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RESEARCH ARTICLE

Challenges in the Integration of Bioclimatic Design Strategies (BDS) in Buildings in the Warm-humid Climate of South-East Nigeria: A Critical Review

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ABSTRACT

Bioclimatic design strategies (BDS) offer a viable pathway for reducing energy demand and enhancing thermal comfort in buildings, particularly in warm-humid climates. However, their integration into mainstream architectural practice remains limited in many developing regions. This study critically reviews the challenges that impede effective integration of BDS in buildings within the warm-humid climate of South-East Nigeria and proposes evidence-based pathways for wider adoption. A systematic literature review (SLR) methodology was employed, drawing from peer-reviewed journals, conference proceedings, policy documents, and technical reports published between 2000 and 2026. The review identifies ten major challenges: lack of technical expertise among design professionals; economic constraints and high upfront costs; limited availability of sustainable materials; absence of standardized integration metrics and frameworks; weak institutional and regulatory enforcement; climate dependence complicated by climate change uncertainty; socio-cultural preferences for mechanical cooling; persistent performance gaps between predicted and actual building performance; lack of financial incentives; and spatial constraints from rapid urbanization. Findings reveal that while awareness of BDS exists among building professionals in South-East Nigeria, implementation remains fragmented due to systemic barriers spanning technical, economic, regulatory, and cultural domains. The study concludes that overcoming these challenges requires a multi-pronged strategy encompassing regulatory reform, financial incentives, capacity building, promotion of indigenous materials, and investment in climate-specific research. This review contributes a comprehensive barrier framework and actionable recommendations to support the transition toward climate-responsive, energy-efficient architecture in warm-humid regions of sub-Saharan Africa.

Keywords: *Bioclimatic; Warm-humid; Climate; Energy efficiency; Nigeria; Sustainable architecture*

1. INTRODUCTION

Buildings account for a significant proportion of global energy consumption and greenhouse gas emissions Yassaghi & Hoque, 2019). Estimates of the energy consumption pattern of buildings reported in different studies vary from 32% to 87%

of the global energy consumption (Suma, Tarabeli, Ulpiani & Perna, 2020; Kalua 2020; Mangan, 2020; Li, Wang, Wang, Xin, He & Zhao, 2021). According to Wang (2017) the global building energy consumption contributes around 40% of the total carbon emission. The increasing demand for energy in the building sector has severe implications in warm–humid regions such as South-East Nigeria. Buildings in these climates are characterized by high cooling loads due to persistent heat and humidity, leading to overdependence on mechanical air-conditioning systems. Empirical studies have also shown that poorly designed buildings particularly in tropical climates often exacerbate heat gain and reduce indoor air quality, thereby undermining both occupant health and productivity (Oladokun & Odesola, 2015; Adebamowo & Adejumo, 2012).

Rapid urbanization and globalization of architectural practice have led to the widespread adoption of modern building forms that often neglect climatic responsiveness. According to Manzano-Agugliaro (2015) modern architecture focuses more on the function-shape concept rather than energy-shape concept, which was the focus of traditional architecture. Building envelopes designs are developed to meet clients' requirements without much concern to the local climate (Al-Timimi, Fadzil, & Harum, 2011; Mobolade & Pourvahidi (2020). Designers frequently rely on conventional methods that prioritize aesthetics, cost minimization, or rapid construction timelines over environmental performance. Widera (2015) observed that the so called green or sustainable buildings, although constructed from renewable materials and even awarded with green certificates, are often designed without proper analysis of the specifics of local environment.

The global push toward sustainability has intensified the need for environmentally responsive building practices that reduce dependence on mechanical systems while improving occupant comfort. Among these approaches, Bioclimatic design has gained global recognition as a sustainable approach to building design, aiming to reduce energy consumption while improving thermal comfort. It takes advantage of local climate and natural environment to create a safe and comfortable building which does not harm the environment but contributes to its health and enriched biodiversity (Widera 2015). The relevance of bioclimatic design is particularly pronounced in warm–humid climates, where high temperatures, elevated humidity levels, and intense solar radiation create significant thermal discomfort and drive increased reliance on air-conditioning systems.

Despite the recognized benefits of bioclimatic design, its integration into mainstream architectural practice in Nigeria remains limited. Okoye et al (2020) observed that though the building professionals in South-East Nigeria are aware of bioclimatic design strategies, the level of implementation is low. The opportunities created by the building location, especially in terms of occurring bioclimatic conditions are usually ignored. Effective integration of bioclimatic strategies in building design holds a great potential in improving thermal comfort, reducing energy consumption, and promoting sustainable development within the built environment. Couvelas (2020) asserts that although architecture is globalized in different ways, it should follow the principle of inter-local sustainable design, while being multicultural, retains and enriches local identity. This study thus aims to investigate the major challenges that hinder effective integration of bioclimatic design strategies in buildings in the warm-humid-climate of South-East Nigeria with a view to creating potential pathways for wider integration into contemporary architectural practice. The objectives formulated in order to achieve the aim of the study include to review existing literature on bioclimatic design strategies; examine key challenges in the integration of bioclimatic design strategies in buildings in the warm-humid climate of South-East Nigeria; and investigate strategies for overcoming inherent challenges in the integration of bioclimatic design strategies in buildings in the warm-humid climate of South-East Nigeria.

2. LITERATURE REVIEW

Meaning and Concept of Bioclimatic Design

According to Larasati & Mochtar (2012) bioclimatic design is a concept of sustainable approach that considers climate and human relations in reviewing the feasibility of a design. The principle behind bioclimatic design is the understanding of climatic factors of a site. This involves analysis of the influence of microclimate (solar radiation, sunshine, temperature, humidity, rainfall, wind velocity and direction) on the proposed building design. The indigenous ideas, originally developed from vernacular architecture, formed the basis for contemporary bioclimatic buildings (Widera 2015). According to Larasati and Mochtar (2012), the two justifications of bioclimatic design concept are: achievement of maximum thermal comfort level for the users of the building and minimum energy consumption with low cost of building operation.

Many researchers have given different definitions of bioclimatic architecture; Bugenings and Kamari (2022) defined bioclimatic architecture as the design of building using passive strategies to achieve a favorable indoor environmental quality at the lowest possible energy consumption. According to the Building Energy Efficiency Guideline for Nigeria (2016) bioclimatic architecture is the design based on climatic consideration which attempt to achieve physical, mental and emotional comfort for occupants with minimum use of resources while taking into account behavioural and psychological aspects. Bioclimatism is a design concept in architecture that takes into account the relationship between a building and its systems, its natural environment mainly through its (micro-) climate and its occupants especially in connection with human thermal comfort conditions (Nguyen & Reiter 2017). All the definitions of bioclimatic design have foci on local climate; improvement of energy efficiency and thermal comfort as illustrated in Figure 1.

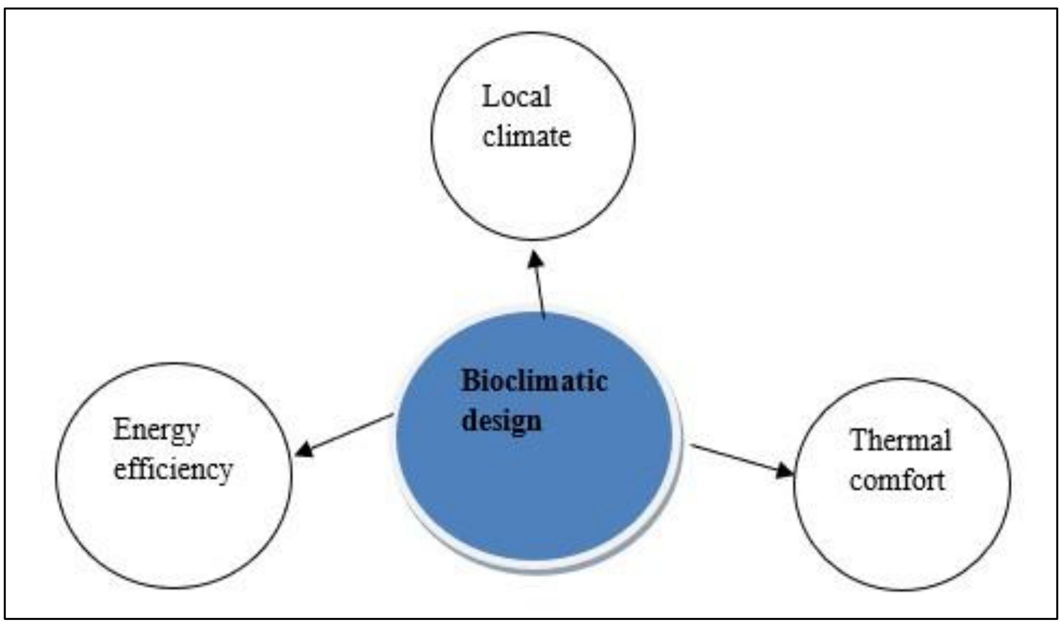

Figure 1. The foci of bioclimatic design

Watson (2013) stated that in using the term "bioclimatic," architectural design is linked to the physiological and psychological need for health and comfort. Nguyen and Reiter (2017) further revealed that bioclimatic approach takes into account three disciplines complementary to the architectural design as shown in Figure 2.

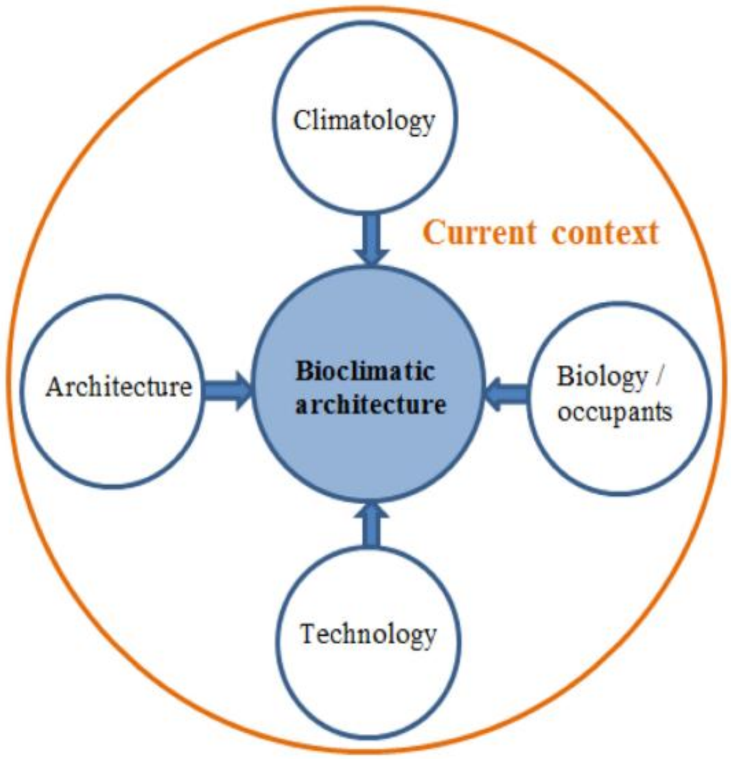

Figure. 2. The bioclimatic architecture

Source: Nguyen and Reiter (2017)

According to Košir (2019) bioclimatic architecture involves two approaches; (1) Analytical bioclimatic design: This analyses the local climate, identifies the bioclimatic potential and determines suitable bioclimatic measures; (2) Symptomatic bioclimatic design: This analyses vernacular buildings that have already adapted bioclimatic measures and replicates the identified measures.

Weber and Yannas (2014) state that observation of vernacular dwellings brings about the opportunity to study the application of passive techniques that are integral constituents of the buildings' architecture and the inhabitants' lifestyle. Victoria et al., (2016) added that traditional buildings are among the past architecture that is found to be practicing bioclimatic design due to lack of electricity and absence of modern technology. According to the study every traditional house was built using environmentally friendly local materials and architectural design that allow natural solar protection, natural ventilation, and natural lighting. They were designed according to the local climate to provide comfort to the dwellers without the presence of modern cooling technology.

The bioclimatic Chart

The bioclimatic chart pioneered by Olgyay in 1963 relates climatic data to thermal comfort limits. It is a preliminary analysis tool used throughout the first planning stages of a building project. Historical data related to temperature and relative humidity are plotted in the chart. Mobolade and Pourvahidi (2020) stated that the use of a bioclimatic chart enables the architect to use specific building techniques and methods to scale back energy consumption. This includes a passive solar heating plant, natural cooling systems and techniques, and natural lighting systems and techniques. The comfort zone for various types of built environments can be explored in the chart as shown in fig 3. Corrective measures essential for factors such as wind, solar radiation, and shading can also be identified.

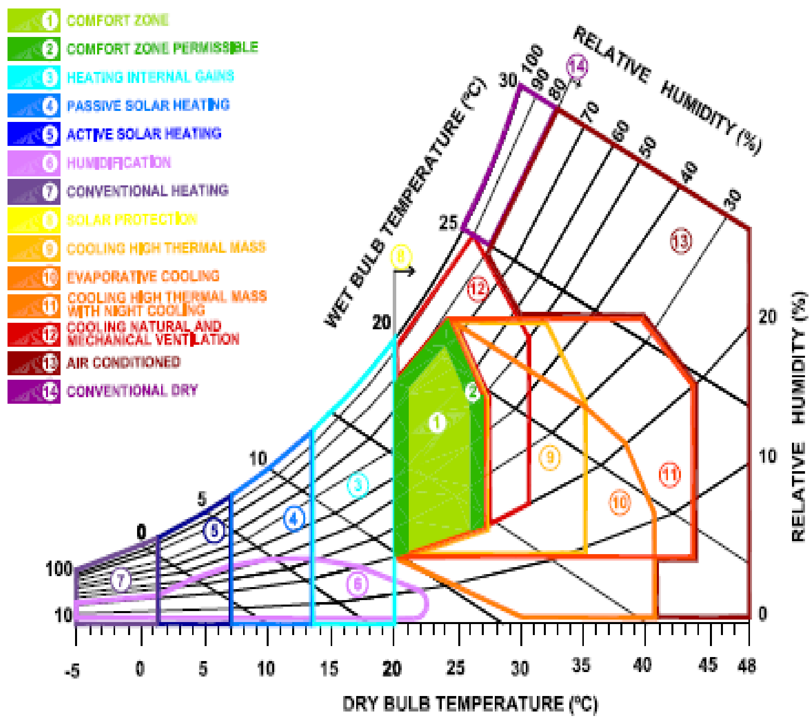

Figure 3. Psychometric Chart

Source: Agugliaro, Montoya, Sabio-Ortega and García-Cruz (2015)

Principles of Bioclimatic Architecture

Bioclimatic approach tends to apply passive design strategies. This relies on the architect's ability to design buildings that are able to anticipate climate problems (Lasarati & Mochtar 2012). According to the building energy efficiency guideline for Nigeria, (2016) bioclimatic design does not impose any particular style on an architect; however optimized orientation and incorporation of solar protection are recognizable trait of buildings that demonstrate effective bio-climatic responsiveness in their respective climates. The energy saving is through the use of day lighting and wind passively, without conversion of solar and wind to electrical energy. To apply bioclimatic architecture, it is essential to take into consideration the various climate levels of the area in which the building is located. This includes the overall climate, the mesoclimate and the climate close to the building defined by the nearby elements or microclimate (Yusuf 2020; Lasarati & Mochtar 2012).

3. MATERIALS AND METHODS

This research was conducted in the warm-humid climate of South-East Nigeria. The South-East geopolitical zone lies between Latitude 4° 45N and 7° 05N Longitude 7° 54E and 8° 27E as shown in Figure 4.

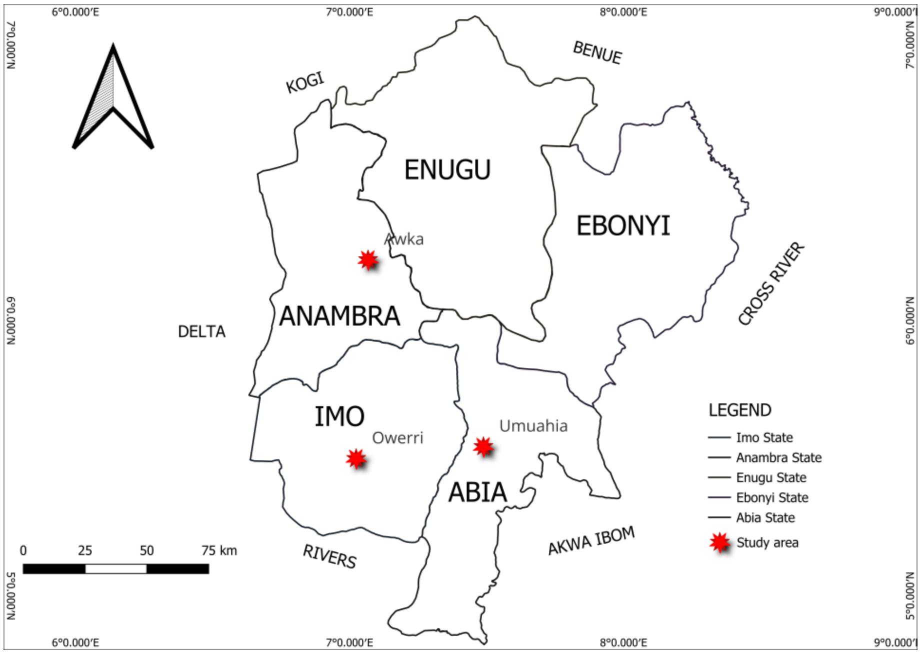

Figure 4. Map of South-East geopolitical zone showing the selected cities

Source: Data base and modification from GIS

South-East Nigeria is about 530km away from north of the equator, solar radiation is high all year round. The study area is also characterized by high temperature and humidity all year round. The average temperature value is about 27°C, while the average relative humidity ranges between 60-70% and 80-90% in January and July respectively (Okoye et al., 2020). It is dominated by the Igbo and majority of the indigenes speak Igbo language.

This study adopted a systematic literature review (SLR) methodology to critically examine the challenges affecting the integration of bioclimatic design strategies in buildings located within the warm-humid climate of South-East Nigeria. A qualitative exploratory research approach was employed to enable a comprehensive examination and interpretation of scholarly publications, theoretical perspectives, empirical studies, policy documents, and environmental reports relevant to climate-responsive architecture and sustainable building practices. The review process followed established systematic review principles adapted from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework and other evidence-based review protocols commonly used in academic research. The systematic review process involved literature identification, screening, eligibility assessment, quality appraisal, data extraction, thematic categorization, and synthesis of findings. This approach ensured that the study-maintained consistency, minimized selection bias, and enhanced the credibility of the analytical outcomes.

Data for the study were obtained entirely from secondary sources through systematic searches of internationally recognized academic databases and scholarly repositories. The primary databases consulted included Scopus, ScienceDirect, Web of Science, Google Scholar, SpringerLink, Taylor & Francis Online and ResearchGate. The use of multiple academic databases ensured broad coverage of relevant literature and reduced the risk of omitting significant studies associated with the research topic. The literature search process was conducted systematically using carefully selected keywords and search phrases relevant to the study objectives. Keywords used during the search included bioclimatic design, climate-responsive architecture, warm-humid climate, passive cooling strategies, sustainable buildings, thermal comfort, tropical architecture, environmental performance, and Nigeria. The search focused primarily on literature published between 2000 and 2026 in order to capture recent developments, contemporary sustainability debates, and emerging technological innovations related to climate-responsive architecture.

Specific inclusion and exclusion criteria were established to ensure quality and relevance of the reviewed studies. The inclusion criteria covered peer-reviewed journal articles, scholarly publications written in English language, studies related to bioclimatic and sustainable architecture, literature focusing on tropical and warm-humid climates, and publications addressing environmental performance and implementation challenges in sustainable building practices. The screening and selection process was conducted in multiple stages. Initially, relevant publications were identified through database searches using the predefined keywords and search strings. Subsequently, titles and abstracts of retrieved studies were reviewed to determine their relevance to the study objectives. Irrelevant articles and duplicate records were removed at this stage. Thereafter, full texts of eligible studies were critically examined to confirm their suitability for inclusion in the review. The selected studies were further subjected to quality appraisal based on methodological rigor, relevance to the research topic, clarity of findings, academic credibility, and citation impact. Only studies that satisfied the quality assessment criteria were included in the final synthesis.

Data extraction was carried out systematically using a structured review framework developed specifically for the study. Relevant information extracted from the selected studies included authorship, year of publication, study location, research objectives, methodological approach, climatic context, identified bioclimatic strategies, implementation challenges, key findings, and recommendations. The extracted data were carefully organized into thematic categories and analytical matrices to facilitate comparison and synthesis of findings across different studies and geographical contexts. Ethical considerations were strictly observed throughout the conduct of the research. All consulted sources were appropriately acknowledged and cited in accordance with internationally accepted academic referencing standards to ensure intellectual integrity and avoid plagiarism.

4. RESULTS AND DISCUSSION

Challenges in the integration of bioclimatic design strategies

Although bioclimatic design has been widely recognized as an effective approach to achieving energy efficiency and thermal comfort in buildings, the implementation in many developing countries remains limited. Factors that impede successful integration of bioclimatic design strategies in buildings particularly in the warm-humid climate of South-East Nigeria are as follows;

Lack of Expertise: A major barrier to the application of bioclimatic design strategies is the limited expertise in climate-responsive design among architects and designers. Implementing bioclimatic design requires a high level of technical knowledge, interdisciplinary collaboration, and an understanding of local climatic conditions. Many designers are trained in conventional design approaches that prioritize aesthetics and structural efficiency over environmental performance.

Additionally, the effective use of building performance simulation tools, energy modeling software, and digital design technologies demands specialized skills. Many practitioners lack the technical competencies required to utilize these technologies effectively (Shahcheraghian et al., 2024; Oke et al., 2023). The shortage of adequately trained professionals, coupled with limited exposure to advanced sustainability-oriented design methods, continues to constrain the widespread adoption of bioclimatic design principles in practice (Brandsma et al., 2024; Okonta & Ayinla, 2024; Attia et al., 2024).

Economic and financial constraints: This constitutes a major barrier to the implementation of bioclimatic design strategies, particularly in developing countries such as Nigeria. The adoption of bioclimatic principles often requires additional investment in climate-responsive building components, high-performance materials, advanced simulation tools, renewable energy systems, and specialized design expertise, resulting in higher upfront construction costs compared to conventional building approaches (Attia, 2018; Sayigh, 2020). Although passive design measures such as natural ventilation, daylight optimization, thermal mass utilization, and solar shading can significantly reduce operational energy consumption and lifecycle costs, these long-term benefits are frequently overlooked by developers and clients who are more concerned with minimizing initial capital expenditure (IPCC, 2022). Consequently, the perceived high initial cost of sustainable building technologies continues to hinder the widespread adoption of bioclimatic design despite its proven economic and environmental benefits over the building lifecycle (IEA, 2023).

Technological and Material Limitations: According to Kibert, (2022) bioclimatic design relies on use of sustainable materials and technological advancements that have a minimal environmental impact throughout their lifecycle. In many developing regions, these materials are unavailable, expensive, or reliant on importation. The limited availability of locally produced sustainable construction materials increases project costs and creates supply chain challenges that discourage their adoption (International Finance Corporation [IFC], 2023). As a result, many architects and developers continue to rely on conventional construction materials and methods, even when more environmentally sustainable alternatives could provide superior long-term performance and resilience (World Green Building Council, 2023).

Lack of Metrics/Frameworks for Integrating Bioclimatic Design Strategies: One of the most persistent challenges in the application of bioclimatic design is the absence of comprehensive, standardized metrics and evaluation frameworks capable of systematically integrating passive strategies into the building design process. While there are numerous resources and best practices available, the absence of universally accepted guidelines poses difficulties for architects and designers. Standardized guidelines would provide a clear framework for incorporating bioclimatic features and sustainability measures into building designs. They would serve as a reference point for architects, ensuring that key principles are consistently followed and facilitating regulatory compliance. This limitation creates a significant gap between design intent and actual building performance, undermining the reliability and scalability of climate-responsive architecture. Bera et al. (2024) observed that while simulation technologies have improved the analysis of passive strategies, there is still no unified framework that integrates these tools into a coherent design methodology applicable across different climatic and socio-economic contexts.

Institutional and regulatory frameworks: Effective building regulations, energy codes, and sustainability policies provide the legal and institutional foundation necessary to promote climate-responsive architecture and improve building performance. However, in many developing countries, including Nigeria, existing building codes often inadequately address energy efficiency, passive design strategies, and climate adaptation measures (UN-Habitat, 2022). Even where sustainability-oriented regulations and standards exist, weak institutional capacity, inadequate monitoring mechanisms, and poor enforcement frequently result in widespread non-compliance (Agyekum et al., 2021).

Climate Dependence: The effectiveness of bioclimatic design is dependent on the local climate; this presents challenges in adaptability and customization. Different climates require tailored design approaches to optimize energy efficiency, thermal comfort, and natural ventilation. The increasing uncertainty associated with climate change introduces additional complexity, as buildings must be designed not only for current climatic conditions but also for future climate scenarios and extreme weather events (IPCC, 2022). This implies that architects must thoroughly analyse the local climate and environmental conditions to determine the most effective bioclimatic strategies for each project.

Socio-cultural factors: The successful implementation of bioclimatic design requires not only technical solutions but also user acceptance and behavioral adaptation. In many cases, occupants prefer air-conditioned environments due to perceived comfort and status, even when passive solutions could provide adequate conditions. Traditional architectural elements such as courtyards and shading devices—once integral to climate-responsive design—are increasingly viewed as outdated. This cultural transition has contributed to the decline of indigenous climate-responsive building practices and the growing dependence on energy-intensive mechanical systems (UN-Habitat, 2022).

Performance gap: This refers to the discrepancy between predicted building performance during the design stage and the actual performance observed during operation (De Wilde, 2014). Many existing frameworks rely heavily on predictive models that use standardized assumptions about occupancy, behavior, and environmental conditions. While these models provide valuable design guidance, they often fail to capture the complexity and variability of real-world building operation (Yan et al., 2015). Studies indicate that buildings frequently consume significantly more energy than predicted due to oversimplified modeling and incomplete consideration of real-life variables such as occupant behavior and unregulated energy loads.

Lack of Incentives: There is absence of financial incentives or subsidies for green building practices in many developing countries. UNEP, (2023) asserts that limited access to green financing mechanisms, inadequate financial incentives, and the absence of robust policy support for sustainable construction further discourage investment in bioclimatic buildings in many developing economies.

Spatial Constraints: In many cities, design decisions are driven more by land economics than environmental considerations, compromising bioclimatic performance. Rapid urbanization in developing countries has intensified pressure on available land; often resulting in compact developments that prioritize economic returns over environmental sustainability (UN-Habitat, 2022). Limited land availability reduces flexibility in site planning.

Overcoming Challenges that Hinder Effective Integration of Bioclimatic Design Strategies in the Warm-humid Climate of South-East Nigeria

Bioclimatic design presents a sustainable pathway for building design in tropical regions. Although challenges persist, the prospects for its adoption are promising. Several strategies can be adopted to ensure its effective integration in building design particularly in the warm-humid climate of South-East Nigeria. These include;

Strengthening and enforcement of building regulations: According to Ajia, (2025) strong regulatory frameworks are critical drivers of sustainable building adoption. In Nigeria, various policies promoting energy efficiency and environmental sustainability exist however their implementation remains weak due to inadequate enforcement and institutional challenges. There is need to revise and update the National Building Code to incorporate mandatory climate-responsive design requirements such as building orientation, natural ventilation, passive cooling systems, daylight utilization, and energy-efficient building envelopes. Effective monitoring and compliance mechanisms should as well be established to ensure that developers and design professionals adhere to these standards. Strengthening regulatory frameworks, improving enforcement mechanisms, and enhancing institutional capacity are essential for accelerating the adoption of bioclimatic design and achieving sustainable development objectives in the built environment (International Energy Agency [IEA], 2023).

Provision of financial incentives and green financing mechanisms: According to Unegbu et al., (2025) economic support mechanisms have proven effective in promoting sustainable construction practices. It also encourages private sector participation in environmentally responsible development. As high initial cost of implementing bioclimatic design strategies often discourages developers and property owners there is need for governments to provide financial incentives for sustainable building projects. These include; tax reliefs, grants, subsidies, and low-interest loans. Green financing schemes can encourage developers to invest in energy-efficient buildings by reducing capital constraints.

Capacity building and professional training: The successful implementation of bioclimatic design depends largely on the technical competence of architects, and other building professionals. This calls for continuous professional development workshops and training programs on climate-responsive architecture and sustainable construction methods. Ezema et al., (2024) pointed out that improving professional capacity will help bridge the knowledge gap that currently hinders sustainable building implementation in Nigeria.

Promotion of Indigenous sustainable building materials: According to Kalu et al., (2025) indigenous building materials such as laterite, compressed earth blocks and bamboo often align more closely with traditional climate-responsive construction practices. The utilization of locally available and environmentally friendly building materials can significantly enhance the adoption of bioclimatic design strategies.

Investment in Research and Technological Innovation: Research and innovation play a crucial role in advancing bioclimatic design implementation. Universities, research institutions, and industry stakeholders should collaborate to generate locally relevant knowledge on climate-responsive design strategies, thermal comfort standards, and sustainable building technologies. Ezema et al., (2024) stated that continuous research is necessary for developing innovative solutions tailored to Nigeria's diverse climatic conditions. Greater use of digital tools such as Building Information Modelling (BIM), energy simulation software, and environmental performance assessment tools can help optimize building designs and improve decision-making during the design process.

5. CONCLUSION

Bioclimatic design is an approach that streamlines buildings to local climate conditions in order to maximize comfort while minimizing energy use. Its key principles include adaptation to local climate, use of passive cooling techniques and integration of natural systems into building form. Despite the potential of BDS in enhancing thermal comfort, reducing building energy consumption, and promoting environmental sustainability, synthesis of evidence reveals a persistent gap between theoretical recognition and practical application. This study thus critically examined the challenges affecting the implementation of bioclimatic design strategies in buildings within the warm-humid climate of South-East Nigeria through a systematic review of existing literature.

Ten interconnected challenges were identified, these include; a deficiency in specialized expertise and limited use of performance simulation tools among local architects; economic barriers arising from high initial costs and the prioritization of capital expenditure over lifecycle savings; the absence of standardized, locally calibrated frameworks for integrating passive strategies into routine design workflows; and weak regulatory enforcement despite the existence of nominal sustainability policies. Furthermore, socio-cultural factors—including a preference for air-conditioned environments as symbols of modernity—have eroded traditional climate-responsive practices such as deep verandas, courtyards, and high-thermal-mass walls. The performance gap between modelled and actual building behaviour further undermines confidence in passive solutions.

The intensity of these challenges is amplified by rapid, unplanned urbanization, limited access to green financing and inadequate institutional capacity. The study concludes that the effective application of BDS in South-East Nigeria cannot be achieved through technical solutions alone. Instead, it demands a systemic shift that addresses professional education, regulatory frameworks, economic incentives, and cultural perceptions simultaneously. Without such an integrated approach, buildings in the region will continue to rely on energy-intensive mechanical systems, exacerbating both operational costs and environmental impacts.

6. COMPETING INTEREST

None to declare

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