Circular Construction Materials for Low-Carbon Housing in Nigeria Based on Systematic Evidence

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Abstract: Nigeria's urban housing deficit is increasing alongside rising construction-related greenhouse gas emissions driven by carbon-intensive materials and linear supply chains. This study adopts a systematic review and meta-synthesis approach to examine circular construction materials as pathways for low-carbon housing in Nigeria's urban communities. A total of 45 peer-reviewed studies published between 2015 and 2025 were identified, screened, and analysed using descriptive statistics, thematic analysis, and comparative synthesis, grounded in circular-economy and life-cycle frameworks. The results indicate that circular material strategies, including earth-based materials, recycled aggregates, industrial by-products, timber systems, and low-carbon cement alternatives, can achieve embodied carbon reductions of approximately 30–70% while maintaining structural and functional performance. Material substitution, reuse, and local sourcing emerged as the most effective strategies, particularly when integrated across the building life cycle. However, adoption remains constrained by technical capacity gaps, weak regulatory frameworks, fragmented supply chains, limited life-cycle data, and socio-cultural perceptions of alternative materials. The study concludes that circular construction materials provide a practical, scalable, and cost-effective pathway for low-carbon housing in Nigeria. However, their successful mainstreaming requires coordinated policy support, professional capacity development, and strengthened market systems.

Keywords: *Circular Economy; Low-Carbon Housing; Circular Construction Materials; Embodied Carbon; Life-Cycle Assessment; Nigerian Urban Housing.*

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I. INTRODUCTION

The global building sector is a major contributor to greenhouse gas emissions, encompassing both operational and embodied carbon across the building lifecycle, particularly in rapidly developing economies [1][2][3]. In Nigeria, rapid urbanisation, population growth, and rising housing demand have intensified reliance on carbon-intensive materials and linear production systems, especially in urban centres, thereby exacerbating environmental pressures [4][5][6]. Conventional materials such as cement and sandcrete blocks significantly contribute to emissions due to the high energy intensity of their production and associated supply chains [7][8][9]. Consequently, there is an urgent need to transition towards low-carbon, resource-efficient housing systems that integrate material efficiency, life-cycle thinking, and affordability [10].

Circular economy principles provide a viable framework for addressing these challenges by promoting resource efficiency, waste minimisation, and material reuse, particularly in contexts with increasing resource constraints and waste generation [11][12][13]. Unlike the linear "take–make–dispose" model, circular construction emphasises closed-loop material flows, life-cycle optimisation, and the decoupling of economic growth from resource consumption. However, implementation varies with institutional capacity [14][15][16]. In practice, this involves using recycled, renewable, and low-impact materials alongside design strategies that enhance reuse, adaptability, and durability in housing systems [17][18][19]. These approaches align with sustainability transition frameworks that advocate systemic transformation in socio-technical systems, including construction practices and material supply chains [20][21].

In Nigeria, the adoption of circular construction materials remains limited despite growing awareness of sustainable building practices [22][23][24]. Locally sourced materials such as stabilised laterite, compressed earth blocks, and timber systems show strong potential to reduce embodied carbon while improving affordability and resource efficiency, particularly in low- and medium-income housing contexts [25][26][27][28]. Evidence from Sub-Saharan Africa further indicates that earth-based and alternative materials can enhance thermal performance and reduce life-cycle energy use. However, outcomes vary depending on material composition and construction techniques [29][30][31][32]. Advances in material science continue to expand viable low-

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carbon options, though their application is often constrained by cost and technical capacity [33][34][35][36].

However, adoption is hindered by weak regulatory frameworks, limited technical expertise, fragmented supply chains, and socio-cultural perceptions, particularly within informal and rapidly developing urban housing sectors [37][38]. Inefficient construction and demolition waste management systems further restrict material recovery and circularity [39]. These constraints highlight the need for integrated approaches combining policy support, capacity development, and market-based incentives.

Existing research on circular construction remains fragmented, often focusing on individual materials or case-specific applications, lacking a comprehensive synthesis across material systems and performance indicators [40][41]. Although life-cycle assessment is widely recognised as a critical tool for evaluating environmental performance, inconsistencies in system boundaries and assumptions limit comparability [42][43]. Systematic reviews demonstrate the value of integrating diverse evidence to support policy and design decisions in emerging research areas [43][44][45].

This study, therefore, systematically reviews and synthesises the literature on circular construction materials for low-carbon housing in Nigeria's urban communities. By integrating life-cycle assessment, circular economy theory, and sustainability transition frameworks [20][21], it provides a robust, context-sensitive evidence base to inform policy, research, and practice, while also offering a comparative, policy-relevant framework for sustainable housing delivery.

II. LITERATURE REVIEW

➢ *Decarbonisation of the Building Sector and Housing Imperatives*

The building sector is a major contributor to global greenhouse gas emissions, driven by both operational energy use and the embodied carbon of construction materials [5][1][2][3]. In Nigeria, rapid urbanisation and growing housing demand have intensified reliance on carbon-intensive materials such as cement and sandcrete blocks, thereby increasing environmental impacts [4][6]. Evidence from cement and concrete production further highlights their substantial emissions footprint and the urgency of adopting low-carbon alternatives [7][8].

Embodied carbon has emerged as a critical concern, as emissions from material production and construction processes constitute a significant share of total building impacts [46]. This reinforces the importance of material-efficiency strategies and life-cycle-based approaches to reducing emissions throughout the building life cycle [9]. However, despite growing attention to material efficiency, there remains limited consensus on the relative contribution of embodied versus operational carbon in developing-country housing contexts, highlighting the need for integrated assessment frameworks.

➢ *Circular Economy and Construction Materials*

The circular economy provides a transformative framework for addressing resource inefficiency and environmental degradation in the construction sector by promoting resource recovery, reuse, recycling, and closed-loop material systems [14][11][12]. Within construction, these principles are operationalised through material reuse, design for disassembly, waste reduction, and life-cycle optimisation, thereby enhancing resource efficiency and reducing environmental impacts [13][17][18][45].

The circular economy further supports the decoupling of economic growth from resource consumption, particularly in developing countries facing increasing resource constraints and environmental pressures [15][16]. In Nigeria, circular construction presents a viable pathway for addressing housing deficits while minimising environmental footprints. However, its implementation remains constrained by informal material flows and weak recycling infrastructure, which limit the effectiveness of closed-loop systems.

➢ *Life-Cycle Assessment and Material Performance*

Life-cycle assessment (LCA) is widely recognised as a key tool for evaluating the environmental performance of building materials and systems. It enables quantification of embodied carbon across the construction stages, from raw material extraction to end-of-life disposal [42][43].

Comparative LCA studies demonstrate that alternative materials and circular construction approaches can significantly reduce environmental impacts compared to conventional systems [32][49]. Research on earth construction and material substitution further confirms the potential of low-impact materials in achieving sustainability goals [31]. In addition, LCA-based evaluations of housing systems show that material choices play a critical role in determining overall environmental performance, reinforcing the need for integrated life-cycle thinking in building design. However, variations in system boundaries, functional units, and data assumptions across LCA studies reduce comparability, highlighting the need for standardised assessment protocols.

➢ *Circular Construction Materials for Low-Carbon Housing*

A growing body of literature highlights the potential of circular construction materials in reducing embodied carbon while supporting affordable housing delivery. Locally sourced materials such as laterite, earth blocks, and stabilised soil systems have been widely recognised for their low environmental impact and suitability for tropical climates [25][26][27].

Empirical studies confirm the viability of red earth, quarry dust, and stabilised lateritic soils as alternatives to sandcrete blocks [28][35][36]. Evidence from Sub-Saharan Africa shows these materials significantly reduce embodied carbon and enhance thermal performance [30][29]. Timber systems and other low-carbon substitutes further support emission reduction in construction [48][19]. Advances in green materials and circular design reinforce material

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substitution, combined with local sourcing and life-cycle optimisation, as a key pathway for low-carbon tropical housing [33][34].

- *Waste Management and Resource Efficiency in Construction*

Construction and demolition waste management is a critical component of circular construction. Effective waste recovery and reuse can significantly reduce environmental impacts and resource consumption. However, studies indicate that waste management practices in Nigeria remain underdeveloped, limiting opportunities for material recovery and recycling [39].

Improving waste management systems is therefore essential for enhancing circularity in the construction sector. This includes strengthening supply chains, improving material recovery processes, and integrating waste reduction strategies into project planning and execution.

- *Barriers to Adoption and Implementation Challenges*

Despite the benefits of circular construction materials, their adoption in Nigeria is constrained by multiple barriers. Technical challenges include limited expertise and inadequate integration of sustainable practices in design and construction processes [37].

Economic barriers, particularly the perception of higher initial costs, further hinder adoption, even though circular materials often provide long-term cost savings. Institutional challenges, including weak regulatory frameworks and a lack of policy incentives, also limit widespread implementation [38][22].

Socio-cultural factors, such as user preferences and perceptions of alternative materials, contribute to resistance to change. These challenges highlight the need for coordinated efforts across policy, industry, and research to promote circular construction practices [24][23]. These barriers are interdependent, indicating that technical, economic, and institutional constraints operate as a reinforcing system rather than isolated challenges.

- *Theoretical and Research Gaps*

Sustainability transitions theory provides a useful lens for explaining the slow adoption of circular construction practices, highlighting the influence of socio-technical systems and institutional structures on the uptake of innovation [20][21]. Despite valuable contributions, existing studies remain fragmented, with limited integration of material, environmental, and socio-economic dimensions. Much of the literature focuses on individual materials or case-specific applications, lacking a comprehensive synthesis.

Critically, few studies combine environmental performance, material efficiency, and socio-economic feasibility within a unified analytical framework, limiting their relevance for policy and large-scale implementation. Systematic review approaches offer a robust means of integrating diverse evidence and identifying gaps [44]. This study therefore provides a comprehensive synthesis to inform policy, practice, and future research.

- *Conceptual Framework*

The conceptual framework for this study illustrates the relationships among circular construction material strategies, their performance outcomes, and the barriers to their adoption in Nigeria’s housing sector. It is grounded in circular economy theory, life-cycle thinking, and sustainability transition frameworks, which emphasise resource efficiency, environmental performance, and systemic constraints [11][13][20].

The framework conceptualises the application of circular material strategies, including material substitution, reuse and recycling, local sourcing, and design for material efficiency, as directly influencing performance outcomes, particularly embodied carbon reduction, resource efficiency, and cost optimisation. However, the effectiveness and scalability of these outcomes are constrained by implementation barriers, including weak regulatory frameworks, limited technical expertise, fragmented supply chains, and socio-cultural perceptions [37][38].

The framework further recognises feedback interactions, where performance outcomes can inform policy improvements and market acceptance, thereby reducing barriers over time.

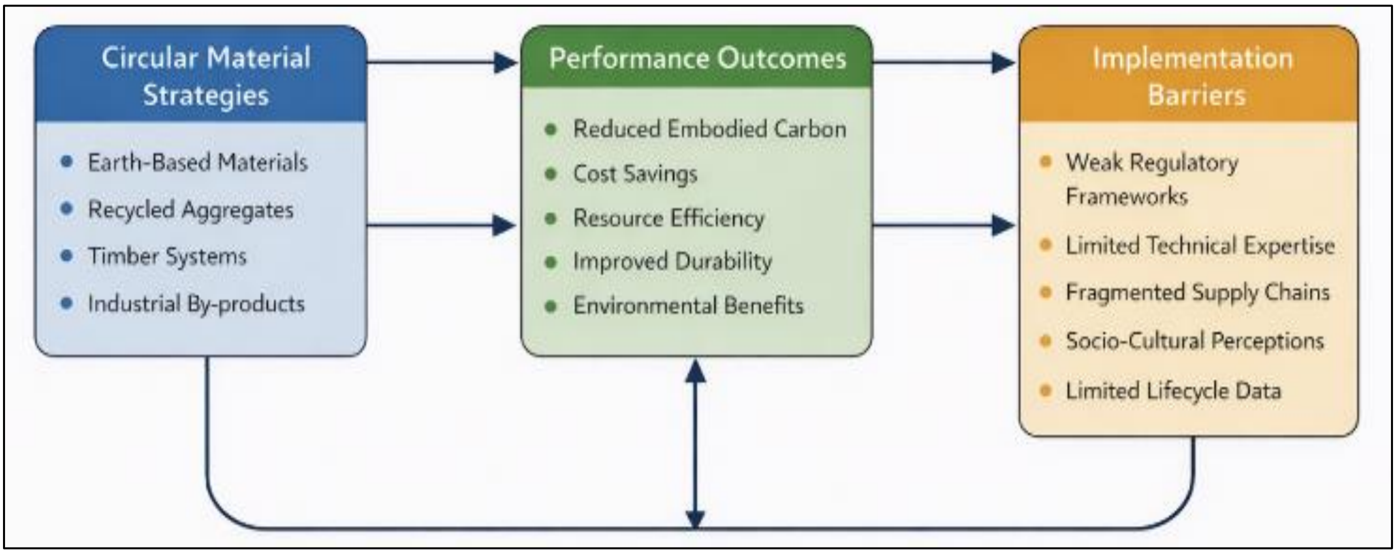

Fig 1 Conceptual Framework for Circular Construction Materials in Low-Carbon Housing

III. RESEARCH METHODOLOGY

➢ *Research Design*

This study adopts a systematic review and meta-synthesis to examine circular construction materials for low-carbon housing in Nigeria. The approach provides a transparent and replicable framework for identifying, evaluating, and synthesising evidence, enhancing reliability and validity [44]. Unlike narrative reviews, which may be selective [47], it follows structured procedures to minimise bias. The study integrates descriptive statistics, thematic synthesis, and comparative analysis to assess material trends and interpret circular strategies.

➢ *Identification and Search Strategy*

A comprehensive literature search was conducted across major academic databases, including Scopus, Web of Science, ScienceDirect, Google Scholar, and SpringerLink, to capture high-quality peer-reviewed publications. The search focused on studies published between 2015 and 2025, reflecting recent developments in the circular economy, sustainable materials, and low-carbon housing.

Search strings combined keywords and Boolean operators such as: "circular construction materials," "low-carbon housing," "embodied carbon," "life-cycle assessment," "sustainable building materials," "Nigeria," and "urban housing." The search strings were adapted for each database using controlled vocabulary and Boolean operators to improve retrieval accuracy.

The identification stage yielded an initial pool of 256 records.

➢ *Screening Process*

The screening stage involved removing duplicate entries and excluding studies based on titles and abstracts. Studies that did not focus on construction materials, circular economy principles, or housing-related applications were excluded. To minimise selection bias, screening decisions were cross-checked and inconsistencies resolved through iterative review.

Of the 256 identified records, 182 studies were excluded for being irrelevant, duplicative, or not focused on circular construction materials. This resulted in 74 studies progressing to full-text assessment.

➢ *Eligibility Assessment*

Full-text articles were evaluated against predefined inclusion and exclusion criteria:

- *Inclusion Criteria:*

✓ Peer-reviewed journal articles (2015–2025)
✓ Studies addressing circular construction materials or material efficiency
✓ Research focusing on housing or transferable residential applications
✓ Studies employing life-cycle assessment or reporting environmental impacts
✓ Articles with clear methodology and verifiable results

- *Exclusion Criteria:*

✓ Studies focused solely on operational energy without material considerations
✓ Non-peer-reviewed publications (e.g., editorials, abstracts)
✓ Studies lacking methodological rigour or empirical evidence
✓ Non-building-related material studies

These criteria ensured the inclusion of methodologically rigorous and policy-relevant studies. Following this process, 29 studies were excluded, primarily due to insufficient methodological clarity or lack of relevance to housing.

➢ *Inclusion of Final Studies*

A total of 45 studies met the eligibility criteria and were included in the final analysis. The PRISMA-aligned selection

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process began with 256 identified records, of which 182 were excluded during screening. Subsequently, 74 full-text articles were assessed, leading to the exclusion of 29 studies that did not meet the inclusion criteria. This resulted in a final sample of 45 high-quality studies for detailed analysis and synthesis. The selection process is illustrated in Figure 1.

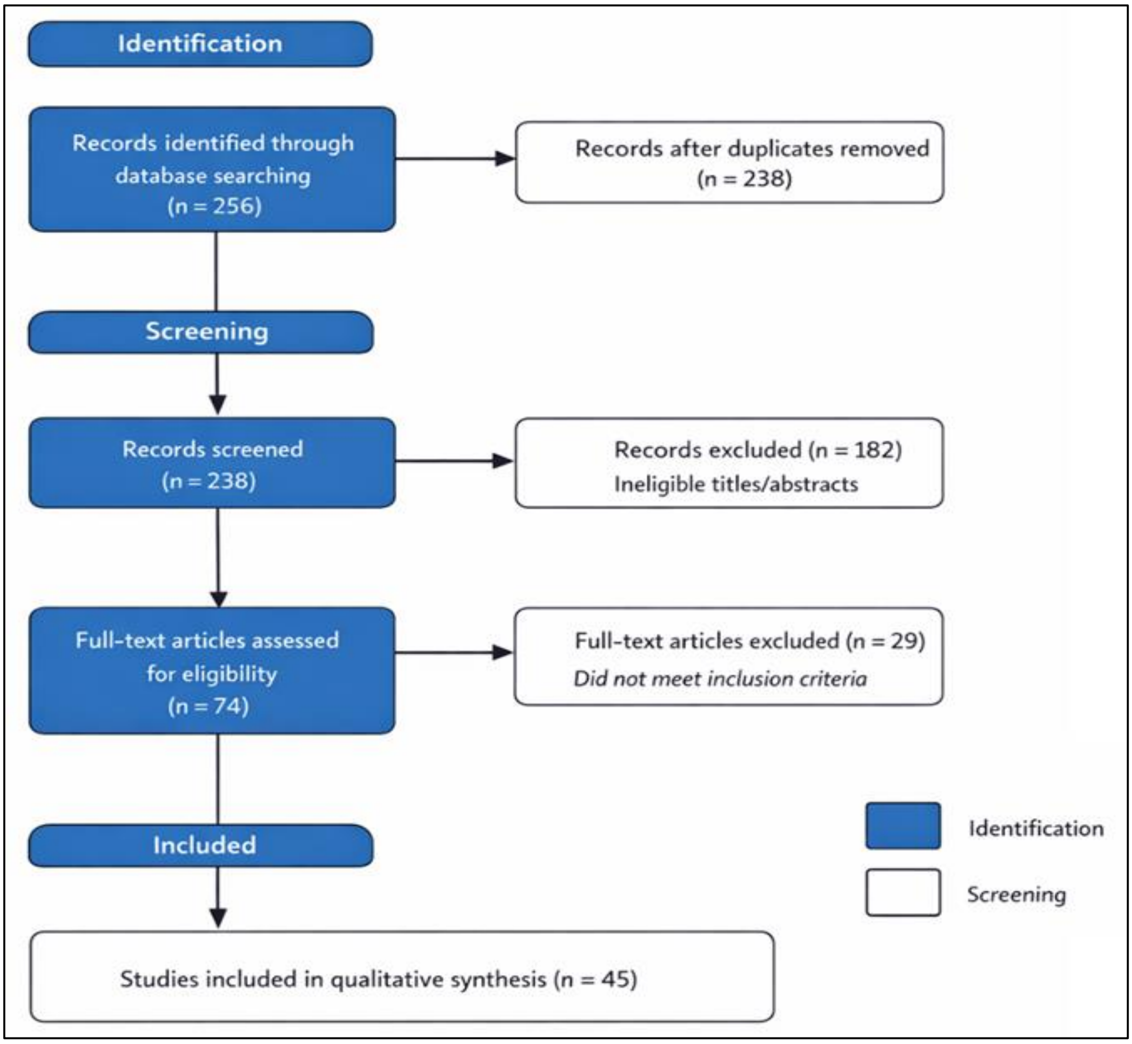

Fig 2 PRISMA Flow Diagram of Study Selection Process

➢ *Data Extraction and Coding*

Data were extracted using a standardised review template to ensure consistency. Key variables included study location, material type, construction application, life-cycle assessment approach, embodied carbon outcomes, and identified barriers and enabling factors.

Extracted data were coded into thematic categories, including earth-based materials, recycled materials, timber systems, industrial by-products, and circular material strategies, facilitating structured comparisons across studies.

➢ *Data Analysis*

Descriptive, thematic, and comparative analyses were employed to examine the reviewed studies. Descriptive statistics were used to quantify the distribution and frequency of circular material strategies, while thematic analysis identified recurring patterns and conceptual relationships across the literature. Comparative analysis examined variations in material performance and applicability across different contexts.

These analytical approaches were complemented by cross-study aggregation of performance indicators to enhance analytical robustness and identify consistent patterns across the reviewed literature.

➢ *Data Synthesis*

A meta-synthesis approach was used to integrate qualitative and quantitative findings. Reported performance indicators, particularly embodied carbon reductions and material efficiency outcomes, were aggregated to derive typical performance ranges and identify dominant material strategies.

This synthesis enabled the identification of key trends, levels of effectiveness, and interrelationships among circular construction materials.

➢ *Reliability and Validity*

Reliability was ensured through predefined selection criteria, the use of peer-reviewed sources, and a standardised extraction process. Validity was enhanced through

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triangulation of findings across multiple studies and contexts, improving the robustness and generalisability of conclusions.

Triangulation across methodological approaches and geographic contexts further enhances the robustness and generalisability of the findings.

IV. RESULTS

➢ *Study Characteristics and Evidence Base*

A total of 45 peer-reviewed studies (2015–2025) met the inclusion criteria, providing a robust evidence base for analysing circular construction materials in low-carbon housing. The studies cover Nigeria (44.4%, n = 20) and comparable contexts (55.6%, n = 25), enhancing both contextual relevance and external validity. As shown in Table 4.1, life-cycle assessment (LCA)-based studies dominate (40.0%), followed by experimental/material studies (26.7%), case studies (20.0%), and review-based studies (13.3%). Material focus is dominated by earth-based materials (37.8%), followed by recycled materials (24.4%), industrial by-products (20.0%), and timber systems (17.8%). This distribution reflects a strong emphasis on material substitution using local or renewable resources. The dominance of LCA approaches suggests convergence on embodied-carbon metrics, though design-led strategies and post-occupancy evidence remain underrepresented.

Table 1 Descriptive Profile of Reviewed Studies (n = 45)

Variable	Category	Frequency	Percentage (%)
Study Type	LCA-based studies	18	40.0
	Experimental studies	12	26.7
	Case studies	9	20.0
	Review-based	6	13.3
Geographic Focus	Nigeria	20	44.4
	Other regions	25	55.6
Material Type	Earth-based materials	17	37.8
	Recycled materials	11	24.4
	Industrial by-products	9	20.0
	Timber systems	8	17.8

This distribution reflects a strong emphasis on material-based decarbonisation strategies, supported by empirical and analytical evaluation methods.

➢ *Distribution of Circular Material Strategies*

The frequency distribution of circular construction strategies (Table 4.2) reveals a clear hierarchy of adoption. Low-carbon material substitution is the most dominant strategy (75.6%), followed by material reuse and recycling (68.9%) and the use of locally sourced materials (64.4%). Material efficiency strategies appear in 57.8% of studies, while design for disassembly remains comparatively limited (46.7%).

Table 2 Frequency of Circular Material Strategies

Strategy	Frequency (n)	Percentage (%)
Low-carbon material substitution	34	75.6
Material reuse and recycling	31	68.9
Locally sourced materials	29	64.4
Material efficiency strategies	26	57.8
Design for disassembly	21	46.7

The dominance of substitution and recycling indicates a material-centric focus on immediate carbon reduction. Conversely, the low emphasis on disassembly highlights underdeveloped end-of-life recovery strategies, reflecting a bias toward short-term decarbonisation over full life-cycle circularity.

➢ *Thematic Synthesis of Circular Construction Strategies*

Thematic analysis identifies five coherent and recurring domains:

- *Material Substitution and Innovation:*

  Adoption of low-carbon materials such as laterite, timber, and recycled aggregates reduces embodied emissions.

- *Life-Cycle Optimisation:*

  Integrating LCA frameworks improves decision-making in material selection and building design.

- *Resource Efficiency and Waste Reduction:*

  Circular practices reduce construction waste and promote reuse.

- *Local Material Utilisation:*

  Locally sourced materials enhance affordability and reduce transportation-related emissions.

- *System Integration and Circular Design:*

  Combining material strategies with circular design principles yields improved sustainability outcomes.

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- *Analytical Insight:*

The co-occurrence of these themes across multiple studies demonstrates strong conceptual convergence, reinforcing the internal validity of the synthesis and highlighting the transition from isolated material innovations toward system-level circular approaches.

➢ *Meta-Synthesis of Performance Outcomes*

Quantitative aggregation of performance indicators (Table 4.3) reveals consistent environmental and economic benefits across studies.

Table 3 Meta-Synthesis of Performance Outcomes

Performance Indicator	Range	Mean Estimate
Embodied carbon reduction	25–70%	~45%
Material cost savings	10–35%	~22%
Construction waste reduction	20–60%	~38%

- *Embodied Carbon Reduction:*

Circular material strategies achieve reductions of 25–70% (mean ≈45%), with higher performance associated with earth-based and timber substitutions. Variability reflects differences in system boundaries, climatic conditions, and LCA modelling assumptions.

- *Cost Efficiency:*

Material efficiency and local sourcing produce cost savings of 10–35%, indicating alignment between environmental and economic performance.

- *Waste Reduction:*

Waste reductions of 20–60% demonstrate significant improvements in resource efficiency and landfill diversion.

- *Robustness Consideration:*

While cross-study aggregation strengthens reliability, heterogeneity in methodologies limits the application of advanced statistical validation such as variance estimation, weighting, and sensitivity testing. This introduces moderate uncertainty but does not undermine the consistency of directional findings.

➢ *Comparative Effectiveness of Material Strategies*

Comparative analysis reveals differentiated performance levels:

- *High-Impact:*
  Material substitution and reuse/recycling

- *Moderate-Impact:*
  Local sourcing and material efficiency

- *Emerging-Impact:*
  Design for disassembly and circular integration

Circular construction performance is maximised through integrated, multi-strategy approaches. Studies consistently show that combining substitution, reuse, and efficiency strategies yields cumulative benefits that exceed those of isolated interventions, indicating strong synergistic effects.

➢ *Barriers to Implementation*

The frequency of identified barriers (Table 4) highlights systemic constraints affecting adoption.

Table 4 Frequency of Identified Barriers

Barrier Type	Frequency (n)	Percentage (%)
Technical barriers	31	68.9
Economic barriers	27	60.0
Institutional barriers	25	55.6
Supply chain barriers	23	51.1
Socio-cultural barriers	21	46.7

Technical barriers stem from limited expertise in circular design and material applications. Economic constraints reflect cost uncertainty despite demonstrated long-term benefits. Institutional weaknesses include inadequate policy enforcement, while supply chain limitations restrict material recovery and distribution. Socio-cultural resistance further constrains adoption.

- *Systems Insight:*

The recurrence of these barriers across studies indicates deeply embedded structural constraints within the construction ecosystem, rather than isolated implementation challenges.

➢ *Synthesis of Findings*

The results reveal three dominant patterns. First, circular construction research is strongly oriented toward material substitution and recycling, reflecting a pragmatic focus on immediate carbon reduction. Second, there is consistent, convergent evidence of significant environmental benefits, particularly reductions in embodied carbon of 25–70% and measurable gains in resource efficiency. Third, despite proven effectiveness, large-scale adoption remains constrained by persistent, multi-dimensional systemic barriers.

Collectively, these findings confirm that circular construction materials offer a viable and scalable pathway for low-carbon housing. However, their full potential depends on

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integrated implementation across material innovation, design processes, and institutional systems.

V. DISCUSSION

➢ *Interpretation of Key Findings in a Global Context*

The findings confirm that material substitution and recycling strategies dominate circular construction research, reflecting a broader global transition toward material decarbonisation in the built environment. This aligns with international evidence indicating that reducing reliance on carbon-intensive materials such as cement and steel remains one of the most immediate and scalable pathways for emissions reduction [4][7]. Globally, studies have shown that material substitution alone can account for 40–60% of achievable embodied-carbon reductions in residential buildings, particularly when combined with low-impact materials and optimised design strategies. This finding also reflects global trends in material decarbonisation, in which substitution strategies are prioritised for their immediate impact and scalability.

The prominence of earth-based and locally sourced materials within the reviewed studies further reinforces their relevance in tropical and resource-constrained contexts. Similar trends have been observed in Sub-Saharan Africa and parts of Asia, where locally available materials reduce both environmental impacts and supply chain dependencies. In Nigeria, this is particularly significant given the dual challenge of affordability and environmental sustainability [25].

The meta-synthesis results, indicating embodied carbon reductions of 25–70%, are consistent with global life-cycle assessment benchmarks, which report reductions of 20–80%, depending on material systems and design integration. These findings corroborate the critical role of material selection in determining building life-cycle performance [42][46]. However, the observed variability highlights a persistent challenge in LCA-based research, namely, inconsistencies in system boundaries, functional units, and data assumptions. This variability limits cross-study comparability and underscores the need for harmonised methodological frameworks.

Importantly, the findings demonstrate that integrated circular strategies consistently outperform isolated interventions. This supports circular economy theory, which emphasises systemic, multi-level integration rather than single-point optimisation [11]. Global best practices similarly indicate that combining material substitution, reuse, and design for disassembly can yield synergistic benefits that exceed the sum of individual strategies.

➢ *Implications for Low-Carbon Housing in Nigeria and Comparable Contexts*

The results highlight the strong potential of circular construction materials to support low-carbon housing delivery in Nigeria, particularly when benchmarked against global sustainability targets. Given that embodied carbon can account for up to 50% of total building emissions in rapidly developing regions, the adoption of circular material strategies presents a critical opportunity for emissions mitigation. This is especially relevant in Nigeria, where housing demand continues to rise, and construction practices remain largely resource-intensive [10], particularly in low-income housing delivery, where cost constraints are critical.

The use of locally sourced materials such as stabilised laterite and earth-based systems aligns with both circular economy principles and sustainable housing frameworks. Beyond environmental benefits, these materials contribute to economic resilience by reducing dependence on imported construction inputs and supporting local industries [26]. Comparable studies in other developing economies have demonstrated that local material utilisation can reduce construction costs by up to 30% while improving environmental performance.

Furthermore, the integration of circular materials supports global decarbonisation pathways outlined by international agencies, which emphasise demand-side material efficiency alongside energy efficiency [5][1]. In this regard, circular construction represents a practical and scalable approach to achieving low-carbon housing outcomes in rapidly urbanising regions.

➢ *Structural Barriers and Systemic Constraints*

Despite strong evidence of effectiveness, adoption remains constrained by interrelated systemic barriers. Technical limitations, particularly inadequate expertise in circular design and life-cycle assessment, reflect broader capacity gaps within the construction sector [37]. While this challenge exists globally, it is more pronounced in developing contexts with limited professional training and institutional support.

Economic barriers, especially the perception of high upfront costs, further hinder adoption. However, evidence suggests that circular material strategies often achieve life-cycle cost savings, indicating a disconnect between short-term investment decisions and long-term performance outcomes [49].

Institutional constraints, including weak regulatory enforcement and the absence of embodied carbon standards, also limit implementation. In contrast, regions with established policies, such as mandatory carbon reporting, demonstrate higher adoption rates, suggesting that Nigeria's uptake will remain limited without similar frameworks [38].

Additionally, fragmented supply chains, inadequate material recovery infrastructure, and socio-cultural preferences for conventional materials further restrict scalability, highlighting the need for coordinated policy, industry, and practice-based interventions.

➢ *Research Gaps and Future Directions*

The study identifies key gaps requiring attention to advance circular construction research. First, standardised life-cycle assessment methodologies are needed to improve comparability and reliability across studies, as variations in

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system boundaries and data assumptions currently limit the robust synthesis of results [42].

Second, empirical evidence on long-term performance remains limited, with existing studies largely dominated by laboratory and simulation approaches; future research should prioritise longitudinal assessments of durability, maintenance, and user acceptance. Third, integration of circular materials with emerging approaches such as modular construction, prefabrication, and design for disassembly remains underexplored in Nigeria. Finally, more context-specific studies are required to address regional variations in climate, material availability, and socio-economic conditions.

➢ *Policy and Practice Implications*

The findings underscore the need for transformative policy and institutional frameworks to accelerate the adoption of circular construction materials. Governments should embed circular economy principles within building codes, procurement systems, and housing policies. Policy frameworks should integrate mandatory embodied-carbon assessments into building approvals, aligning Nigeria with emerging global standards.

Incentive mechanisms, including tax reliefs, subsidies, and green certification schemes, can further stimulate market adoption. Additionally, investment in recycling infrastructure and material recovery systems will be essential to enable closed-loop material flows.

For professional practice, the study highlights the importance of integrating circular design principles into mainstream workflows. This includes the use of LCA tools, digital material databases, and performance-based design approaches. Strengthening collaboration among academia, industry, and policymakers will be critical to bridging knowledge gaps and scaling implementation.

➢ *Limitations of the Study*

This study is limited by its reliance on secondary data and variations in life-cycle assessment methodologies across the reviewed studies, which may affect comparability. Additionally, the absence of primary empirical validation restricts context-specific generalisation of the findings.

VI. RECOMMENDATIONS AND CONCLUSION

➢ *Recommendations*

Based on the findings, several measures are required to enhance the adoption of circular construction materials for low-carbon housing in Nigeria. First, policy and regulatory frameworks should be strengthened to embed circular economy principles within building codes, procurement systems, and housing policies. Clear guidelines on material efficiency, reuse, and embodied-carbon assessment should be established and supported by incentives such as tax reliefs and green certification schemes.

Second, professional capacity development is essential. Architectural and construction education should integrate life-cycle assessment, circular design principles, and low-carbon material technologies, while continuous professional development programmes should equip practitioners with practical implementation skills.

Third, the promotion of locally sourced materials should be prioritised through targeted research, demonstration projects, and public awareness initiatives. This will help address misconceptions about performance while supporting affordability and local economic development.

Fourth, circular material supply chains require strengthening through improved material recovery systems, recycling infrastructure, and distribution networks to ensure availability and scalability.

Finally, research and data development should focus on standardising life-cycle assessment methodologies and establishing localised performance benchmarks to support evidence-based design and policy decisions.

➢ *Conclusion*

This study systematically examined the role of circular construction materials in advancing low-carbon housing in Nigeria's urban communities. The findings demonstrate that material substitution, reuse, and local sourcing can significantly reduce embodied carbon, improve resource efficiency, and enhance housing sustainability.

The evidence confirms that circular material strategies are both environmentally effective and economically viable when integrated within a life-cycle framework. However, adoption remains constrained by technical, economic, institutional, and socio-cultural barriers. Addressing these challenges requires coordinated action across policy reform, professional capacity building, industry innovation, and public engagement.

The transition to circular construction materials is therefore not optional but essential for achieving sustainable, resilient, and low-carbon housing systems in Nigeria.

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