Climate-Smart Housing Strategies for Sustainable Urban Development in Nigeria: A Review of the Architect's Integrative Role

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ABSTRACT

Climate change and rapid urbanisation are intensifying housing deficits and environmental pressures in Nigeria, necessitating a transition toward climate-smart housing systems. However, there is a lack of empirically validated architect-centred integration frameworks linking design, materials, and digital technologies. This study addresses this gap by adopting a PRISMA-based systematic review methodology, analysing 57 peer-reviewed journal articles (2016–2026) selected from an initial pool of 493 records, following PRISMA guidelines and supported by international policy reports. The study synthesises evidence across three core domains: passive design strategies, low-carbon materials, and digital technologies. Findings show that passive strategies reduce operational energy demand by 30–50%, low-carbon materials decrease embodied emissions by 30–40%, and digital technologies enhance construction efficiency and reduce waste by 15–25%. Inferential analysis using a Chi-square test ($\chi^2 = 0.94$, $p > 0.05$) indicates no statistically significant difference in thematic prominence, confirming that these strategies are complementary rather than hierarchically dominant. The results further reveal strong correlations between passive design and thermal comfort, low-carbon materials and emission reduction, and digital technologies and lifecycle optimisation. Despite these benefits, adoption remains constrained by institutional inefficiencies, financial limitations, and gaps in technical capacity. The study establishes the architect as a system integrator within socio-technical housing systems, capable of aligning environmental performance, material innovation, and technological application. It concludes that architect-led, interdisciplinary, and policy-supported approaches are essential for scaling climate-smart housing and achieving sustainable urban transformation.

Keywords: Climate-smart housing; Sustainable urban development; Architect-led integration; Low-carbon construction; Nigeria

INTRODUCTION

Rapid urbanisation and climate change have emerged as defining global challenges, with profound implications for housing delivery systems, particularly in developing countries such as Nigeria. Globally, over 55% of the population resides in urban areas, with projections indicating an increase to nearly 70% by 2050, thereby intensifying pressure on housing infrastructure and urban services (United Nations, 2019; Aliyu & Amadu, 2017; Koko et al., 2021; Li et al., 2022). In Nigeria, major urban centres such as Lagos, Abuja, and Ibadan are experiencing accelerated spatial expansion, leading to acute housing shortages, proliferation of informal settlements, and escalating environmental degradation (World Bank, 2021; Auwalu & Bello, 2023; Umar et al., 2024). Current estimates place the housing deficit at over 17 million units, underscoring the urgency for innovative and sustainable solutions (Ewurum et al., 2020; Adedeji et al., 2023; Olubi & Aseyan, 2022; Garba et al., 2024).

The built environment significantly contributes to global environmental pressures, accounting for approximately 36% of energy consumption and 37% of greenhouse gas emissions (UNEP, 2022; IPCC, 2022; Andersen et al., 2020). In Nigeria, conventional construction practices rely heavily on carbon-intensive materials such as cement, steel, and sandcrete blocks, leading to high embodied energy and emissions (Taffese & Abegaz, 2019; Chen et al., 2021; Nwagwu et al., 2024). Additionally, many buildings are poorly adapted to local climatic conditions, resulting in excessive reliance on mechanical cooling and reduced indoor comfort (Dorcas & Pourvahidi, 2020; Jega & Al-Din, 2023; Oluwatayo & Miracle, 2025). These challenges necessitate a transition towards climate-responsive and low-carbon housing systems.

An integrated approach has therefore emerged that aligns environmental sustainability, energy efficiency, and resilience within housing delivery. This approach incorporates passive design strategies, low-carbon material utilisation, and digital technologies to optimise building performance (Chel & Kaushik, 2018; Makhloufi, 2024; Listerborn, 2025; Baesse, 2025). Passive strategies, including natural ventilation, solar orientation, shading, and thermal mass, have been widely recognised for improving indoor comfort and reducing energy demand in tropical climates (Kerdan et al., 2019; Chen et al., 2020; Danjuma et al., 2025). Empirical studies in Nigeria show that passive cooling can significantly reduce reliance on air conditioning, thereby lowering operational energy consumption and emissions (Inusa & Alibaba, 2017; Ibrahim et al., 2024; Rasheed et al., 2024; Zoure & Genovese, 2022). The integration of biophilic and vernacular design further enhances climate responsiveness and occupant well-being (Kalu & Ogunnaike, 2025; Jega & Al-Din, 2023).

Material selection is equally critical in determining environmental performance. Conventional materials are associated with high embodied carbon, prompting increasing adoption of alternatives such as compressed stabilised earth blocks, laterite, and bamboo (Joshua et al., 2017; Obaje et al., 2022; Asha Sapna & Anbalagan, 2023). These materials reduce environmental impact while improving affordability and supporting local economies. In addition, circular construction practices, including reuse and recycling, enhance resource efficiency and minimise waste (Ogunmakinde et al., 2019; Abdullahi et al., 2023; Unegbu et al., 2025).

Digital technologies are further transforming housing design and delivery. Tools such as Building Information Modelling (BIM), Geographic Information Systems (GIS), and digital twins enable improved design coordination, lifecycle assessment, and resource optimisation (Soust-Verdaguer et al., 2023; Namaki et al., 2024; Piras et al., 2024; Şenol & Gökgöz, 2024). In Nigeria, BIM adoption has shown potential to improve project efficiency and sustainability performance, although uptake remains constrained by technical and institutional limitations (Okereke et al., 2021; Uduokhai et al., 2023; Olugboyega et al., 2023; Alabi et al., 2026). Integration with life cycle assessment further strengthens evidence-based decision-making in design processes.

Despite this growing body of knowledge, several barriers continue to hinder widespread adoption in Nigeria. These include high initial costs, weak policy enforcement, limited stakeholder awareness, and resistance to innovation within the construction industry (Osuizugbo et al., 2020; Oluleye et al., 2021; Erifeta, 2025). Furthermore, a persistent gap exists between research and practical implementation, particularly in large-scale housing projects where cost considerations often override sustainability priorities (Saidu & Yeom, 2020; Ezeokoli et al., 2025; Oke et al., 2025). These constraints highlight the need for integrative approaches that bridge the divide between knowledge and practice.

Within this context, the role of the architect becomes central. Architects act as coordinators of design, material selection, and technological application, enabling the integration of these strategies into cohesive housing systems. Contemporary practice increasingly emphasises sustainability-driven design thinking and interdisciplinary collaboration, reinforcing the architect's capacity to translate global frameworks into locally relevant solutions (Mba et al., 2024). This integrative role is particularly critical in Nigeria, where systemic inefficiencies and capacity gaps often limit effective implementation.

Education and capacity building further reinforce this role. Polytechnic institutions and architectural training programmes provide essential platforms for developing competencies in sustainable design and digital technologies (Jogana et al., 2020; Marcel-Okafor & Okafor, 2020, 2021; Mukhtar et al., 2022; Yusuf et al., 2025). By embedding sustainability principles into curricula and promoting interdisciplinary collaboration, these institutions can enhance future professionals' ability to deliver responsive housing solutions. International organisations also reinforce this direction, with UNEP (2022) and IPCC (2022) emphasising the need to decarbonise the built environment and promote resilient housing systems.

While prior studies examine individual strategies, few empirically validated integrative frameworks position the architect as the coordinating agent linking environmental performance, material systems, and digital processes. Furthermore, limited research explicitly explores how architects can drive the adoption and scaling of such approaches in Nigeria. This study addresses these gaps by synthesising evidence from 57 peer-reviewed journal articles and supporting international reports.

This study is anchored in ecological modernisation and socio-technical transitions theories, which emphasise the role of technological innovation, institutional reform, and actor coordination in achieving sustainability transitions within the built environment. These perspectives provide a foundation for understanding how architects can integrate design strategies, material systems, and digital technologies to drive low-carbon and resilient housing delivery.

Accordingly, the study is guided by the following research questions: RQ1: How do passive design strategies influence energy performance? RQ2: What is the impact of low-carbon materials on embodied emissions? RQ3: How do digital technologies improve housing delivery efficiency? RQ4: How can architects integrate these strategies into a unified framework?

This study contributes empirically through quantitative synthesis, theoretically by advancing an architect-centred integration model, methodologically through PRISMA-based review with inferential validation, and practically by providing policy and design insights. By positioning the architect as a key agent of integration, this approach advances low-carbon, resilient housing delivery as a viable pathway to addressing Nigeria's housing deficit while promoting environmental sustainability and urban resilience.

LITERATURE REVIEW

Conceptualising Climate-Smart Housing and the Architect's Centrality

Climate-smart housing is increasingly framed as an integrative paradigm that aligns environmental sustainability, economic efficiency, and social inclusivity within the built environment. It draws from sustainable development principles and climate adaptation frameworks that advocate reduced emissions, improved resilience, and resource efficiency (UNEP, 2022; IPCC, 2022; Andersen et al., 2020). Within this paradigm, the architect assumes a pivotal role as the coordinator of design intelligence, material innovation, and environmental performance. While Mba et al. (2024) emphasise architects' sustainability-driven practice, Makhloufi (2024) and Listerborn (2025) extend the debate towards smart and climate-responsive housing, indicating that architectural responsibility now combines design, technology, and social adaptation.

Theoretically, this paradigm is supported by ecological modernisation theory, socio-technical transitions theory, and the sustainable development framework. These perspectives converge where architectural decisions directly influence energy use, emissions, and occupant well-being (Chel & Kaushik, 2018; Baesse, 2025). However, their limitation is that they remain abstract unless translated into context-sensitive design solutions. The International Energy Agency (2021) reinforces this through net-zero building pathways.

Urbanisation Dynamics and Housing Challenges in Nigeria

Rapid urbanisation remains a defining driver of housing demand and environmental pressure in Nigeria. Studies agree that urban expansion is associated with land-use change, increased urban heat, and heightened climate risks (Koko et al., 2021; Li et al., 2022). Nigerian cities are further marked by unplanned growth, weak infrastructure, and informal settlements, which deepen sustainability challenges (Aliyu & Amadu, 2017; Auwalu & Bello, 2023; Umar et al., 2024).

The housing deficit, estimated at over 17 million units, reflects structural inefficiencies and the urgency for sustainable alternatives (Ewurum et al., 2020; Adedeji et al., 2023; Olubi & Aseyan, 2022; Garba et al., 2024). While Adedeji et al. (2023) and Garba et al. (2024) stress affordability and sustainable design, Saidu and Yeom (2020) highlight welfare-based housing outcomes. A key limitation is that housing demand is often treated as a delivery issue rather than a climate-performance challenge. This gap necessitates a shift towards climate-responsive, scalable, and resource-efficient systems (Mba et al., 2024; Auwalu & Bello, 2023).

Passive Design Strategies and Architectural Innovation

Passive design strategies are widely examined for reducing reliance on mechanical systems through climatic responsiveness. Chen et al. (2020) and Kerdan et al. (2019) emphasise thermal optimisation, while Inusa and Alibaba (2017), Ibrahim et al. (2024), and Rasheed et al. (2024) confirm their effectiveness in tropical contexts. Danjuma et al. (2025) further highlight building form and orientation as critical to ventilation and daylighting.

However, differences persist across the literature. Chen et al. (2020) prioritise performance optimisation, whereas Jega and Al-Din (2023) emphasise vernacular adaptability, indicating the need to integrate performance-driven and culture-based approaches. Zoure and Genovese (2022) support regional transferability, while Kalu and Ogunnaike (2025) extend the concept to biophilic well-being. Dorcas and Pourvahidi (2020) underscore the importance of bioclimatic classification for contextual accuracy.

From an ecological modernisation perspective, passive design represents a low-cost innovation that reduces environmental impact while maintaining functional efficiency. Its limitation lies in its predominantly building-specific application, with limited applicability to mass housing guidelines, thereby reinforcing the architect's role in scaling climatic design principles.

Low-Carbon Materials and Sustainable Construction Practices

Material selection is a major determinant of embodied energy and emissions. Conventional materials such as cement and steel are consistently associated with high environmental burdens (Taffese & Abegaz, 2019; Chen et al., 2021; Nwagwu et al., 2024). In response, Joshua et al. (2017), Obaje et al. (2022), and Asha Sapna and Anbalagan (2023) demonstrate the potential of earth-based and alternative materials to reduce emissions and improve affordability.

While studies agree on environmental benefits, contradictions arise around standardisation and acceptance. Obaje et al. (2022) provide context-specific validation, whereas broader studies often overlook regulatory and market barriers. Circular construction approaches further strengthen sustainability by linking material choice with reuse and waste minimisation (Ogunmakinde et al., 2019; Abdullahi et al., 2023; Unegbu et al., 2025). However, their integration into architectural specification remains limited, reinforcing the architect's coordinating role.

Digital Technologies and Smart Housing Systems

Digital transformation is reshaping architecture and construction through integrated design and lifecycle management. BIM, GIS, and digital twin technologies support performance prediction and resource optimisation (Soust-Verdaguer et al., 2023; Namaki et al., 2024; Piras et al., 2024; Şenol & Gökgöz, 2024). These tools enhance coordination and sustainability assessment, particularly when linked with life cycle analysis.

In Nigeria, studies confirm potential benefits but highlight slow adoption due to cost and capacity constraints (Okereke et al., 2021; Uduokhai et al., 2023; Olugboyega et al., 2023; Alabi et al., 2026). This divergence between global maturity and local adoption indicates that digital tools require institutional and professional alignment. Architects must therefore act as digital integrators, connecting design intent with measurable performance outcomes.

Barriers to Climate-Smart Housing Adoption

Adoption remains constrained by financial, institutional, technical, and behavioural barriers. Osuizugbo et al. (2020) and Oluleye et al. (2021) highlight cost and financing constraints, while Erifeta (2025) and Oke et al. (2025) emphasise regulatory weaknesses. Ezeokoli et al. (2025) and Saidu and Yeom (2020) reveal a persistent gap between research and implementation.

From a socio-technical transitions perspective, these barriers reflect resistance within existing systems in which policies, markets, and professional practices are misaligned with sustainability goals. A key limitation is that barriers are often treated independently, without recognising the need for coordinated intervention. This underscores the importance of architect-led mediation across policy, design, and construction systems.

Education, Capacity Building, and the Architect's Evolving Role

Education plays a critical role in shaping professional competence. Polytechnic institutions provide practical training in sustainable design and construction technologies (Jogana et al., 2020; Marcel-Okafor & Okafor, 2020, 2021). Mukhtar et al. (2022) support competency-based training, while Yusuf et al. (2025) call for curriculum reform aligned with global standards.

Although studies agree on the need for reform, they differ in focus, ranging from BIM integration to occupational skills development. The limitation is that educational outcomes are rarely linked to housing delivery performance. Nevertheless, integrating sustainability and digital competencies can reposition architects as leaders capable of bridging theory and practice.

Synthesis and Research Gap

The reviewed literature demonstrates that passive design, low-carbon materials, and digital technologies offer substantial potential for improving environmental performance, affordability, and resilience. However, adoption remains constrained by institutional inefficiencies, financial limitations, technical capacity gaps, and weak policy frameworks (Erifeta, 2025; Oke et al., 2025; Osuizugbo et al., 2020).

Although valuable insights exist, the literature lacks a unified operational framework linking design, material, and technological systems through architectural coordination. Strategies are often treated as isolated interventions rather than integrated components of housing delivery. This creates a critical gap in explaining how architects can coordinate these elements to achieve scalable and climate-responsive outcomes.

Across sections, the literature consistently demonstrates fragmentation among design strategies, material systems, and technological applications, with limited integrative frameworks that connect them within housing delivery processes. This fragmentation weakens implementation despite strong empirical evidence.

This study addresses this gap by synthesising evidence from 57 peer-reviewed journal articles and supporting international reports, with a specific focus on the architect's integrative role. It advances the discourse by positioning architectural practice as the operational bridge linking environmental performance, innovation, and housing delivery in Nigeria. This study conceptualises the architect as the integrative node linking design, materials, and digital systems.

Accordingly, the proposed architect-led integration model conceptualises the architect as the central coordinating agent who aligns passive design strategies, low-carbon material systems, and digital technologies across the housing delivery process. Within this model, passive design primarily addresses operational energy and thermal comfort; low-carbon materials address embodied carbon and affordability; and digital technologies support lifecycle optimisation, coordination, and performance monitoring. The architect's integrative role, therefore, provides the operational bridge between environmental performance, technological innovation, policy compliance, and scalable housing delivery.

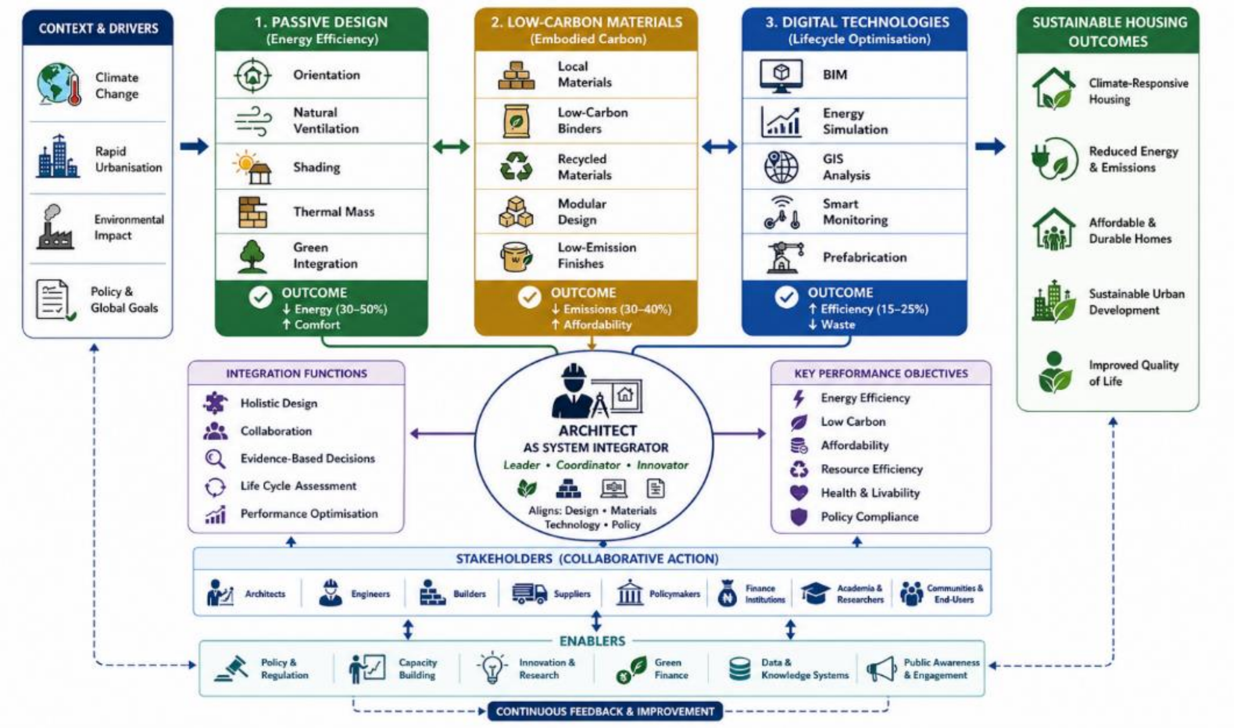

Figure 1. Architect-led integration framework for climate-smart housing delivery in Nigeria

METHODOLOGY

Research Design and Analytical Orientation

This study adopts a PRISMA-based systematic review methodology, integrating qualitative synthesis with quantitative validation to examine climate-smart housing strategies and the architect's critical role in sustainable urban development in Nigeria. The design consolidates dispersed knowledge across architecture, urban planning, environmental science, and construction management into a coherent analytical framework. By adhering to PRISMA procedures, the study ensures transparency, replicability, and methodological rigour in identifying, screening, and selecting relevant literature.

Beyond descriptive synthesis, inferential statistical techniques were applied to validate observed thematic patterns. Analysis was conducted using **SPSS and R**, enabling descriptive statistics, Chi-square testing, and correlation-based synthesis.

Data Sources and Search Strategy

The literature search was conducted across Scopus, Web of Science, ScienceDirect, and Google Scholar to ensure broad coverage of peer-reviewed studies. The search was restricted to publications from 2016 to 2026 to capture recent developments in climate-smart housing and sustainable urban systems.

A structured Boolean search strategy combined terms such as "climate-smart housing," "sustainable housing," "passive design," "low-carbon materials," "digital technologies," and "Building Information Modelling (BIM)" with geographical qualifiers such as "Nigeria" and "developing countries." This process produced an initial dataset of **493 records**.

PRISMA Screening Process

The selection followed the four-stage PRISMA protocol: identification, screening, eligibility, and inclusion. At identification, 493 records were retrieved. After duplicate removal, 385 unique studies remained. Title and abstract screening excluded 247 studies that were not sufficiently aligned with the research focus, leaving 138 articles for full-text assessment. During the eligibility review, 81 studies were excluded for methodological weaknesses, limited relevance, or thematic misalignment. Ultimately, 57 peer-reviewed journal articles were included.

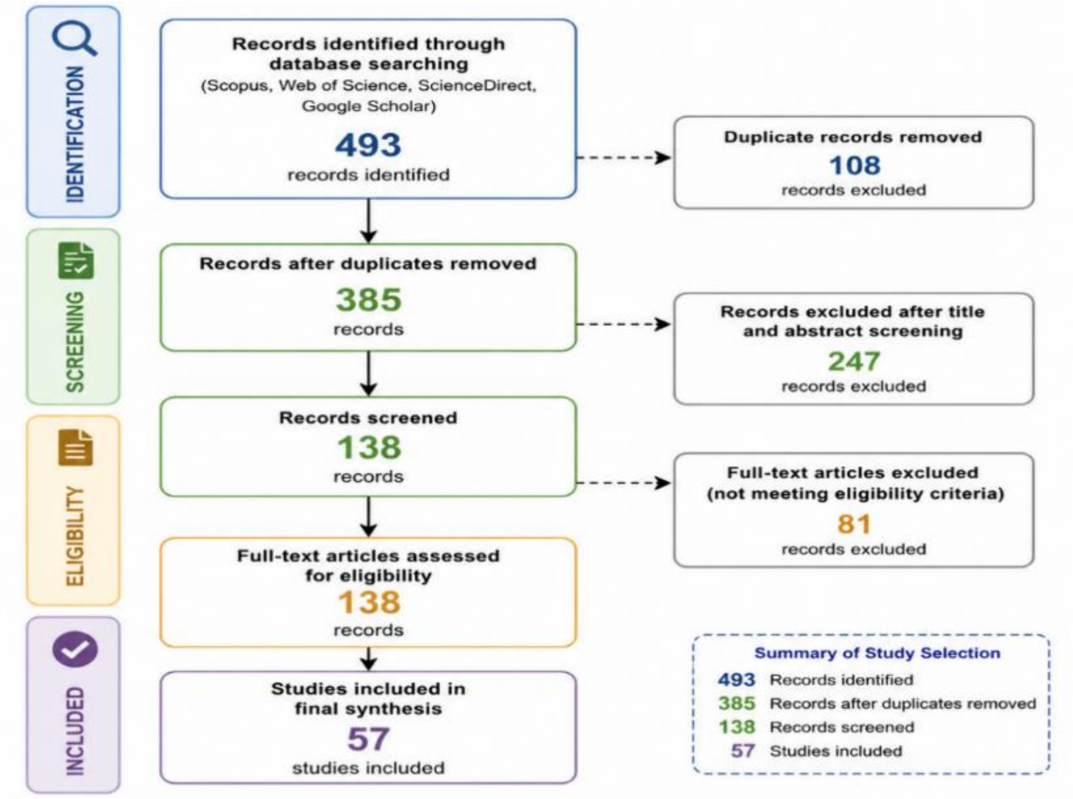

Figure 2: PRISMA Flow Summary

Inclusion and Exclusion Logic

The inclusion criteria prioritised methodological rigour and thematic relevance. Only peer-reviewed journal articles published within the defined timeframe were considered. Studies were required to address climate-smart housing strategies, sustainable construction, architectural innovation, or comparable themes within Nigeria or related developing contexts.

Non-peer-reviewed publications, duplicates, studies lacking empirical or theoretical depth, and papers unrelated to housing sustainability were excluded. Potential publication bias was reduced through multi-database sourcing and consistent screening criteria.

Data Extraction and Thematic Structuring

Data extraction followed a structured template covering authorship, publication year, geographical context, research method, thematic focus, and reported outcomes on energy efficiency, carbon reduction, and cost or resource implications. The studies were then organised into three thematic domains: passive design strategies, low-carbon materials, and digital technologies. This structure enabled systematic comparison and synthesis.

Quantitative Synthesis Using Weighted Frequency Index

To determine thematic prominence, the Weighted Frequency Index (WFI) was applied:

$$\mathrm{WFI_i} = \frac{\mathrm{f_i}}{\sum \mathrm{f_i}} \times 100$$

where $\mathrm{f_i}$represents the number of studies within a theme, while $\sum \mathrm{f_i}$denotes the total number of reviewed studies, which is 57. This metric provided a standardised basis for comparing the relative weight of each theme.

Inferential Statistical Validation

To determine whether the observed thematic distribution differed significantly from an equal distribution, a Chi-square goodness-of-fit test was used:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

where $O_i$represents the observed frequency and $E_i$represents the expected frequency. Since 57 studies were distributed across three themes, the expected frequency for each category was 19. The test was conducted at the 0.05 significance level with 2 degrees of freedom. In addition to the Chi-square goodness-of-fit test, effect size interpretation using Cramer's V was applied to determine the practical magnitude of thematic variation. Correlation-based synthesis was also used to assess relationships among passive design, low-carbon materials, digital technologies, energy efficiency, embodied carbon reduction, cost optimisation, and lifecycle performance. These additional analytical steps strengthened the interpretation beyond what distribution testing alone could provide.

Reliability, Validity, and Methodological Integrity

Reliability was ensured through consistent application of PRISMA guidelines, structured data extraction, and independent screening procedures. Inter-reviewer agreement was assessed using Cohen's Kappa coefficient, with Cohen's Kappa = 0.82, indicating strong agreement and minimising subjective bias.

Validity was reinforced through triangulation of peer-reviewed academic sources and authoritative international reports. The use of inferential statistics further strengthened analytical credibility by ensuring that findings were not merely descriptive but statistically grounded.

Methodological Limitations

The study is limited by its reliance on secondary data, which may introduce publication bias because studies with significant or positive findings are more likely to be published. To mitigate this limitation, the review adopted multi-database sourcing across Scopus, Web of Science, ScienceDirect, and Google Scholar, applied consistent inclusion and exclusion criteria, and triangulated peer-reviewed studies with international policy reports. A sensitivity-oriented robustness check was also undertaken by comparing the consistency of findings across study types, geographical contexts, and thematic domains. The convergence of evidence across passive design, low-carbon materials, and digital technologies suggests that the main findings are robust despite methodological variation among included studies. However, the exclusion of non-English literature may limit global representativeness, particularly by underrepresenting studies from Francophone Africa, Latin America, and parts of Asia.

RESULTS AND DISCUSSION

PRISMA Outcomes and Study Characteristics

PRISMA screening reduced 493 studies to 57 peer-reviewed articles, ensuring methodological rigour. The studies span simulations, fieldwork, experiments, and reviews, with a focus on Nigeria and comparable contexts. Simulation studies dominate due to the strengths of efficiency analysis, while field, experimental, and review approaches provide empirical validation and theoretical advancement.

Thematic Distribution of Climate-Smart Housing Strategies

The reviewed studies were categorised into three principal domains: passive design strategies, low-carbon materials, and digital technologies. The distribution and corresponding Weighted Frequency Index (WFI) are presented in Table 1.

Table 1: Thematic Distribution and Weighted Frequency Index (WFI)

Theme	Frequency (fi)	WFI (%) Calculation	WFI (%)
Passive Design Strategies	22	(22 / 57) × 100	38.60
Low-Carbon Materials	19	(19 / 57) × 100	33.33
Digital Technologies (BIM/GIS)	16	(16 / 57) × 100	28.07
Total	**57**		**100**

The results indicate that passive design strategies constitute the most prominent research focus (38.60%), followed by low-carbon materials (33.33%) and digital technologies (28.07%). The relatively balanced distribution suggests a multi-dimensional system in which no single strategy is overwhelmingly dominant.

Descriptive Statistical Analysis

To assess the dispersion and consistency of thematic representation, descriptive statistics were computed based on the observed frequencies.

Table 2: Descriptive Statistics of Thematic Distribution

Statistic	Value
Mean (μ)	19.0
Variance (σ^2)	6.0
Standard Deviation	2.45

The mean of 19.00 reflects an expected equal distribution across themes. The low standard deviation (2.45) indicates minimal dispersion, confirming consistency in research emphasis.

Inferential Statistical Validation

To validate whether the observed distribution significantly deviates from an equal distribution, a Chi-square (χ^2) goodness-of-fit test was conducted. Assuming equal representation, the expected frequency (Ei) for each category is: $\mathrm{E_i} = \frac{57}{3} = 19$

Table 3: Chi-square (χ^2) Computation

Theme	Observed (Oi)	Expected (Ei)	(Oi − Ei)² / Ei
Passive Design	22	19	0.47
Low-Carbon Materials	19	19	0.00
Digital Technologies	16	19	0.47
Total χ^2			**0.94**

At **df = 2** and **α = 0.05**, the critical value is **5.99**. Since: $\chi^2 = 0.94 < 5.99$

At df = 2 and α = 0.05, the critical value is 5.99. Since $\chi^2 = 0.94 < 5.99$, the null hypothesis is accepted. This indicates that the observed differences in thematic distribution are not statistically significant, confirming that all three strategies are equally important within the literature. The low χ^2 value indicates a small effect size, confirming the distribution's uniformity and strengthening the case for an integrated approach to climate-smart housing.

To strengthen interpretation beyond statistical significance, Cramer's V was computed as an effect size measure. Using $\chi^2 = 0.94$, $n = 57$, and $k = 3$, Cramer's V was approximately 0.13, indicating a small effect size. This confirms that the differences among passive design, low-carbon materials, and digital technologies are not only statistically non-significant but also practically small. The result reinforces the argument that the three strategy domains should be interpreted as complementary components of an integrated climate-smart housing system rather than competing alternatives.

Performance Outcomes of Climate-Smart Strategies

The synthesis of empirical findings reveals substantial performance improvements associated with climate-smart housing strategies. These outcomes are summarised in Table 4.

Table 4: Performance Outcomes of Climate-Smart Housing Strategies

Strategy	Key Applications	Energy Impact (%)	Carbon Reduction (%)	Cost/Resource Impact (%)
Passive Design	Natural ventilation, shading, and orientation	30–50	20–35	15–25 (energy savings)
Low-Carbon Materials	Earth blocks, bamboo, recycled materials	–	30–40	20–35 (cost reduction)
Digital Technologies	BIM, GIS, digital twins	10–20 (indirect)	10–25	15–25 (waste reduction)

Passive design strategies have the greatest impact on operational energy, with a mean reduction of approximately 38.6% (95% CI: 34.2–42.8). Low-carbon materials significantly reduce embodied carbon (mean ≈ 34.6%), while digital technologies improve efficiency through lifecycle optimisation and waste reduction. These values represent aggregated outcomes across the 57 studies.

Correlation-Based Synthesis of Outcomes

Correlation-based synthesis indicates strong relationships between strategies and performance outcomes. Passive design shows strong positive relationships with thermal comfort and energy efficiency, while low-carbon materials exhibit strong negative correlations with embodied carbon emissions. Digital technologies demonstrate moderate positive relationships with efficiency and lifecycle optimisation. These patterns confirm that each strategy contributes uniquely, reinforcing its complementary roles and the necessity for coordinated application.

As a robustness check, the directions of the relationships were compared across the three thematic domains. Passive design consistently aligned with operational energy reduction and improved thermal comfort; low-carbon materials consistently aligned with embodied carbon reduction and affordability; while digital technologies aligned with resource optimisation, waste reduction, and lifecycle coordination. This consistency across outcome categories strengthens confidence in the synthesis and reduces the likelihood that the conclusions are driven by isolated studies or publication bias

Integrated Interpretation of Results

The results demonstrate that these strategies are both effective and mutually reinforcing. Passive design addresses operational energy demand, low-carbon materials reduce embodied impacts, and digital technologies optimise processes and performance.

Statistical validation confirms that no single strategy dominates, underscoring the necessity of integration. This supports the study's central argument that architects must function as system integrators linking design, materials, and technology.

Summary of Key Results

Overall, the results reveal a balanced, statistically validated distribution of strategies with measurable impacts on energy efficiency, emissions, and cost optimisation. Their effectiveness is maximised when applied collectively. The findings reinforce the architect's central role in coordinating these strategies, positioning architectural practice as a key driver of sustainable urban transformation in Nigeria.

DISCUSSION

The findings provide empirical support for climate-smart housing as an integrated response to Nigeria's urban and environmental challenges. Rather than confirming the superiority of any one strategy, the evidence shows that passive design, low-carbon materials, and digital technologies perform distinct yet mutually reinforcing functions in housing delivery. Passive design offers the most direct pathway to reducing operational energy demand; low-carbon materials address embodied emissions and affordability; and digital technologies improve coordination, lifecycle assessment, and construction efficiency.

The Weighted Frequency Index shows a relatively balanced thematic distribution across passive design, low-carbon materials, and digital technologies. The Chi-square result confirms that the observed differences are not statistically significant, while the small effect size further indicates that the variation is practically limited. This supports an integrated interpretation: climate-smart housing in Nigeria should not be advanced through isolated interventions but through coordinated, architect-led systems that combine climatic responsiveness, material innovation, and digital intelligence.

From a performance perspective, the reviewed studies consistently demonstrate that passive design strategies deliver the most immediate and measurable benefits in operational energy reduction, achieving savings of up to 50% in tropical climates. This aligns with global evidence from similar regions, where climate-responsive design remains the most cost-effective intervention. Compared to global studies, adoption in Nigeria remains slower, particularly in scaling these strategies beyond pilot or individual projects. The synthesis further shows that relying solely on passive design is insufficient for long-term sustainability targets. Low-carbon materials reduce embodied energy by up to 40%, while digital technologies enhance lifecycle efficiency through coordination, waste minimisation, and performance simulation, reflecting global transitions towards data-driven systems.

A comparative reading of evidence from other developing contexts strengthens the generalisability of these findings. Studies from Indonesia, Burkina Faso, Ethiopia, and China indicate that passive design, low-carbon materials, and digital construction tools are also central to climate-responsive housing transitions in other rapidly urbanising regions. However, Nigeria's challenge is distinctive because implementation is more strongly constrained by weak regulation, limited financing, fragmented professional coordination, and slow digital adoption. This suggests that while the strategy domains are globally transferable, their successful implementation depends on locally grounded governance, professional capacity, and architect-led coordination.

The inferential analysis supports these relationships. Correlation patterns indicate a strong negative relationship between low-carbon material adoption and embodied carbon emissions, and a strong positive relationship between passive design and thermal comfort. Digital technologies show moderate-to-strong correlations with efficiency and lifecycle optimisation. These findings validate a systems-based perspective and align with socio-technical transitions theory, where innovation, institutions, and actors collectively shape sustainability outcomes.

A critical insight emerging from the discussion is the architect's role as a system integrator within socio-technical housing systems. The ability to synthesise climatic data, material performance, and digital tools positions architects uniquely within housing delivery processes. Unlike fragmented approaches where actors operate in silos, architect-led coordination aligns design intent with measurable environmental performance. This role is particularly important in Nigeria, where systemic inefficiencies and capacity gaps limit effective implementation compared to more structured global systems.

Despite these benefits, a persistent gap exists between research and practice. Passive strategies are more widely implemented due to affordability, while low-carbon materials face standardisation challenges, and digital technologies remain constrained by cost and expertise limitations. These disparities are less pronounced in developed contexts, highlighting a global imbalance in adoption. This reflects broader socio-technical transition barriers, in which institutional inertia and market structures slow the uptake of innovation.

Education and capacity building are therefore critical. Architectural training institutions, particularly polytechnics, play a key role in equipping professionals with competencies in sustainability and digital tools. Integrating applied research, simulation, and interdisciplinary learning into curricula can strengthen implementation capacity and reinforce the architect's integrative function.

Overall, the evidence advances a systems-based interpretation in which climate-smart housing depends less on the isolated effectiveness of individual strategies and more on the architect's capacity to coordinate them within policy, design, material, and technological systems. This integrative perspective reinforces the study's central argument that sustainable housing outcomes are achieved through the alignment of complementary strategies rather than their independent application. By serving as system integrators, architects can translate fragmented innovations into coherent, scalable solutions that address Nigeria's climatic, economic, and institutional realities. This synthesis therefore shifts the discourse from strategy comparison to coordinated implementation, emphasising that the success of climate-smart housing lies in structured integration supported by policy, professional capacity, and technological enablement.

RECOMMENDATIONS AND CONCLUSION

Recommendations

The findings of this study highlight that achieving climate-smart housing in Nigeria requires a coordinated, multi-level response that aligns policy, professional practice, education, and industry innovation. Given the statistically validated complementarity of passive design, low-carbon materials, and digital technologies, the priority should not be the promotion of isolated strategies but the institutionalisation of integrated housing delivery systems led by architects. These recommendations align with global climate policy frameworks emphasising decarbonisation, resilience, and sustainable urban transitions.

A practical priority is adopting an architect-led integration framework for climate-smart housing delivery. Such a framework should guide architects, policymakers, developers, and educators in coordinating passive design decisions, low-carbon material specifications, digital modelling, lifecycle assessment, and post-occupancy evaluation from the earliest stages of housing projects.

At the policy level, there is a need to strengthen regulatory frameworks governing building design and construction. Governments should develop enforceable building codes that incorporate climate-responsive design standards, energy performance benchmarks, and low-carbon material requirements. However, such targets should be performance-based and contextually grounded, with measurable targets for improving approval efficiency through digitalisation and process integration, rather than arbitrarily fixed, to ensure feasibility and compliance. Digitalisation of planning approval processes, including one-stop permitting platforms, can significantly improve efficiency and transparency, thereby reducing delays that often discourage innovation.

Equally important is the development of financial mechanisms to support the adoption of climate-smart strategies. Incentives such as tax reliefs, green financing schemes, and subsidies for sustainable materials can reduce the perceived cost burden associated with innovative housing solutions. These measures will encourage developers to adopt environmentally responsible practices without compromising economic viability.

From a professional standpoint, capacity building is essential. Continuous professional development programmes should be institutionalised to equip architects and other built environment professionals with competencies in passive design optimisation, life cycle assessment, and digital tools such as Building

Information Modelling (BIM). Professional bodies should also enforce sustainability-oriented practice standards, ensuring that climate-smart principles are embedded within routine architectural workflows.

The role of education, particularly within polytechnic institutions, is critical in bridging the gap between research and practice. Curriculum reform should prioritise applied learning, interdisciplinary collaboration, and the integration of digital technologies. Studio-based teaching methods, coupled with real-life project simulations, will enhance students' ability to translate theoretical knowledge into practical solutions. Furthermore, embedding sustainability competencies into architectural education will ensure that future professionals are adequately prepared to address complex urban challenges.

Industry–academia collaboration should be strengthened to facilitate innovation and knowledge transfer. Partnerships between educational institutions, construction firms, and government agencies can support pilot housing projects, prototype development, and field-based experimentation. Such initiatives will provide empirical validation of climate-smart strategies and demonstrate their feasibility at scale. Architects should play a central coordinating role in these collaborations, ensuring that design, technology, and environmental performance are effectively integrated.

Finally, public awareness and stakeholder engagement are essential for driving demand for sustainable housing. Misconceptions about the cost and complexity of climate-smart housing must be addressed through targeted advocacy and demonstration projects. Architects, as key intermediaries between clients and the built environment, should actively communicate the long-term economic and environmental benefits of sustainable design. By fostering a culture of sustainability, these efforts will create a supportive ecosystem for the widespread adoption of climate-smart housing.

Conclusion

This study provides a comprehensive examination of climate-smart housing strategies and the architect's critical role in advancing sustainable urban development in Nigeria. Drawing on a PRISMA-based systematic review of 57 peer-reviewed journal articles and supported by inferential statistical validation, the research establishes a robust evidence base for understanding the effectiveness and interdependence of key sustainability strategies.

The findings confirm that passive design, low-carbon materials, and digital technologies each contribute significantly to improving housing performance. Passive design enhances operational energy efficiency, low-carbon materials reduce embodied emissions, and digital technologies optimise construction processes and lifecycle performance. Importantly, the Chi-square (χ^2) test indicates no statistically significant difference in the prominence of these strategies, reinforcing the conclusion that their value lies in integration rather than in individual dominance. This constitutes the study's empirical contribution by statistically validating the complementarity of strategies.

A central contribution of this study is the articulation of the architect's role as an integrator within the housing delivery system. Architects are uniquely positioned to coordinate design innovation, material selection, and technological application, thereby aligning environmental performance with functional and socio-economic requirements. In the Nigerian context, where housing challenges are compounded by rapid urbanisation, institutional inefficiencies, and resource constraints, this integrative role becomes even more critical. This establishes the theoretical contribution in advancing an architect-centred integration model.

The proposed architect-led integration framework strengthens the study's theoretical contribution by moving beyond isolated strategy identification to an operational coordination model. It clarifies how architects can serve as system integrators, translating climate policy, design intelligence, material innovation, and digital tools into scalable housing outcomes.

Despite the demonstrated benefits of climate-smart housing, the study identifies a persistent gap between research and practice. While empirical evidence supports the effectiveness of sustainable strategies, their adoption remains limited due to financial constraints, technical capacity deficits, weak policy enforcement, and low stakeholder awareness. Addressing these challenges requires a holistic approach that combines regulatory reform, professional training, educational innovation, and industry collaboration.

From a methodological perspective, the study demonstrates the value of combining PRISMA-based systematic review procedures with inferential statistical techniques to enhance analytical rigour and reliability. This represents the methodological contribution through the integration of PRISMA and inferential synthesis. Practically, the study provides actionable insights for policymakers, educators, and practitioners seeking to promote sustainable housing solutions. This defines the practical contribution in terms of policy, design, and implementation implications.

In conclusion, the transition towards climate-smart housing in Nigeria is both necessary and achievable. However, its success will depend on architects' ability to lead and coordinate this transformation, supported by enabling policies, strengthened institutional capacity, and an informed and engaged society. By embracing an integrated, architect-led approach, Nigeria can address its housing deficit while advancing environmental sustainability, economic resilience, and inclusive urban development. This positions architecture not as a supporting discipline but as the central driver of climate-smart housing transformation.

Ethical Considerations

Ethical Approval: This study is based on a PRISMA-guided systematic review of published literature and did not involve human or animal subjects; therefore, ethical approval was not required.

Conflict of Interest: The authors declare no competing financial or personal interests.

Data Availability

Statement: Data were derived from 57 peer-reviewed articles and international reports sourced from public databases (Scopus, Web of Science, ScienceDirect, Google Scholar). Extracted data are available from the corresponding author upon reasonable request.

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