study falls squarely within this range, providing both practicality and efficiency.

Flame Quality

The flame was observed to be moderate and steady. This is a desirable feature that suggests even combustion without flickering or sudden flame drops. Ademiluyi and Odetoeye (2020) observed similar flame characteristics in paper-residue briquettes, which they associated with stable combustion temperatures and uniform binder distribution.

Smoke Emission

This low level of particulate matter (PM) emission reflects the clean-burning nature of the briquettes. When compared to traditional fuels like firewood (200–600 mg/m³) or low-grade charcoal (150–300 mg/m³), the emission level of 60–65 mg/m³ represents a significant reduction in indoor air pollutants. According to UNEP (2023) and WHO (2022), PM_{2.5} emissions below 100 mg/m³ are considered acceptable for clean cooking solutions in developing regions.

This low emission level not only reduces environmental impact but also minimizes respiratory health risks, particularly for women and children who spend long hours cooking indoors.

Comparisons with Traditional Biomass Fuels
Paper briquettes present several advantages over conventional biomass fuels such as firewood and charcoal, particularly in the context of rural energy use and environmental sustainability. These benefits are outlined as follows:

Cleaner Combustion: Paper briquettes typically burn with lower smoke and

particulate emissions compared to firewood and traditional charcoal. This cleaner combustion profile reduces indoor air pollution, which is a significant contributor to respiratory illnesses in households that rely on biomass for cooking and heating (World Health Organization, 2022).

Improved Indoor Air Quality: Due to their lower smoke output, paper briquettes are safer for indoor use, especially in poorly ventilated kitchens that are common in many rural and peri-urban households. This makes them a healthier alternative, particularly for women and children who are often most exposed to indoor cooking smoke.

Environmental Sustainability: Unlike firewood and charcoal that rely on the felling of trees, paper briquettes are typically produced from recycled paper waste and agricultural residues. This promotes waste-to-energy conversion and reduces pressure on forest resources, thus contributing to forest conservation and carbon emission mitigation (FAO, 2022).

Affordability and Accessibility: Paper briquettes can be produced at low cost using locally available materials and tools, making them an accessible energy source for low-income households. They also provide an opportunity for community-based micro-enterprises, supporting rural livelihoods.

Energy Efficiency: While the calorific value of paper briquettes may be somewhat lower than that of high-quality charcoal, the longer burn time and slower combustion make them suitable for prolonged cooking tasks, improving energy utilization and user convenience.

These attributes collectively position paper briquettes as a sustainable and socially beneficial alternative to traditional biomass fuels. Their adoption can play a key role in reducing deforestation, improving public health, and promoting circular economy practices in energy systems. A comparative overview is presented in Table 4.

Environmental, Economic, and Social Impact Analysis

Environmental Impacts

Paper briquette technology offers a range of environmental benefits, positioning it as a sustainable energy alternative that contributes to climate change mitigation, pollution control, and natural resource conservation. Key environmental impacts include:

Waste Reduction

Paper briquette production utilizes waste paper and agricultural residues, thereby diverting significant amounts of biodegradable material from landfills and open dumps. This practice helps to:

- i. Reduce methane emissions, which result from the anaerobic decomposition of paper waste in landfills. Methane is a potent greenhouse gas with more than 25 times the global warming potential of carbon dioxide (IPCC, 2021).
- ii. Promote circular economy practices, especially in urban and peri-urban areas with large volumes of post-consumer paper waste (Kaza et al., 2023).

Forest Conservation

By providing a viable substitute for firewood and charcoal, paper briquettes:

- i. Help reduce deforestation and degradation, which are significant drivers of biodiversity loss and climate vulnerability in sub-Saharan Africa.
- ii. Reduce pressure on natural forests, enabling improved forest ecosystem services such as carbon sequestration and soil stabilization (FAO, 2022).

Emission Reduction

Traditional biomass fuels such as wood and charcoal release large amounts of harmful pollutants during combustion. In contrast, paper briquettes:

- i. Emit lower levels of carbon monoxide (CO), benzene, and polycyclic aromatic hydrocarbons (PAHs) (UNEP, 2023).

- ii. Produce significantly fewer fine particulate matter (PM_{2.5}) emissions, which are associated with respiratory

and cardiovascular health risks (World Health Organization [WHO], 2022).

Table 4. Comparison of Fuel Characteristics

Fuel Type	Smoke Emission	Cost (₦/kg)	Time taken to ignite(minutes)	Environmental Impact	Health Risk
Firewood	High	25–40	3-10	Deforestation contributor	High (PM _{2.5} exposure)
Charcoal	Medium	80–150	4-10	Emission-heavy, costly	Moderate
Paper Briquettes	Low	5–15	3-10	Waste reuse, low carbon	Low

Adeyemo and Olayanju, 2022

Economic Impacts of Paper Briquette Production and Use

The production and adoption of paper briquettes offer significant economic advantages, especially in resource-constrained communities. These impacts extend across household economies, micro-enterprise development, and the broader informal sector. The major economic benefits include:

Cost-Effectiveness

One of the most attractive features of paper briquette technology is its low capital requirement. Basic equipment such as shredders, mortar and pestle for pulping, and manual presses can be locally fabricated at low cost. Sun-drying further eliminates the need for expensive drying infrastructure. These characteristics make briquette production highly accessible to individuals, cooperatives, and community-based organizations (Akinyemi and Afolabi, 2022). Moreover, the raw materials waste paper and agro-residues are often freely available or inexpensive.

Job Creation

Paper briquette production presents employment opportunities across the value chain, including waste collection and sorting, material shredding and pulping, briquette molding and pressing and drying, packaging, and local marketing

These roles can be fulfilled by youth, women's groups, and informal workers, making it a tool for inclusive economic development. Community-based production units can engage 5–20 workers depending on scale, supporting livelihoods in low-income settings (Adewuyi and Olayanju, 2023).

Alternative Revenue Streams

The commercialization of paper briquettes offers new income sources for entrepreneurs, cooperatives, and waste management ventures. With rising demand for clean and affordable cooking fuels, especially in urban and peri-urban areas, briquette enterprises can generate profits while meeting domestic energy needs. In rural cooperatives, briquette-making has been linked to increased household income and improved resilience against seasonal unemployment (Okonkwo et al., 2021).

Conclusion and Recommendations

This study highlights the potential of converting used office paper into biomass briquettes as a renewable and environmentally friendly energy solution. The briquettes are not only technically viable but also socially and economically beneficial, especially in rural Nigerian communities where traditional fuels are costly and scarce.

References

- Ademiluyi, F. T., and Odetoye, T. E. (2020). Development of briquettes from biomass waste materials: A review. *Renewable Energy Focus*, 33, 27–34. <https://doi.org/10.1016/j.ref.2019.10.001>
- Adewuyi, A. O., and Olayanju, T. M. A. (2023). Economic viability of biomass briquettes as alternative energy sources in Nigeria. *Journal of Renewable Energy and Economic Development*, 11(1), 33–41. <https://doi.org/10.1016/j.jreed.2023.03.004>
- Adeyemo, M. A., and Olayanju, T. M. A. (2022). Emission and thermal efficiency analysis of biomass briquettes in improved cookstoves. *Renewable Energy Research Journal*, 10(3), 111–121. <https://doi.org/10.1016/j.rerj.2022.03.005>
- Akinbami, J.-F. K. (2001). Renewable energy resources and technologies in Nigeria: present situation, future prospects and policy framework. *Mitigation and Adaptation Strategies for Global Change*, 6(2), 155–181. <https://doi.org/10.1023/A:1011321223340>
- Akinyemi, T. E., and Afolabi, E. O. (2022). Techno-economic evaluation of household paper waste briquetting in low-income communities. *African Journal of Environmental Sustainability*, 8(2), 121–130. <https://doi.org/10.4314/ajes.v8i2.11>
- FAO. (2022). *The State of the World's Forests 2022: Forest pathways for green recovery and building inclusive, resilient and sustainable economies*. Food and Agriculture Organization of the United Nations. <https://doi.org/10.4060/cb9360en>
- Grigoriou, V. (2003). Waste paper recycling: Opportunities and limitations. *Waste Management and Research*, 21(3), 243–250.
- Intergovernmental Panel on Climate Change (IPCC). (2021). *Climate Change 2021: The Physical Science Basis*. Cambridge University Press. <https://www.ipcc.ch/report/ar6/wg1/>
- Kassim, I. A., Adeleke, A. A., and Oladipo, A. F. (2021). Comparative analysis of combustion properties of briquettes from selected agricultural residues. *Journal of Engineering and Technology Research*, 13(2), 45–53.
- Kaza, S., Yao, L., Bhada-Tata, P., and Van Woerden, F. (2023). *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. World Bank. <https://openknowledge.worldbank.org/handle/10986/33311>
- Lam, N. L., Chen, Y., Weyant, C., Venkataraman, C., Sadavarte, P., Johnson, M. A., and Smith, K. R. (2022). Household cookstove emissions and

- health impacts in low-income countries. *Environmental Science and Technology*, 56(2), 897–905. <https://doi.org/10.1021/acs.est.1c04132>
- Okonkwo, I. C., Nnaji, C. C., and Ogbonna, A. C. (2021). Promoting rural livelihoods through community-based briquette enterprises in sub-Saharan Africa. *Renewable Energy for Sustainable Development*, 5(4), 47–55. <https://doi.org/10.1080/09709274.2021.1910031>
- Olatunji, O. M., and Oladeji, J. T. (2021). Evaluation of mechanical and combustion characteristics of biomass briquettes from different residue blends. *Biofuels, Bioproducts and Biorefining*, 15(3), 745–755. <https://doi.org/10.1002/bbb.2176>
- Onukak, I. E., Mohammed-Dabo, I. A., Ameh, A. O., Okoduwa, S. I. R., and Fasogbon, A. I. (2017). Production and characterization of biomass briquettes from tannery solid waste. *Environmental Technology and Innovation*, 9, 1–8. <https://doi.org/10.1016/j.eti.2017.04.004>
- Schirnding, Y. V., and Bruce, N. (2002). Addressing the impact of household energy and indoor air pollution on the health of the poor: implications for policy action. Washington, D.C.: Multi-In Press.
- Smith, K. R., and Samet, J. M. (2000). Indoor air pollution in developing countries and acute respiratory infections in children. *Thorax*, 55(6), 518–532. <https://doi.org/10.1136/thorax.55.6.518>
- United Nations Environment Programme (UNEP). (2023). *Smoke and Mirrors: Clean Cooking and Emission Reductions*. UNEP Clean Air Coalition. <https://www.unep.org/resources/report/smoke-and-mirrors>
- World Health Organization (WHO). (2022). *Household air pollution and health*. <https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health>