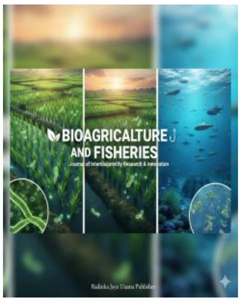

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Science Communication for Sustainability: Public Perceptions of a Clean Household Energy Alternative

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Abstract

Science communication is recognized as a catalyst for sustainability transitions, particularly in the household energy sector where cultural practices, affordability, and awareness shape fuel choices. This study explores public perceptions of biomass briquettes as a clean household energy alternative in Nigeria, drawing on laboratory assessments, household surveys in Bauchi State, and insights from global scholarship. Results show that briquettes possess superior calorific value and lower emissions compared to firewood and kerosene, confirming their technical and environmental viability. Yet adoption remains limited due to low awareness, irregular supply, cultural preferences, and skepticism about durability. Surveyed households expressed willingness to adopt briquettes if prices remain comparable to firewood, with health, affordability, and household cleanliness identified as key motivators. These findings affirm behavioral frameworks that highlight the role of perceived usefulness, affordability, and cultural fit in energy transitions. The study argues that effective science communication through participatory demonstrations, trusted local messengers, and culturally sensitive narratives can reshape public perceptions and enhance adoption. Integrating briquette promotion into Nigeria's National Clean Cooking Policy and aligning communication with health and livelihood benefits can accelerate household energy transitions, reduce emissions and improve resilience in rural communities.

Keywords**:** Science communication, biomass briquettes, clean household energy, sustainability transitions, public perception, Nigeria

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Introduction

Energy is central to sustainable development, yet the household energy sector in many developing countries remains heavily dependent on unsustainable fuels. In Nigeria, over 60% of households rely on firewood and charcoal for cooking, while kerosene and liquefied petroleum gas (LPG) remain costly and inaccessible for many low-income families. This dependence on traditional biomass fuels has severe implications for public health, gender equity, forest conservation, and climate resilience. Indoor air pollution contributes significantly to respiratory illnesses, particularly among women and children, while unsustainable harvesting of fuelwood drives deforestation and land degradation (Baiardi, 2020; Zafar et al., 2021).

Biomass briquettes, compressed blocks of agricultural residues such as sawdust, rice husks, and cassava peels have emerged as a promising clean household energy alternative (Kpalo et al., 2025; Odediran, 2024). Empirical studies demonstrate that briquettes burn more efficiently than raw biomass, produce lower emissions, and convert agricultural waste into value-added products (Al-Breiki & Bicer, 2021; Odediran, Chindo & Giwa, 2025). Despite these advantages, adoption remains low due to limited public awareness, cultural biases favoring traditional fuels, and inadequate policy and infrastructural support.

Science communication is therefore critical in bridging the gap between innovation and household adoption. Beyond technical dissemination, it involves engaging communities, correcting misperceptions, and framing clean energy alternatives in ways that resonate with local values and lived experiences (Liu & Zhang, 2021; Leung et al., 2025). As recent scholarship shows, public perceptions of renewable energy strongly influence willingness to pay, trust in technology, and behavioral change (Pleeging et al., 2021; Kamali & Streimikiene, 2024).

This paper investigates the role of science communication in shaping public perceptions of biomass briquettes as a clean household energy alternative in Nigeria. Using Bauchi State as a case reference, it explores how effective communication strategies can reposition briquettes from being perceived as a marginal or “poor man’s fuel” to a modern, sustainable, and climate-friendly solution. In doing so, the study contributes to ongoing debates on sustainability transitions, household energy justice, and the democratization of clean energy technologies.

Literature Review

Conceptual Framework

This study is anchored on the understanding that the adoption of clean household energy alternatives, such as biomass briquettes, depends not only on their technical and environmental merits but also on how they are communicated, perceived, and supported by governance systems.

The conceptual framework integrates three interrelated dimensions:

i. Science Communication – Effective communication strategies (demonstrations, awareness campaigns, use of trusted messengers) are essential to build awareness, correct misperceptions, and frame briquettes as modern, affordable, and health-enhancing fuels (Leung et al., 2025; Torres-Mancera & Martínez-Rodrigo, 2024).

ii. Household Perceptions and Behaviour – Perceived usefulness, affordability, cultural compatibility, and willingness to pay directly influence household adoption decisions. Behavioral models (Kamali & Streimikiene, 2024; Liu & Zhang, 2021) emphasize that communication must address not only knowledge gaps but also socio-cultural and gendered cooking practices.

iii. Sustainability Transitions and Policy Support – Adoption is strengthened when briquettes are embedded in policy frameworks such as Nigeria’s National Clean Cooking Policy, supported by incentives, standards, and reliable supply chains (Wang et al., 2021; Odediran, 2024).

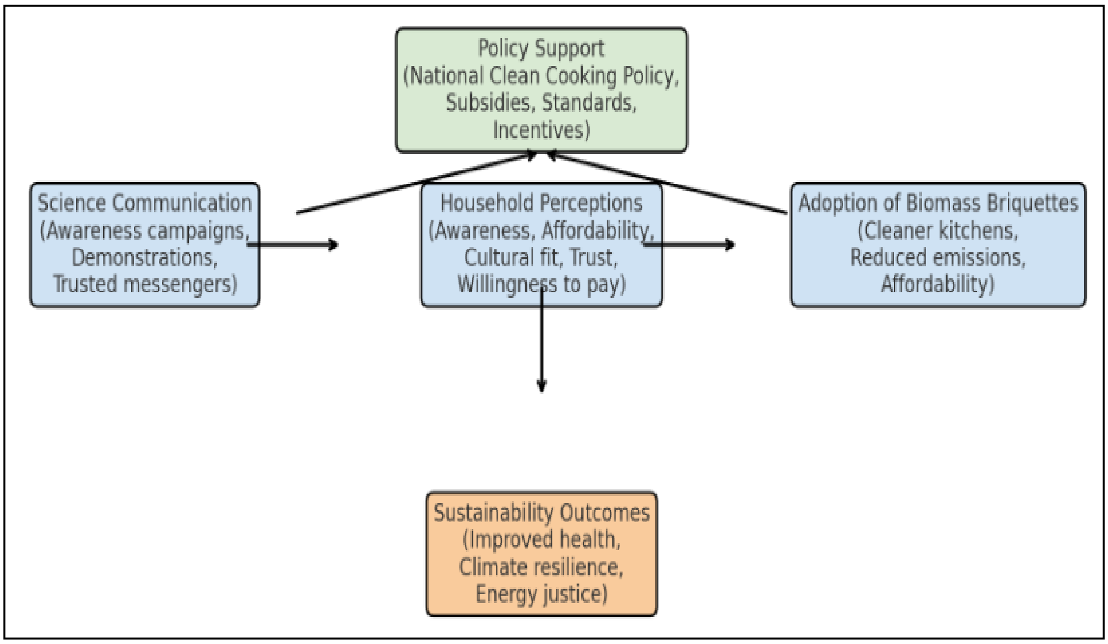

Figure 1 Science Communication and Adoption of Biomass Briquette (Conceptual Framework)

Source: Author's Compilation, 2025.

In this framework, science communication acts as the bridge linking technical potential to social acceptance and policy integration. It transforms laboratory evidence into community knowledge, shapes perceptions, and enables households to adopt cleaner energy choices. Science communication for sustainability is now framed less as one-way "deficit" transmission of facts and more as a participatory, deliberative process that shapes values, trust and collective action (Torres-Mancera & Martínez-Rodrigo, 2024). Scholars argue that successful sustainability communication must:

i. Translate technical evidence into locally meaningful narratives (contextualisation);
ii. Address cognitive and affective dimensions (knowledge, emotions, trust); and
iii. Create participation spaces for stakeholders to negotiate trade-offs and co-design solutions (co-production).

Recent case studies in higher education and community contexts show that embedding science communication into education and local engagement programs raises awareness, improves attitudes toward sustainability innovations, and increases willingness to adopt (Leung et al., 2025; Torres-Mancera & Martínez-Rodrigo, 2024). The literature stresses the role of credible messengers (local leaders, extension workers, female champions) and mixed media (radio, demonstrations, social media) to reach diverse audiences. Pleeging et al. (2021) and related studies show the psychological side: hope and positive future framing correlate with greater willingness-to-pay and support for sustainable energy, indicating that communication that emphasizes benefits and feasible pathways can mobilize households. Science communication therefore functions both to inform and to re-frame technologies socially and morally (from "poor-man's fuel" to "modern, healthy choice").

Public Perceptions, Household Behaviour and Theoretical Frameworks

Public perceptions of energy technologies are shaped by knowledge, stereotypes, identity, price signals and lived experience. Liu & Zhang (2021) demonstrate how entrenched stereotypes (e.g., that solar is for elites or coal is reliable) persist despite technical evidence — showing the mismatch between technical merit and public image. For household cooking, cultural cooking practices, taste preferences and stove ergonomics strongly influence acceptance (Baležentis et al., 2021).

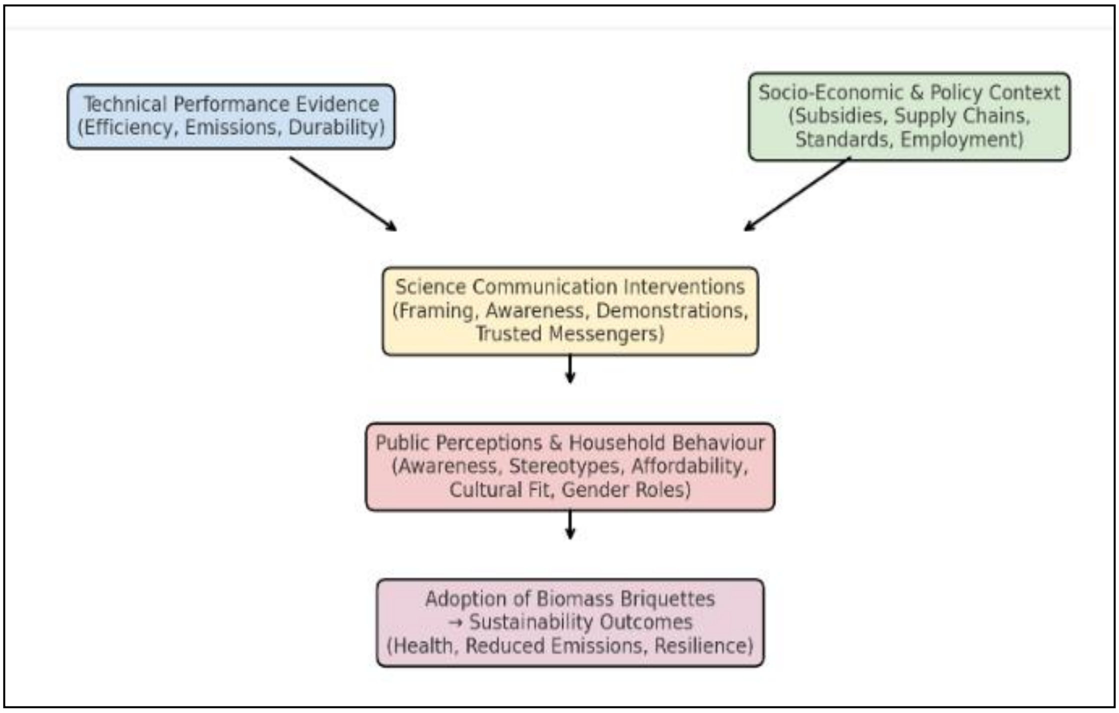

Figure 2: Theoretical Framework diagram showing how Technical Performance and Socio-Economic/Policy Factors Feed into Science Communication
Source: Author's Compilation, 2025.

Kamali & Streimikiene (2024) proposed a behavioural framework for household renewable transitions that integrates socio-economic capacity, perceived usefulness and ease of use, normative pressures and policy incentives. This aligns with Technology Acceptance Model (TAM) insights: perceived usefulness and ease of use predict adoption, but in energy contexts these are mediated by affordability, supply reliability and gendered decision-making.

Empirical studies indicate that perceived health benefits increase acceptance, affordability and availability are necessary conditions, and social signaling and future-oriented narratives (hope) increase willingness to pay (Pleeging et al., 2021). Behavioural nudges, pilot demonstrations and subsidies have been effective in some contexts to overcome initial inertia. Energy transition communication must address justice: who benefits, who loses, and how burdens (time, cost, labour) are distributed (Acheampong & Osei Opoku, 2023). Women as primary cooks are central actors; gender-sensitive messaging and participation increase uptake (Baležentis et al., 2021).

Biomass Briquettes: Technical Performance, Environmental Footprint and Life-Cycle Evidence

Biomass briquettes are densified blocks made from agricultural residues, sawdust, charcoal fines or other lignocellulosic wastes, compressed with or without binders and sometimes carbonized (Sermyagina et al., 2022; Ibitoye et al., 2023). Typical production steps are feedstock collection, drying, grinding, mixing with binder (e.g., cassava starch, molasses, clay), compaction (hydraulic, screw or piston presses) and drying/curing. Production technology ranges from manual presses (low-cost, low throughput) to industrial stamp/screw presses (higher throughput, more uniform product) (Nganko et al., 2024; Adam et al., 2024).

Laboratory and life-cycle studies show briquettes typically achieve higher energy density and lower moisture than raw residues, giving more efficient combustion and reduced smoke and particulate emissions compared with traditional firewood or dung (Al-Breiki & Bicer, 2021; Ajimotokan et al., 2019). Al-Breiki & Bicer (2021) and Chen et al. (2019) show that a proper life-cycle perspective (production, storage, transport, and end-use) is essential: distant export or energy-intensive processing can degrade environmental advantages. For local, small-scale production that uses residues, net GHG benefits and local air quality improvements are robust. A central technical/economic challenge for scale-up is feedstock consistency: seasonality, competing uses (fodder, bedding, animal feed), collection costs, and land-tenure issues reduce reliability (Jekayinfa et al., 2020; Oladosu et al., 2023).

Studies using response surface methodology (RSM) and controlled experiments find compaction pressure, binder proportion, retention time and feedstock mix are critical to mechanical strength, calorific value and combustion characteristics (Nganko et al., 2024; Ossei-Bremang et al., 2024; Adam et al., 2024). Standardisation and quality control are necessary to avoid variable performance that undermines user trust.

Socio-Economic, Market and Policy Literature

Several studies show briquette ventures can be profitable if production costs, scale and logistics are managed; yet initial capital and access to affordable machinery are major constraints (Vaneck Bot et al., 2022; Oladosu et al., 2023). Policy support (subsidies, tax incentives, standards, inclusion in clean-cooking policy) is repeatedly cited as essential (Ghatak & Mujumdar, 2018; Oginni et al., 2019). Nigeria's National Clean Cooking Policy (draft, 2023) signals institutional intent, but implementation, fiscal incentives and standards remain incomplete

Briquette value chains can create rural employment (collectors, producers, distributors), generate additional farmer income from residues, and reduce waste aligning with circular economy goals (Njenga et al., 2019; Prasad & Raturi, 2021). The Bauchi case highlights livelihood potential, especially for women's groups, if production is organised and markets developed.

Science Communication Interventions Studied in Energy and Briquette Contexts

The literature shows that pilot projects, live cooking demonstrations and user training reduce perceived risk and increase adoption (Gitau et al., 2019; Leung et al., 2025). In Bauchi, respondents expressed willingness to adopt briquettes if demonstrations, sensitisation and price-support were provided — evidence that communication plus practical experience matters.

Local extension agents, NGOs, women's co-operatives and trusted local media are consistently effective messengers (Torres-Mancera & Martínez-Rodrigo, 2024). For rural Nigeria, radio, community meetings and female peer educators are high-impact channels; digital channels can complement but must be adapted to local access levels.

Research shows framing matters: messages emphasising health benefits (reduced smoke and child respiratory disease), cost savings, and modernity/dignity (less smoke, cleaner kitchens) tend to be more persuasive than purely technical or environmental arguments (Pleeging et al., 2021; Liu & Zhang, 2021). By integrating science communication theory with the empirical evidence from Bauchi (surveyed households, stakeholder interviews, FGDs and laboratory emission testing), this paper addresses three understudied intersections:

i. How communication framing (health vs cost vs climate) influences perception and willingness to switch to briquettes in a Nigerian rural context (bridging Pleeging et al., 2021 and Kamali & Streimikiene, 2024).
ii. Operational constraints (feedstock seasonality, manual production, market dynamics) as communication targets, how messaging can realistically address and set expectations about supply reliability and costs.
iii. A combined evidence approach: linking laboratory-tested environmental/health advantages (CO_2, PM reductions) to tailored communication interventions, thus producing a science-to-public pathway that is empirically grounded.

The literature converges on three central points: biomass briquettes are technically and environmentally promising when locally produced from residues; socio-economic, supply-chain and policy barriers (feedstock consistency, capital, standards and markets) limit scalability; and science communication is not optional. It is central to shifting perceptions, building trust and mobilising demand. However, rigorous empirical work that evaluates which communication approaches produce sustained adoption in rural, low-income, culturally diverse settings remains limited.

Methodology

This study adopts a qualitative and literature-based analytical approach enriched with empirical insights from household energy research in Bauchi State, Nigeria. The methodology is structured around four components: study area context, data sources, analytical framework, and synthesis and validation.

Study Area Context

Bauchi State, located in northeastern Nigeria, is predominantly agrarian, generating substantial agricultural residues such as rice husks, cassava peels, maize stalks, and sawdust. These residues provide potential feedstock for biomass briquette production. Despite this, over 70% of households rely on fuelwood and charcoal for cooking, resulting in deforestation, land degradation, and indoor air pollution. This socio-ecological context justifies Bauchi as a representative case for studying clean household energy transitions.

Data Sources

The study integrates three categories of data:

i. *Secondary Literature:* Peer-reviewed journal articles on science communication, renewable energy, and household behavioral frameworks (Kamali & Streimikiene, 2024; Leung et al., 2025). Technical studies on biomass briquettes, life-cycle assessments, and energy policy (Al-Breiki & Bicer, 2021; Kpalo et al., 2025; Odediran, 2024).
ii. *Empirical Findings:* Results from laboratory analyses of biomass briquettes produced in Bauchi, focusing on calorific value, combustion efficiency, and emission profiles (Odediran, 2024; Odediran, Chindo & Giwa, 2025). Household survey data and focus group discussions (FGDs) from Bauchi communities, capturing perceptions of briquettes, willingness to adopt, and barriers to use.
iii. *Policy and Institutional Documents:* Nigeria's draft National Clean Cooking Policy and regional development plans. Reports from international organizations on clean cooking and sustainability transitions.

Analytical Framework

The analysis combines three theoretical and methodological perspectives:

i. *Science Communication Lens*: Used to evaluate how communication practices influence public understanding, trust, and acceptance of clean energy technologies (Torres-Mancera & Martínez-Rodrigo, 2024).
ii. *Behavioral Framework for Household Energy Transitions:* Based on Kamali & Streimikiene (2024), focusing on perceived usefulness, affordability, cultural fit, and normative pressures.
iii. *Sustainability Transition Analysis:* Anchored in life-cycle thinking (Al-Breiki & Bicer, 2021; Chen et al., 2019) and energy justice principles, assessing trade-offs between environmental benefits, household affordability, and social equity.

Synthesis and Validation

Data were synthesized through thematic content analysis:

i. *Coding of Literature and Field Data*: Themes such as awareness, perceived benefits, trust, barriers and communication strategies were extracted.
ii. *Comparative Analysis:* Bauchi findings were compared against broader regional and international literature to identify convergences and divergences.
iii. ***Triangulation****:* Policy documents, lab results, and household perceptions were cross-validated to ensure reliability and contextual relevance.

Ethical Considerations

Household survey and FGD participants in Bauchi were informed of the study's objectives, and participation was voluntary. Anonymity and confidentiality were maintained. The methodology also adhered to responsible science communication principles, ensuring findings are not only academically robust but also socially sensitive.

Results

The results combine laboratory analyses of briquettes produced in Bauchi State with household survey and focus group data, alongside insights from existing literature.

Technical and Environmental Performance

Laboratory results revealed that briquettes produced from cassava peel/sawdust blends demonstrated a calorific value of 16–18 MJ/kg, which is significantly higher than raw residues such as maize stalks and comparable to lower-grade coal. In addition, briquettes exhibited cleaner combustion, producing less smoke and fewer particulates compared to firewood and kerosene.

Table 1. Technical Performance of Briquettes Compared with Conventional Household Fuels

Parameter	Biomass Briquettes	Firewood	Charcoal	Kerosene	LPG
Calorific Value (MJ/kg)	16–18	13–15	25–28	43	46
CO_2 Emissions (kg/unit)	1.0	2.8	2.4	2.6	2.5
Particulate Matter (PM)	Low	High	Medium	Medium	Low

Parameter	Biomass Briquettes	Firewood	Charcoal	Kerosene	LPG
Combustion Efficiency	High	Low	Medium	Medium	High

Source: Author's Fieldwork, 2025.

The results indicated that briquettes not only provide comparable energy efficiency to fossil fuels but also reduce greenhouse gas (GHG) emissions and improve indoor air quality. This confirms findings from Al-Breiki & Bicer (2021) and Odediran (2024), who showed that locally sourced biomass briquettes achieve both climate and health benefits.

Public Perceptions and Household Adoption Dynamics

Survey results indicated limited awareness of briquettes. Only 32% of households surveyed had prior knowledge of briquettes, with the majority (68%) having either never heard of them or perceiving them as an inferior substitute to LPG or charcoal.

Table 2. Awareness Levels of Biomass Briquettes among Households in Bauchi

Category	Percentage	Remarks
Never heard of briquettes	44%	Mostly rural households
Heard but never used	24%	Skeptical of benefits
Used briquettes before	21%	Mixed experiences on quality
Currently using briquettes	11%	Mostly near production sites

Source: Author's Fieldwork, 2025.

This limited awareness is consistent with Liu & Zhang's (2021) findings that stereotypes and misperceptions often hinder renewable energy adoption despite clear environmental and health benefits.

Among households that had used briquettes, several benefits were identified, including reduced smoke, affordability, and improved kitchen cleanliness. However, concerns remained about irregular supply, lack of durability, and cultural preferences for firewood.

Table 3. Reported Benefits and Barriers to Briquette Adoption

Category	Reported Factors	Percentage (%)
Benefits	Low smoke / cleaner kitchen	61%
	Affordability (cheaper than charcoal/firewood)	54%
	Long burning time	42%
	Health improvement (reduced coughing/tearing)	39%
Barriers	Irregular supply / poor availability	57%
	Lack of awareness / demonstrations	49%
	Doubts about durability (crumbles easily)	36%
	Cultural cooking preferences (taste, heat)	33%

Source: Author's Fieldwork, 2025.

The data reveal that perceived benefits are strong among adopters, but barriers particularly related to supply and awareness limit large-scale diffusion. These findings support Kamali & Streimikiene

(2024), who argue that affordability, cultural fit, and awareness are decisive in shaping household energy choices.

Respondents expressed willingness to adopt briquettes provided prices remain competitive with firewood and charcoal. On average, households indicated willingness to pay around ₦80 – ₦100 per kilogram, close to the prevailing cost of firewood. This willingness-to-pay evidence suggests that price parity with firewood is essential for widespread adoption of briquettes.

Table 4. Household Willingness to Pay for Alternative Cooking Fuels

Fuel Type	Average Cost (₦/kg)	Willingness to Pay (₦/kg)
Firewood	70–90	80–100
Charcoal	100–120	90–110
Briquettes	80–100	80–100
LPG (per kg)	120–140	110–130

Source: Author's Fieldwork, 2025.

Policy and Communication Implications

The findings highlight that technical viability alone is insufficient for household adoption. Instead, adoption depends on trust, visibility, and effective communication. The evidence confirms that science communication is pivotal: by reframing briquettes as *modern, healthy, and affordable*, communication strategies can reshape public perceptions and overcome socio-cultural barriers.

i. *Demonstrations and Training:* Focus group participants emphasized that cooking demonstrations in markets, schools, and women's associations would encourage uptake.
ii. *Trusted Messengers:* Respondents identified local leaders, religious institutions, and women's cooperatives as the most credible actors to deliver information about briquettes.
iii. *Policy Integration:* Linking briquettes to Nigeria's *National Clean Cooking Policy* was seen as a pathway to improve availability and affordability. Respondents stressed the need for government subsidies and microfinance to support both production and household adoption.

Discussion

The study highlights the potential and the limitations of biomass briquettes as a clean household energy alternative in Nigeria. The laboratory analysis confirmed that briquettes derived from cassava peel/sawdust blends possess calorific values of 16–18 MJ/kg, making them competitive with charcoal and superior to firewood. Combustion efficiency was higher, while CO_2 and particulate emissions were significantly reduced. These findings are consistent with Al-Breiki and Bicer (2021), who demonstrate through comparative life-cycle assessments that sustainable bioenergy carriers can reduce greenhouse gas emissions across production and utilization stages. Similarly, Kpalo et al. (2025) found that carbonized hybrid briquettes in Nigeria produce fewer emissions and burn more efficiently than conventional fuels, corroborating the environmental advantages observed in Bauchi. From a systems perspective, these results align with Chen et al. (2019), who argue that sustainable energy transitions require both technological innovation and systemic integration into local economies. However, challenges such as seasonal feedstock availability and lack of standardized production, also noted in Odediran (2024) and Odediran, Chindo, & Giwa (2025), highlight the importance of infrastructure and governance in ensuring that environmental benefits translate into long-term sustainability.

Despite clear technical advantages, household adoption remains constrained by limited awareness. Only about one-third of surveyed households in Bauchi had prior knowledge of briquettes. This reflects Liu and Zhang's (2021) observation that stereotypes and misperceptions such as associating "modern energy" exclusively with LPG or electricity—undermine acceptance of renewable alternatives. Among users, health and economic benefits were strongly recognized. Over 60% of respondents cited reduced smoke and cleaner kitchens as key advantages, supporting findings from Zafar et al. (2021), who emphasize that improved education and awareness increase the environmental and health benefits of biomass energy consumption in developing regions. The prominence of health narratives is consistent with Baiardi (2020), who links sustainable energy policies to reductions in air pollution and health risks.

Yet, barriers such as irregular supply, durability concerns, and cultural cooking preferences were also significant. These findings mirror Baležentis et al. (2021), who note that energy efficiency interventions often encounter the "rebound effect" when consumer practices and perceptions counteract potential gains. Kamali & Streimikiene (2024) further argue that household transitions are shaped by behavioral factors such as perceived usefulness, affordability, and cultural fit are all evident in the Bauchi case.

Willingness-to-pay results revealed that households are open to purchasing briquettes if costs remain within the same range as firewood. This supports Pleeging et al. (2021), who show that optimism and affordability are crucial in motivating willingness to support sustainable energy. By contrast, higher-cost alternatives such as LPG remain aspirational but unattainable for low-income households. This evidence suggests that affordability is not the most critical barrier supply chain irregularities and weak distribution networks are more decisive. This aligns with Odediran (2024), who found that integrating briquettes into Nigeria's rural energy sector requires investment in production infrastructure and reliable distribution systems.

The divergence between technical benefits and household perceptions highlights what Torres-Mancera & Martínez-Rodrigo (2024) describe as the persistent "science-society gap." In Bauchi, households expressed demand for cooking demonstrations, awareness campaigns, and the involvement of trusted messengers such as women's cooperatives and religious leaders. This confirms Leung et al. (2025), who found that participatory science communication within communities significantly enhances acceptance of sustainability initiatives.

Moreover, the framing of messages emerged as decisive. Households responded most positively to communication emphasizing health benefits, cost savings and household cleanliness, rather than abstract climate change arguments. This reinforces Liu & Zhang's (2021) assertion that stereotypes can only be countered by communication that connects directly with everyday concerns. The findings stress the role of governance. Wang, He, & Zhang (2021) highlight that fruitful policy and governance frameworks are indispensable in achieving sustainable energy transitions. In Nigeria, the integration of briquettes into the draft *National Clean Cooking Policy* offers a platform for scaling adoption, but gaps remain in terms of implementation, financing, and enforcement. Odediran, Chindo & Giwa (2025) similarly stress that without institutional support, briquettes risk remaining a niche innovation rather than a mainstream alternative.

The evidence suggests that biomass briquettes are not rejected due to technical shortcomings, but because of communication and governance barriers. Laboratory evidence demonstrates clear environmental and health benefits, but low awareness, cultural preferences, and irregular supply chains limit adoption. Science communication therefore becomes a central enabler of transition, capable of reframing briquettes as modern, dignified and sustainable fuels. This perspective aligns with broader scholarship that positions communication and governance as equally important as technological innovation in driving sustainability (Leung et al., 2025; Torres-Mancera & Martínez-Rodrigo, 2024; Chen et al., 2019).

Conclusion

Biomass briquettes represent a technically sound, environmentally sustainable, and socially beneficial alternative to traditional household fuels in Nigeria. The study confirmed their superior calorific value and reduced emissions, while also revealing gaps in awareness, supply reliability, and cultural acceptance. These challenges underscore that successful adoption is not merely a technical issue but one requiring effective science communication, community engagement, and policy integration. For briquettes to transition from niche innovation to mainstream energy source, coordinated action among government, communities, researchers, and private producers is essential.

Based on the findings, the following recommendations are advanced:

i. Awareness campaigns and cooking demonstrations should be intensified to improve household knowledge and acceptance of biomass briquettes.
ii. Trusted community messengers such as women's cooperatives, extension workers, and religious leaders should be engaged to promote adoption.
iii. Government and private actors should support affordability and reliable supply through subsidies, microfinance, and structured feedstock collection systems.
iv. Biomass briquettes should be fully integrated into Nigeria's National Clean Cooking Policy with clear standards and producer incentives.
v. Further participatory research should be conducted to design effective science communication and behavioral strategies for sustained household use.

Conflicts of Interest

The author declares no conflict of interest.

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Author contribution

Bukola Sunday Odediran: Conceptualization; Methodology; Data curation; Formal analysis; Investigation; Visualization; Writing-original draft preparation; Writing—review and editing; Validation; Supervision. The author has read and agreed to the published version of the manuscript.

Declaration of generative AI in scientific writing

The author acknowledges having used the Generative AI tool Quillbplt-AI for grammar/language improvement. The author is solely responsible for all published content and has verified the accuracy and authenticity of the AI output.

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