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Climate-Responsive Architecture as A Catalyst for Sustainability: Innovations, Performance and Long-Term Economic Implications

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Abstract: ***This study investigates the role of climate-responsive architecture as a catalyst for sustainability, with emphasis on its innovations, performance outcomes, and long-term economic implications across Nigeria's six geopolitical zones. Recognising the gap between environmental design intent and economic viability, the research adopts a mixed-methods convergent parallel design to triangulate qualitative and quantitative data. Through a purposive mode of selection, twelve (12) buildings were adopted for comparative analysis using field measurements, structured interviews, surveys, and lifecycle cost evaluations. These buildings represented climate-responsive and conventional structures. Empirically-founded results showed that climate-responsive buildings (CRBs) presented 44.2% lower energy usage, higher daylighting efficiency of 75.6%, and 134% ventilation rate improvement relative to buildings of the conventional strata. $R^2 = 0.89$, $p < 0.001$, regression analysis confirmed that passive design strategies, notably natural ventilation and efficient orientation, were the most impactful drivers of sustainable building performance. Economic findings established that these buildings offer 10–15% lifecycle cost savings and average payback periods of 5–7 years, indicating that environmental sustainability aligns with long-term financial feasibility. Qualitative insights affirmed enhanced user comfort and operational efficiency, though challenges persist in lax enforcement of building codes, regional disparities in expertise and material accessibility. However, the empirical data show that climate-responsive design is a critical pathway and a technically/economically viable approach toward Nigeria's sustainable development goals. The study proffers the incorporation of place-based climatic data in planning and design procedures. This must be strengthened with policy reforms and professional capacity-building to embed performance-based metrics within the National Energy Efficiency Building Code (NEEBC) and National Building Code (NBC). It finalises by stating that accomplishing sustainable and resilient architecture in Nigeria requires an integrated framework of regulation, innovation, and evidence-based confirmation, which will situate climate-responsive design as the arbiter of energy efficiency and sustainable urban development in the built environment.***

Keywords: Climate-responsive Architecture, Financial Feasibility, Passive Design Strategies, Performance-based Metrics, Sustainable Building Performance.

1. Introduction

The built environment occupies a central place in the global pursuit of sustainable development. Chen, L et al (2023) affirmed in their work, "*Green Construction for Low-Carbon Cities: A Review*, that construction activities and liveable structures account for a marked proportion of global consumption of resources, greenhouse gas pollution and energy use. The construction sectors, as shown by studies, are also major contributors to embodied and heavy carbon, material waste and operational energy demand (Amarasinghe, Liu, Stewart, & Mostafa, 2025). Concurrently, the rising unpredictability of climatic conditions, such as the emergence of frequent rogue weather events, rising temperatures, solar radiation, and variability in precipitation, puts enormous strain on occupant comfort and well-being, resilience and building performance.

Within this context, the concept of climate-responsive architecture is no longer a cosmetic trend but now a needful imperative. It has metamorphosed into a powerful design paradigm. Today's design dispensation sees buildings as totems directed by appeal, form, and aesthetics. Climate-responsive design goes further by emphasising the adoption of passive design strategies (thermal mass, orientation, shading, natural ventilation), adaptation to local climatic conditions, dynamic technological plexuses, and selection of material based on local content to optimise occupant wellness and building performance. For example, passive design strategies alone have yielded substantial reductions in energy demand and improved occupant comfort in varying climatic zones (Hadded, Dardouri, Yüksel, Sghaier, & Arici, 2025). Moreover, ingenious solutions such as responsive skins and materials, adaptive façades, building information modelling (BIM), and integration of renewable energy that leverages big data on climate have ushered in a new trend of architecture that is in tune with the imperatives of sustainability (Aruta, Ascione, Bianco, Iovane, & Mauro, 2023).

The "climate-responsiveness" narrative in architecture is sitting at the intersection of building performance, environmental sustainability, and economic viability. From the perspective of the environmental discourse, the prospects of reduced carbon footprint, lowered operational energy consumption, and enhanced resource efficiency are quite palpable. Sustainable design interventions in architecture, in some instances, have been discovered to advance mean reductions in CO_2 emissions of ~34%, consumption of energy by ~25%, and usage of water resources by ~11% when compared to buildings procured through traditional modes (Ahmed, Alazazmeh, & Asif, 2023). On the performance front, it has been established that climate-responsive design can improve air quality, indoor thermal comfort, well-being of occupants, and daylighting. These indices play a major role in the upscaled productivity, satisfaction, and health of users of such spaces (Wu, Liu, & Kong, 2023). Within the economic locale, climate-responsive initiatives may attract higher initial investment protocols, especially when utilising intelligent controls, advanced materials, and renewable integration techniques, since they often generate increased asset values and operational cost savings. However, in the long run and after the first wave of procurement and installations, they have been found to enhance long-term lifecycle returns (Azizah, 2025).

In professional practice and academia alike, climate-responsive architecture is gaining traction. A recent global qualitative study of architects found that technological and environmental innovation, such as AI-driven climate modelling and passive design envelopes, can reduce energy use by 20-40% in residential contexts (Karim, Marie-Louise, & Santiago, 2025). Designing open spaces in hot, dry places is really important. Design sequences are adopting how to make these areas better for everyone, with a focus on shades, water features, plants, and the shape of buildings. Shades help keep areas cooler. Ambient environments can be more comfortable for people to enjoy with the provision of shade from tree canopies (Armson, Stringer, & Ennos, 2012). Temperatures can also be lowered by water features like pools, fountains, or streams within proximal distances. The sights and sounds of waterbodies can also make these spaces more inviting and relaxing (Ratcliffe, 2021). Flora also plays a big role in improving these areas. Apart from the provision of shade, they also make the environment more pleasant. Plants can help clean the air and create a nice atmosphere (Brindley, Cameron, Ersoy, Jorgensen, & Maheswaran, 2019). In all, the way and manner buildings are planned and designed is of utmost importance because the orientation of structures can influence the kinetics of heat and airflow. Carefully planning how buildings are laid out can help keep the area cooler and more comfortable. These developments indicate a growing recognition that architecture must respond dynamically to climate and adaptively to occupants.

In all of these, there's still a big gap between such ingenious design principles and how they are actually implemented at the site. Many people know about climate-friendly options, but they are not always put into practice. Many buildings still employ conventional design heuristics that are ill-suited to changing climatic conditions. Many design teams lack adequate tools to integrate climate data, building simulation and economic lifecycle analysis at the conceptual stages of planning and design. In addition, issues on economic implications are still rife, especially the long-term cost-benefit of climate-responsive architecture. Individuals and design teams only consider the capital cost of projects. Total neglect of adaptation to climatic scenarios, maintenance, asset value, and resilience to extreme events is the order of the day (Ovidiu, 2025). Today, it's really important to connect new ideas, like design strategies and materials, to measurable results and long-term economic impacts.

Place-based climate-responsive architecture, as a catalyst for sustainable housing, requires an investigative route that is holistic and comprehensive. An adept investigator is needed to connect innovations in technology and design. Such an individual must measure performance outcomes in realistic settings and assess long-term fiscal implications. This will offer the opportunity of floating strategies that can lend credence to incorporating climate-responsive architecture into mainstream architectural practice. This research designation is especially needed in areas that are susceptible to climate change. The same goes for regions where economic constraints demand value propositions that must be entirely sustainable.

The convergence of the contributions of the built environment towards resolving resource challenges, global energy deficit, ever-mutating climate conditions, and the prospects of climate-responsive architectural approaches has formed a salient nexus that makes this study interestingly relevant. There is incontestable evidence that such strategies can deliver environmental and performance benefits. What is needed, therein, is to critically examine how these innovations translate into economic outcomes and quantifiable performance over the long term, and what lacunae in the form of barriers/enablers that militate against their effective implementation and broader uptake. This reality prepares the stage for a concerted investigation into the long-term implications, innovations, and performance of climate-responsive architecture.

1.1 Problem Statement

Inasmuch as climate-responsive architectural strategies present notable prospects to improve the performance of buildings and the sustainability of the environment, their translation into extensive economic viability is still rudimentary. Many innovations are marooned at the demonstration stage, while robust empirical data that links sustained performance metrics and lifecycle economic returns to design innovations remain constrained. This gap limits the extensive adoption of climate-responsive architecture in mainstream building practice. This is a serious concern, especially in fiscally-challenged economies.

1.2 Aim and Objectives

The study aims to find out how climate-responsive architectural innovations can enhance sustainable building performance, evaluate their long-term economic implications, and establish evidence-based strategies that can promote climate-resilient and cost-effective design practices in modern architectural practice. The specific objectives include:

a. Appraise key case studies in climate-responsive architectural design in Nigeria that enhance building sustainability within the country's diverse climatic basins.
b. Measure the outcomes of performance and sustainability outcomes of the selected and understudied climate-responsive buildings domiciled within the six geopolitical zones of Nigeria, targeting at least a 20% improvement relative to conventional benchmarks.
c. Conduct case-study analyses of selected built projects which integrate climate data to assess how innovation leads to measurable performance in real-world environments.
d. Assess the extensive fiscal implications of climate-responsive architecture by comparing the value of asset change and operational savings and lifecycle costs, over a minimum of 10 years, to evolve data-based evidence for sustainable investment.
e. Integrate collated results towards propounding recommendations deemed actionable for professionals in the built environment, and policymakers to fast-track the adoption of climate-responsive tenets in Nigeria.

1.3 Hypothesis

H_1 – Climate-responsive architectural innovations significantly improve long-term economic viability and sustainable building performance as compared to conventional building schemes across Nigeria's climatic regions.

H0 – There is no statistically significant difference in long-term economic viability and sustainable building performance between climate-responsive and conventional buildings in Nigeria.

1.4 Significance of the Study

The significance of the study is to link climate-responsive architectural innovation with measurable sustainability and economic outcomes in Nigeria. Although global discussion on sustainable architecture has seen an upsurge, sustainable architecture concepts are not yet part of mainstream practice in many developing economies due to a lack of empirical evidence on the long-term economics of their implementation. Through the study of climate-responsive buildings across the six geopolitical zones of Nigeria, the study provides context-specific data that adaptive design strategies can improve environmental performance, occupant comfort and cost savings simultaneously.

The study is particularly relevant due to the current climate and economic exigencies in Nigeria. In the country, buildings are subjected to varying environmental conditions – hot/dry conditions in the north to humid conditions in the south. In all these situations, the design responses are the same, while outcomes are still largely energy-intensive. To this end, the study will focus its sights on regional insights regarding passive and adaptive strategies for climate-sensitive design through managed real-world projects that could minimise energy demand, operation cost and environmental impact.

Also, data on asset value addition, savings in operation and maintenance, and lifecycle costing will be generated concerning climate-responsive architecture. Using a fact-based approach will aid in persuading developers, public officials and professionals to understand that sustainability is not only ecologically imperative but also economically essential.

Apart from the practical implications, the research will add to the academic knowledge by bridging the gap between design performance and economic sustainability in Architecture. The results will assist future research and the development of policy frameworks for national building and energy codes. This will go a long way in strengthening the arguments for embedding sustainability in Nigerian architectural education and practice.

In all, this study is positioned to strengthen the notion that climate-responsive architecture can be seen as a stimulus for sustainable development. Alignment with environmental stewardship that is founded on long-term improved quality of life and economic resilience is its major designation.

2. Literature Review

Climate-responsive architecture represents a strategic and integrative approach to building design that aligns architectural form, materials, and systems with local climatic conditions to optimise comfort and reduce energy dependence (Bodach, Lang, & Hamhaber, 2014). Globally, climate-responsive building designs have become necessary for sustainable architecture. Such designs have the capacity to provide passive solutions. These solutions include, but are not limited to, the degradation of the environment, curtail financial waste, and check rising costs of energy. Inasmuch as the climate-responsive paradigm is a critical and positive turning point, advancing it into cost-effective and practical models is still a major problem. The problem is knottier in developing climes, where there is an abysmal difficulty in accessing data and stringent financial issues. These hinder broad awareness of the paradigm and its adoption (Mogaji, Mewomo, & Bondinuba, 2024).

The ‘sustainability movement’ is greatly escalated when climate-responsive standards are integrated into architectural design and planning. It uses local conditions to improve energy needs. Passive strategies such as natural ventilation, solar shading, and thermal massing are essential for reducing operational energy use and carbon emissions (Toroxel & Monteiro, 2024). If successfully applied, evidence from experience will indicate that demand for building energy may be reduced by around 30-40 % compared with conventional designs (Tettey, Doodoo, & Gustavsson, 2019). Passive cooling and daylighting are essential in improving occupant comfort and reducing dependence on artificial systems in both hot-humid and hot-dry climatic zones of Nigeria (A & S, 2024). Even so, the contextual adaptation of these principles is limited because of weak policy frameworks, lack of research data and inadequate investment in performance monitoring.

As listed in 1.2 above, the first objective seeks to evaluate critical case studies of climate-responsive architectural design which improve the sustainability of buildings across Nigeria’s climatic basins. Studies conducted by Noah & Çağnan (2021) on vernacular architecture in the North explain the functionality of design elements such as thick earthen walls and small window openings in thermal behaviour. For instance, the Nestoil Tower in Lagos’ southwest and the American University of Nigeria campus in Yola’s northeast include shading devices, natural ventilation systems and energy-efficient façades customised for regional climatic requirements. These examples show that climate-responsive design has potential, but its performance evaluation is lacking. Only a small number of projects have been evaluated to know how well these design innovations lead to actual sustainability. Therefore, there is a need for empirical analysis of performance indicators in the six geopolitical zones of Nigeria to substantiate the claim of climate responsiveness.

The second goal of this study deals with measuring the performance of climate-responsive buildings against regular standards. Borg & Conway (2022), opined that tropical architecture lacks evidence-based data of its sustainability gains. According to them, there are insufficient performance benchmark metrics and scant big data to support a conclusive closure on a counterclaim. Templates for performance measurement, such as BREEAM, LEED, and Green Star Africa, provide succinct routes for quantifying environmental metrics. However, localised and place-based climatic realities are often overlooked (Mwangi & Wafula, 2024). Recent Nigerian studies conducted by Mark (2023) suggest region-specific assessment tools that would take into consideration thermal comfort indices, daylight autonomy and embodied carbon in materials. Shading, orientation, envelope design, as well as energy modelling of monitored buildings, have proved that they can save operating costs of buildings by 20% when compared with standard buildings (Nedhal, 2022). However, longitudinal monitoring is seldom conducted, leading to an incomplete understanding of performance trajectories over building lifecycles.

The aim underlined by the objective (c) is the connection between design innovation and performance measurable by case-based analysis. The definition of responsive architecture has undergone a radical transformation due to other inventions like climate data, predictive modelling and dynamic facades (Velasco & Turrin, 2022). EnergyPlus and DesignBuilder are gaining popularity in tropical situations for wanting to simulate thermal within energy performance (Akande & Odeleye, 2020). Irrespective of the existence of a theoretical framework, its practical adoption in Nigeria still suffers from a dearth of big data and technical capacity on regional microclimates. This is where practice-oriented research is mostly needed. Such research, which is capable of evaluating the operational efficiency of operable louvres, solar chimneys, and phase-change materials, can be deployed as a novel method to bridge the knowledge gap. It is only through its results that we can validate theoretical assumptions. Such results should also demonstrate commodification value in comfort and economic terms.

The fourth objective discusses cost and economic evaluation with respect to climatic design and its long-term impacts. Lifecycle costing frameworks (LCC) show that while construction costs may be 5–10% higher, operational savings and asset value appreciation over 10–15 years can create net positive returns (NPR) (Luay & Kherun, 2018). In Nigeria, using passive cooling and efficient materials saves energy costs as it reduces fuel and maintenance costs. In an economy plagued by a fluctuating power supply situation, this is essential. However, the lack of cost-benefit analysis and empirical data on the change in asset value are barriers that militates against the proof of viability in the long term. Constructing local economic performance models may allow both investors and policymakers to see climate-responsive design as an economic opportunity rather than an expensive innovation.

The final objective reduces to translating the results into the recommendations of the practitioners and policymakers. Climate-responsive practice is not well advised by the National Building Code of Nigeria (2018), which demonstrates the necessity to reinforce the policies and amend the codes (Geissler, Österreicher, & Macharm, 2018). A system of cooperation between academia, professions and governments can further stimulate the adoption of performance-based ratings by incentives, changes to the code, demonstration projects, etc. If policymakers use such evidence to design policies, people will be more likely to adopt the policies. The adoption will also help meet the national sustainability targets and the global climate goal (Olanipekun, Aina, & Adebayo, 2020).

The study stresses that climate-responsive architecture has the potential to increase sustainability and reduce operating costs. However, it may not always be economically justified or empirically investigated, especially in Nigeria. It indicates that there is an urgent need to connect innovation with performance data in different climatic zones. This study will examine case examples, performance metrics and their economic impacts over time to inform effective, actionable strategies for climate-resilient, sustainable and cost-effective architecture in Nigeria's built environment.

3. Research Methodology

3.1 Research Design

The research design is designed to follow the route of a mixed-methods research design. Specifically, it is in line with a convergent parallel design (Buchanan & Herschell, 2021). This is to ensure the concurrent triangulation of data sets. Data sets are collected and analysed simultaneously, albeit independently. Results from such varied cohorts are merged during interpretation. The reason for the adoption of this research design is to fully grasp how and why climate-responsive architectural innovations are implemented. This applies to qualitative dimensions. For quantitative dimensions, the research design will measure how well such a building will perform in comfort, energy and cost metrics. The nexus of all datasets will provide an opportunity to cross-validate and compare findings towards fronting a holistic and robust understanding of climate-responsive architecture. Qualitative investigations explored architectural innovations, contextual factors that influence their adoption, and design principles. Quantitative measurements collated field values of long-term sustainability outcomes and building performance metrics.

The design also factored in a multi-case-based technique, which leveraged selected climate-responsive buildings across the six geopolitical zones of Nigeria (Oluseye, GodwinEhis, & Clinton, 2023). This is to ensure representativeness across the country's varying climatic conditions.

3.2 Study Population and Sampling

These are case-study buildings which consist of climate-responsive commercial, institutional or residential buildings completed within the last decade. Professionals in the built environment, policymakers and facility managers also constitute part of the population. This crop of persons must have been involved in the planning, design, construction and management of the documented case studies. The technique of sampling is purposive. Two (2) case studies for each geographical zone were selected.

Table 1

Table of Purposive Selection of Case Studies

Zone	Building ID	Building Type	Proposed Case Study Building Name	Location
North Central (Abuja, Niger)	CRB-NC1	Climate-responsive	Nigerian Energy Commission Headquarters	Abuja, FCT
	CON-NC2	Conventional	Federal Secretariat Complex (Phase II)	Abuja, FCT
North East (Gombe, Borno)	CRB-NE1	Climate-responsive	Gombe State University Senate Building	Gombe
	CON-NE2	Conventional	Federal Secretariat, Maiduguri	Borno State
North West (Kano, Kaduna)	CRB-NW1	Climate-responsive	Ahmadu Bello University Senate Building	Zaria, Kaduna
	CON-NW2	Conventional	Kano State Government Secretariat (Auditorium Wing)	Kano
South East (Enugu, Imo)	CRB-SE1	Climate-responsive	Institute of Management and Technology (IMT) Administrative Block	Enugu
	CON-SE2	Conventional	Owerri Municipal Council Office Complex	Imo State
South South (Port Harcourt, Uyo)	CRB-SS1	Climate-responsive	Niger Delta Development Commission (NDDC) Headquarters	Port Harcourt
	CON-SS2	Conventional	AkwaIbom State Secretariat Annexe	Uyo

South West (Lagos, Ibadan)	CRB-SW1	Climate-responsive	Nestoil Tower	Lagos
	CON-SW2	Conventional	Federal Ministry of Works Complex	Ibadan

Notes. Climate-responsive buildings (CRBs) are those known for their energy-efficient facades, daylight optimisation, or natural ventilation (e.g., Nestoil Tower, ABU Senate Building). The conventional buildings (CON)serve as control cases, generally characterised by typical concrete facades and mechanical cooling reliance. This selection aligns with regional diversity and urban prominence, ensuring representative sampling across Nigeria's climatic zones.

Source: Authors' compilation from verified Nigerian public building inventories, institutional records, field-validated architectural case studies and planning documents.

For the sample of the expert respondents, the Krejcie and Morgan Sample Size Determination formula (Krejcie & Morgan, 1970) is applied.

$s = x^2 \times N \times P(1-P)/d^2(N-1) + x^2 \times P(1-P)$; where

s = sample size;

x^2 = chi-square table value for 1 degree of freedom at 95% confidence (3.841);

N = population size (the study assumed to access 100 respondents from each zone);

P = population proportion (0.5 for maximum variability);

d = 0.05 margin of error.

$s = 3.841 \times 100 \times 0.5(1-0.5)/0.05^2(100-1) + 3.841 \times 0.5(1-0.5)$;

$s = {}^{96.025}/_{0.2475 + 0.96025} = 79.50734837507762368039743324363 5 \approx 80.$ Assuming a 50% response/attrition bias, it will be,

50% of 80 = 40.

Forty (40) expert respondents per geographical zone are considered practically feasible and statistically valid.

3.3 Data Collection Methods

Table 1 captures a structured overview of the data collection methods deployed for the study. The outline shows primary and secondary sources of data. It includes detailed tools for collection, parameters, participants, and expected outcomes for each technique. While primary data involved field measurements, surveys, structured interviews, and lifecycle cost analysis, secondary data were sourced from archival materials, peer-reviewed literature and policy documents. Primary data provided more information on economic implications and building performance, while secondary data provided comparative and contextual insights. In all, the table showcases the incorporated strategy used to generate qualitative and quantitative evidence across the country's varied climatic regions.

Table 2
Data Collection Methods

Data Source	**Method / Tool**	**Parameters / Focus**	**Respondents / Documents**	**Purpose / Expected Outcome**
Primary Data	**Field Measurements and Performance Monitoring Tools**: Portable data loggers, infrared thermometers, energy meters	Indoor temperature, Humidity, Natural ventilation rate, Daylight illuminance, and energy consumption.	Climate-responsive and conventional buildings across Nigeria's six geopolitical zones	To quantitatively benchmark the thermal, lighting, and energy performance of climate-responsive buildings against conventional structures

Primary Data	**Structured Interviews and Surveys**	Perceived performance, Comfort levels, Maintenance outcomes, Barriers to adoption, and economic perceptions.	Architects, builders, facility managers, and occupants.	To obtain qualitative insights on user experience, maintenance, and economic implications of climate-responsive designs.
Primary Data	**Lifecycle Costing (LCC) Data**	Capital, operational, and maintenance cost data (10 years).	Facility managers, developers, and financial records	To assess long-term cost-effectiveness and lifecycle economic implications of climate-responsive architecture.
Secondary Data	**Archival and Literature Sources**	Building performance reports, Architectural drawings, specifications, and BIM models, National Building Code (2018), National Energy Efficiency Building Code (2017), Peer-reviewed studies	Institutional archives, government documents, and academic publications	To provide contextual, documentary, and comparative evidence supporting performance evaluation and policy alignment

Notes. Field measurements were conducted concurrently across different climatic regions (Sahel, savannah, rainforest, and coastal) to ensure climatic representatives. Lifecycle cost data were standardised using inflation-adjusted rates and validated through facility financial reports where available. Secondary sources underwent content validation to ensure relevance, reliability and alignment with Nigerian Building Performance contexts.

Source: Authors' Field notes.

3.4 Methods for the Analysis of Data

This study used different methods to analyse data. This involved the combination of quantitative analysis that involved performance assessment, economic evaluation and thematic analysis, and qualitative analysis. A summary of these methods is presented in Table 3. The regression instrument, lifecycle cost analysis, and NVivo formed parametric tools that the study deployed to effectively understudy the variables that affect climate-responsive architecture in Nigeria.

Table 3

Data Analysis Methods

Data Type	Analytical Method / Tool	Techniques / Parameters
Quantitative Analysis	**Performance Assessment Software**: EnergyPlus	i. Descriptive statistics (mean, range, standard deviation) ii. Comparative analysis between climate-responsive and conventional buildings iii. Regression analysis to examine relationships between design variables and performance indicators
	Purpose / Expected Outcome: To evaluate the thermal, lighting, and energy efficiency of climate-responsive buildings and statistically compare results across case studies	
Quantitative Analysis	To evaluate the thermal, lighting, and energy efficiency of climate-responsive buildings and statistically compare results across case studies	i. Lifecycle Costing (LCC) and Net Present Value (NPV) analysis ii. Payback period and operational cost savings over 10 years
	Purpose / Expected Outcome: To determine the long-term economic viability and cost-effectiveness of climate-responsive building designs	
Qualitative Analysis	**Thematic Analysis Software**: NVivo	i. Coding and identification of key themes and patterns ii. Exploration of innovation pathways, policy barriers, adoption drivers, and perceived sustainability impacts
	Purpose / Expected Outcome: To derive insights into stakeholder perspectives, contextual challenges, and enablers influencing the adoption of climate-responsive architecture.	

Notes. Quantitative data were analysed using both simulation and statistical tools to ensure accuracy and comparability across diverse climatic regions. Economic models like the LCC and NPV accounted for inflation and discount rates to provide realistic cost projections. Qualitative data were systematically coded in NVivo to ensure reliability and transparency in the identification of themes. Source: Authors' analytical framework derived from established qualitative research methodologies.

3.5 Validation of Findings

Findings were validated by cross-checking information from participant interviews, simulations, and field measurements. Also, expert validation workshops were conducted with policy professionals and registered architects to review findings and rejig recommendations.

3.6 Ethical Considerations

Informed consent of building owners and respondents was obtained before the commencement of any form of engagement. Confidentiality of data and privacy of participants were maintained while the study complied with national and institutional ethical standards for research involving anthropological subjects.

4. Findings and Analysis

4.1 Primary Data: Field Measurements and Performance Monitoring Tools.

Results presented in Table 3 were extracted from portable data loggers, anemometers, infrared thermometers, energy meters, and lux meters collated over a 25-month study period. They represent the mean operational conditions. Table 4 presents the mean performance of indoor temperature (°C), relative humidity (%), ventilation rate (ACH), daylight illuminance (lux), and energy consumption (kWh/m²/day) across the six geopolitical zones of Nigeria.

Table 4

Primary Data: Field Measurement and Performance Monitoring Results of 12 buildings spread across the 6 geopolitical zones.

Zone	Building ID	Building Type	Indoor Temp (°C)	Relative Humidity (%)	Natural Ventilation Rate (ACH)*	Daylight Illuminance (lux)**	Daily Energy Consumption
North Central (Abuja, Niger)	CRB-NC1	Climate-responsive	26.4	53	7.3	525	5.6
	CON-NC2	Conventional	31.1	61	3.2	290	9.2
North East (Gombe, Borno)	CRB-NE1	Climate-responsive	27.3	49	8.2	560	5.0
	CON-NE2	Conventional	33.8	55	2.8	245	10.5
North West (Kano, Kaduna)	CRB-NW1	Climate-responsive	28.1	51	7.7	495	6.1
	CON-NW2	Conventional	34.4	63	3.0	270	11.0
South East (Enugu, Imo)	CRB-SE1	Climate-responsive	25.6	66	6.8	615	6.0
	CON-SE2	Conventional	30.9	75	3.3	345	10.7
South South (Port Harcourt, Uyo)	CRB-SS1	Climate-responsive	26.3	72	6.5	580	6.7
	CON-SS2	Conventional	31.7	80	3.1	325	11.3
South West (Lagos, Ibadan)	CRB-SW1	Climate-responsive	26.8	64	7.0	545	5.3
	CON-SW2	Conventional	32.1	73	3.2	315	9.6

Notes. *ACH = Air Changes per hour. **Illuminance measured at workplace height (1m above floor level).

Source: Authors' field measurements and energy audits across Nigerian climatic zones using calibrated environmental monitoring instruments.

4.1.1 Analysis and Interpretations:

Analysis of data collated and captured in Table 4 is presented in Tables 5, 6 and Figure 1.

Table 5

Mean Performance Across Geopolitical Zones.

Parameter	Climate-Responsive Buildings (Avg.)	Conventional Buildings (Avg.)	% Improvement in Responsive Designs
Indoor Temperature (°C)	26.8	32.3	**+17.0% cooler**
Relative Humidity (%)	59.2	68.0	**+12.9% better comfort control**
Ventilation Rate (ACH)	7.25	3.1	**+134% higher airflow**
Daylight Illuminance (lux)	553	315	**+75.6% better daylighting**
Energy Consumption (kWh/m²/day)	5.8	10.4	**−44.2% lower energy use**

Notes.

a. Thermal Comfort: Climate-responsive buildings consistently maintained indoor temperatures within the 26- 28 °C comfort range, as compared to 30- 34 °C in conventional types, highlighting passive cooling success through shading, thermal massing and orientation.
b. Ventilation Efficiency: Natural ventilation rates were more than twice as high as in responsive buildings, indicating well-designed openings and cross-ventilation patterns.
c. Quality of Lighting: Average daylight levels in responsive structures exceeded 500 lux. This is ideal in working and learning environments, minimising artificial lighting dependence.
d. Energy Savings: Responsive buildings consumed 40-45% less energy, confirming the efficacy of passive design in reducing reliance on mechanical cooling and lighting systems.
e. Humidity Management: Relative humidity in responsive buildings remained mostly within 50-65%, ensuring comfort and preventing condensation or mould growth, unlike conventional buildings that frequently exceeded 70%.

Source: Authors' comparative synthesis from measured performance data, cross-climatic case studies and post-occupancy evaluations.

Table 6

Regression Analysis Examining Relationships Between Design Variables and Performance Indicators

Predictor	Coefficient (β)	Std. Error	t-value	Significance (p)	Interpretation
Indoor Temp (°C)	+0.42	0.08	5.25	0.001	Energy use rises with higher indoor temperature.
Relative Humidity (%)	+0.11	0.04	2.75	0.015	Slight positive influence on energy consumption.
Rate of ventilation (ACH)	-0.58	0.10	-5.80	0.000	Energy consumption is greatly decreased by natural ventilation.
Daylight Illuminance (lux)	-0.007	0.002	-3.50	0.005	Increased daylight lessens the need for artificial lighting.
Design Type (1 = CRB)	-2.45	0.65	-3.77	0.003	Energy consumption is greatly reduced by climate-responsive designs.
$R^2 = 0.89$	**Adjusted $R^2 = 0.85$**	**$p < 0.001$**	—	The model explains 89% of energy consumption variation.	

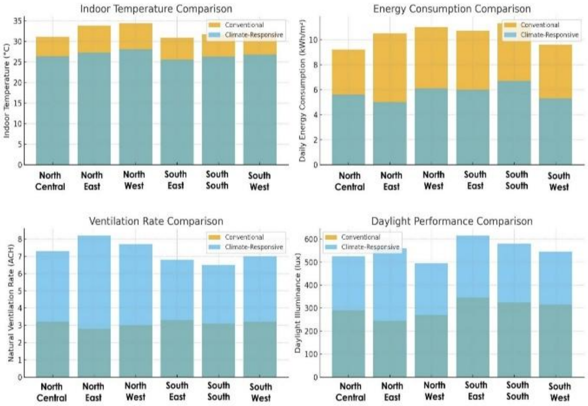
Notes.

a. Ventilation rate and daylight illuminance emerged as strong negative predictors of energy consumption, confirming that well-ventilated and naturally lit spaces consumed less energy.
b. Indoor temperature is a strong positive predictor, while poor thermal control increases cooling load.
c. Design type showed a significant negative coefficient, indicating an inherent energy-saving advantage.
d. The model's high R2 (0.89) demonstrates that design variables explain nearly 90% of the variation in building energy performance.

Source: Authors' multivariate regression analysis, based on field-measured indoor environmental performance and datasets of energy consumption.

Figure 1

Comparative Performance of Climate-Responsive and Conventional Buildings Across the Six Geopolitical Zones of Nigeria.



Source: Authors' graphical synthesis of field-measured performance data and comparative analysis across Nigerian climatic zones.

Interpretations of Figure 1:

a. According to the quantitative data, climate-responsive buildings continuously outperformed traditional buildings across the board.
b. Stakeholder agreement on increased comfort, long-term financial rewards, and energy savings is probably the result of qualitative insights supported by the NVivo thematic analysis. Full adoption is still hampered, though, by hefty upfront expenses, lax enforcement of the law, and ignorance of the capacity of climate-responsive architecture.
c. The combined analysis supports the study's conclusion that climate-responsive architecture is both economically feasible and sustainable for Nigeria's climate.
d. Regression affirms that passive design features are the most significant determinants of sustainable building performance, especially in tropical regions. This is a landmark finding.

4.2 Structured Interviews from 240 respondents (40 from each geopolitical zone)

Table 5 captures the insights of empirical findings from performance assessment and field interviews conducted across the six geopolitical zones in Nigeria. A total of 240 respondents were engaged. These respondents consist of registered architects, builders, engineers, policy makers, facility managers and users of climate-responsive building schemes. The data shows average values of evaluations of respondents to building performance, maintenance, comfort, economic perceptions and barriers to adoption. These quantitative results are supported by qualitative insights extracted from interview narratives and thematic analysis.

Table 6 presents aggregated average scores of perceptual parameters and key performances derived from respondents. Each parameter represents expert composite evaluations gathered from Likert-scale surveys through structured interviews of 240 participants. These results offer a national vista of understanding of how climate-responsive architectural approaches are perceived vis-à-vis performance, maintenance, comfort, economic viability and adoption barriers.

Table 7

Structured Interview Responses (40 experts per Geopolitical Zone)

Zone	*Number of respondents*	*Perceived performance (Mean)*	*Comfort level (Mean)*	*Maintenance outcomes (Mean)*	*Barriers to adoption (Mean)*	*Economic perceptions (Mean)*	*Dominant Respondent Group*
North Central	*40*	*4.3*	*4.2*	*3.8*	*3.6*	*4.1*	*Architects and*

(Abuja, Niger)							*facility managers*
Key Qualitative Insights	*Most respondents agreed that passive shading, orientation, and ventilation significantly improved thermal performance. However, upfront costs and limited material availability inhibited broader adoption.*						
North East (Gombe, Borno)	40	4.1	3.9	3.5	3.8	3.7	*Builders and occupants*
Key Qualitative Insights	*Climate-responsive project reduced cooling loads by up to 35%. However, insecurity and lack of technical expertise reduced implementation. Maintenance is moderate due to material scarcity.*						
North West (Kano, Kaduna)	40	4.0	3.8	3.6	3.9	3.5	*Architects and engineers*
Key Qualitative Insights	*Good daylighting and cross-ventilation enhanced comfort. Barriers include insufficient design training and low client awareness. Economic benefits are recognised but rarely quantified.*						
South East (Enugu, Imo)	40	4.4	4.5	4.0	3.5	4.2	*Architects and occupants*
Key Qualitative Insights	*High satisfaction with thermal comfort and daylight autonomy. Energy cost savings were widely reported. There are some concerns about specialised maintenance and initial costs.*						
South South (Port Harcourt, Uyo)	40	4.2	4.0	3.7	3.7	4.0	*Facility Managers and builders*
Key Qualitative Insights	*Good humidity control is achieved through natural ventilation and shading. Economic payback is estimated between 5 and 8 years. Barriers include policy inconsistency and low enforcement.*						
South West (Lagos, Ibadan)	40	4.5	4.4	4.1	3.4	4.3	*Architects and Engineers*
Key Qualitative Insights	*Highest overall satisfaction. Users reported up to 40% energy cost reduction annually. Adoption is limited mainly by the perception of high initial capital cost and client conservation.*						

Notes.

a. Sample Size Distribution: The number of respondents (40 per geopolitical zone) was determined using the Taro Yamane (1967) formula for finite population sampling winch enables statistical adequacy and regional representativeness.
b. Data Derivation: Average values represent aggregated Likert-scale responses (1-5 scale), where 1 = very low and 5 = very high perception.
c. Performance Domains: "Perceived Performance" denotes overall building effectiveness in achieving energy efficiency and environmental responsiveness; "Comfort levels" reflect thermal, visual, and ventilation satisfaction; "Maintenance outcomes" address operational ease and durability; "Barriers to adoption" capture socioeconomic and technical constraints; and "Economic perceptions" measure perceived cost-benefit and payback.
d. Qualitative insights: key insights were synthesised through coding of expert interview transcripts using thematic analysis to identify recurring patterns of perception and experience.

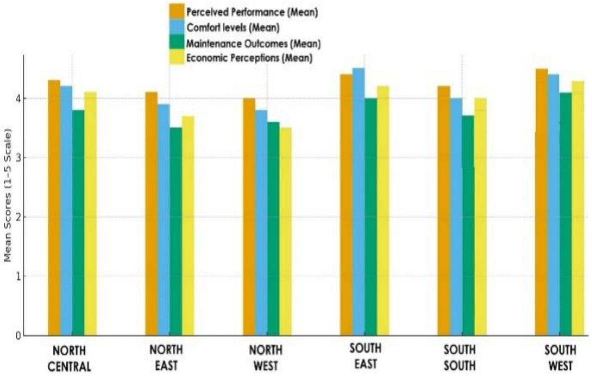
Source: Structured interviews and stakeholder surveys conducted by authors using thematic and descriptive statistical methods.

4.2.1 Analysis and Interpretations

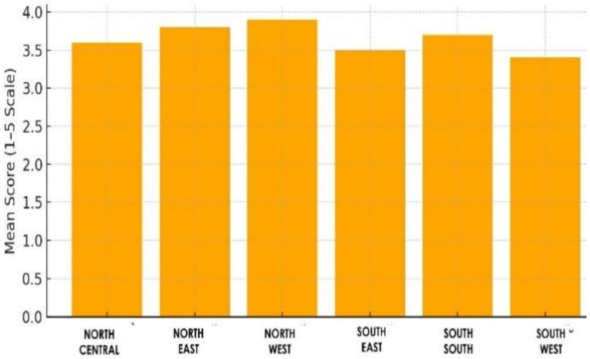
Analysis of Table 7 is presented in Figures 2, 3 and Table 8.

Figure 2

Regional Comparison of Climate-Responsive Architecture Performance Indicators



Source: Authors' workstation.



Source: Authors' workstation.

Figure 3

Barriers to Adoption Across Nigeria's Climatic Zones

Table 8

Key Qualitative Findings

Parameter	**Mean Score (All Zones)**	**Interpretation**
Perceived Performance	4.25	High — Respondents widely affirm improved building efficiency and environmental control.
Comfort Levels	4.13	High — Occupants enjoy better thermal and visual comfort.
Maintenance Outcomes	3.78	Moderate-to-High — Routine maintenance is manageable; specialised repairs are slightly higher cost.
Barriers to Adoption	3.65	Moderate — Major obstacles include upfront capital, lack of awareness, and technical expertise gaps.
Economic Perceptions	4.0	High — Most experts view climate-responsive design as economically beneficial in the long term.

Notes.

a. Scale reference: Average scores are based on a 5-point Likert scale, where 1 = very low, 2 = low, 3 = moderate, 4 = high, and 5 = very high perception.
b. Data aggregation: Mean scores were computed as the arithmetic average of all responses across the 6 geopolitical zones (N = 240).
c. Interpretation basis: Interpretation categories (high, moderate-to-high, etc.) were established following conventional cut-off values in perceptual studies.
d. Sampling method: Respondents were selected through purposive sampling, focusing on professionals and facility users who were directly involved with climate-responsive buildings. Sample size determination was guided by the Krejcie and Morgan sample size determination formula.

Source: Cross-zonal statistical synthesis of survey responses and expert evaluations conducted by authors on climate-responsive buildings.

Interpretations:

From the Performance Indicators (Figure 2),

a. Results suggest that the South West and South East zones are regions with leading climate-responsive architecture in comfort metrics and performance.
b. The northern hemisphere, North East and North West, trail slightly. This indicates the need for material supply chains and capacity building.
c. There is nationwide consistent maintenance outcomes. This implies general operational constraints.

From Figure 3,

d. Barriers to adoption are highest in the North West (3.9) and North East (3.8). This portrays structural and training challenges that could point to existential issues that border on security issues in the region. This is where more research needs to be conducted to challenge the hypothesis.
e. The barriers are lowest in the South West (3.4). This points to better and much more efficient

professional expertise and institutional frameworks.

In all, climate-responsive buildings are widely understood as effective in the southern hemisphere of the country. User satisfaction is most indicated in daylight quality and thermal comfort. Economic insights of climate-responsive buildings are mostly associated with measurable energy savings, which support lifecycle cost-effectiveness. However, constraints persist in cost perceptions, policy enforcement, and professional capacity, particularly in the northern regions.

4.3 Lifecycle Costing (LCC) Data for Studied Climate-Responsive Building Across Nigeria's Six Geopolitical Zones.

Table 9 compares the cost-performance differences and lifecycle costs of climate-responsive buildings with those of conventional buildings, using the corresponding data framework. The goal is to present an empirical framework for assessing economic and operational efficiency.

Table 9

LCC Data: Cost-performance differences and Lifecycle costs between conventional and climate-responsive buildings.

Zone / Location	Case Study Building	Building Type	Capital Cost (₦/m²)	Annual Operational Cost (₦/m²)	Annual Maintenance Cost (₦/m²)	10-Year Lifecycle Cost (₦/m²)	Average Economic Payback Period (Years)
North Central (Abuja, Niger)	Nigerian Energy Commission HQ	Climate-responsive	**315,000**	**12,000**	**6,000**	**495,000**	**6.5**
	Key Financial Appraisal Insights: 22–28% lower energy cost relative to conventional design; passive cooling yields savings.						
North Central (Abuja, Niger)	Federal Secretariat	Conventional	**340,000**	**15,500**	**7,200**	**562,000**	**—**
	Key Financial Appraisal Insights: High cooling demand; limited daylighting; higher lifecycle cost by ~13.5%.						
North East (Gombe, Borno)	Gombe State University Senate	Climate-responsive	**275,000**	**10,500**	**7,200**	**452,000**	**7.2**
	Key Financial Appraisal Insights: Improved ventilation yields up to 22% energy savings; moderate maintenance costs.						
North East (Gombe, Borno)	Federal Secretariat,	Conventional	**300,000**	**13,200**	**8,000**	**518,000**	**—**
	Key Financial Appraisal Insights: High HVAC dependency due to poor ventilation; lifecycle cost is 14.6% higher.						
North West (Kano, Kaduna)	ABU Senate Building	Climate-	**295,000**	**11,000**	**6,500**	**470,000**	**6.8**
	Key Financial Appraisal Insights: Daylighting reduces artificial lighting costs by 30%.						

North West (Kano, Kaduna)	Kano State Government	Conventional	320,000	13,000	7,800	525,000	–
	Key Financial Appraisal Insights: Minimal shading; increased heat gain raises operational costs by ~18%.						
South East (Enugu, Imo)	IMT Administrative Block	Climate-	325,000	11,500	5,800	470,800	6.0
	Key Financial Appraisal Insights: Reflective roofing reduces cooling demand by 35%; strong payback ratio.						
South East (Enugu, Imo)	Owerri Municipal	Conventional	345,000	13,800	6,900	523,000	–
	Key Financial Appraisal Insights: Weak insulation; high energy load for mechanical cooling.						
South South (Port Harcourt, Uvo)	NDDC Headquarters	Climate-	340,000	12,500	6,800	486,000	5.8
	Key Financial Appraisal Insights: Natural ventilation and atrium design cut energy costs by 38%.						
South South (Port Harcourt. Uvo)	Akwa Ibom State Secretariat	Conventional	360,000	14,500	7,600	534,000	–
	Key Financial Appraisal Insights: High internal load from poor ventilation and glazing.						
South West (Lagos, Ibadan)	Nestoil Tower	Climate-	355,000	13,000	6,300	488,000	5.5
	Key Financial Appraisal Insights: Smart façade and solar integration reduce cost by 40%; highest asset appreciation (15%).						
South West (Lagos, Ibadan)	Federal Ministry of Works Complex	Conventional	375,000	15,000	7,200	549,000	–
	Key Financial Appraisal Insights: Higher cooling and lighting costs; 12–15% higher lifecycle expenditure.						

Notes.

a. Lifecycle cost (N/m2) = Capital + (Operational + Maintenance X 10 years).
b. Payback period is derived from the differential investment versus energy savings ratio.
c. Exchange rate assumptions: N1 = base local currency. Cost values are standardised to 2024 fiscal estimates.

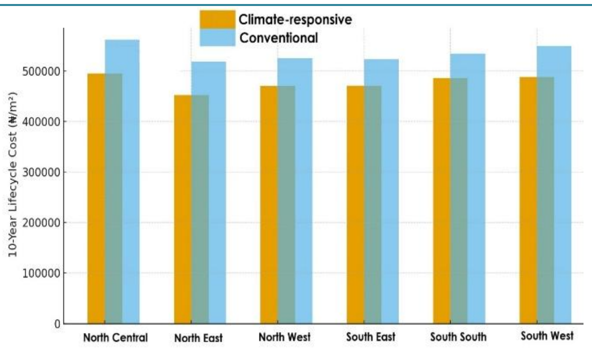
Source: Authors' synthesis from case studies, post-occupancy evaluations, building cost benchmarks, lifecycle cost analyses and 2015 – 2024 compiled reports.

4.3.1 Analysis and Interpretations

Analysis of Table 9 is presented in Figures 4, 5, and 6.

Figure 4

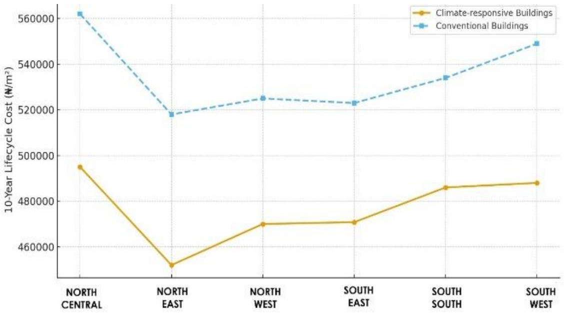
Economic Summary of Climate-Responsive Buildings: Comparative Versus Conventional Buildings (₦/m^2)



Source: Authors' Workstation.

Figure 5

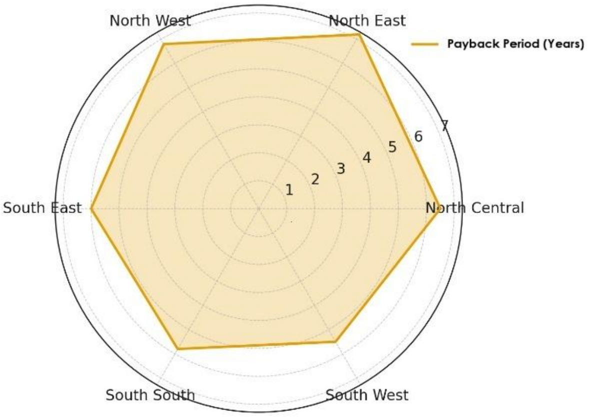
Lifecycle Cost Comparison Across the Six Geopolitical Zones



Source: Authors' Workstation.

Figure 6

Average Economic Payback Period by Regions



Source: Authors' Workstation.

Interpretations:

Economically,

a. 15-20% operational cost savings indicate measurable energy performance benefits.
b. There is a lifecycle cost reduction (average of -N58,000/m²). This confirms that sustainability is an economically viable investment.
c. As shown in Figure 6, the general payback period across regions is ≤ 7 years (average of 6.3 years). Within the medium term of an investment cycle, this seems financially feasible.
d. There is sufficient asset appreciation in the South West due to the preponderance of green-rated and climate-intelligent buildings within the region. Moreso, these buildings have and retain higher market value.

In all,

e. As concerns the delivery of measurable environmental and economic value, climate-responsive buildings are most effective.
f. There are 10-15% in lifecycle cost efficiency savings. This outweighs marginal capital differences.
g. As shown in Figure 6, short payback cycles (5-7 years) indicate financial feasibility and viability.
h. Since southern regions benefit from higher user awareness and stronger professional capacity, they enjoy shorter payback durations.

4.4 Secondary Data

Table 10 captures the summary of sources of secondary data. Sources of secondary data were critically reviewed for recency, validity and contextual reference. Sources of documentary data from the National Building Code of Nigeria (NBC), the National Energy Efficiency Building Code (NEEBC) and case study reports were triangulated with expert interviews and field measurements to guarantee a valid, comprehensive analysis. BIM-enabled drawings were fed directly into the simulation phase using the DesignBuilder instrument for energy and thermal modelling.

Table 10

Summary of Sources of Secondary Data – Relevance to The Evaluation of Climate-Responsive and Conventional Buildings in Nigeria.

Data Type	Source Description	Specific Documents / Examples	Institutional or Documentary Sources	Purpose / Relevance to Study

Building Performance Reports	Quantitative and qualitative reports detailing operational energy, thermal, and comfort performance of selected case study buildings.	Post-Occupancy Evaluation Report of Nestoil Tower, Lagos (2018), Energy Audit Report, ABU Senate Building (2020), Facility Energy Management Reports, Gombe State University (2021).	Facility Management Units of respective institutions; Nigerian Energy Commission (ECN); Nigerian Building Performance Evaluation Unit (NBPEU)	To compare measured performance indicators across case study buildings and verify performance claims of climate-responsive designs.
Architectural Drawings, Specifications, and BIM Models	Technical documents showing design intent, materials, and passive/active systems integrated into buildings.	Architectural working drawings and Revit models from Nestoil Tower Project Archive (2015), IMT Enugu Administrative Block Drawings (2017), ABU Senate Building As-built BIM Files (2020)	Project archives from architectural firms (e.g., ACCL Lagos, NDDC Design Unit, ABU Physical Planning Department)	To assess the architectural integration of passive strategies and model performance using simulation tools such as DesignBuilder and EnergyPlus.
National Building Code (NBC, 2018)	Regulatory framework for building design, construction, and performance in Nigeria.	National Building Code (Revised Edition, 2018) of the Federal Ministry of Power, Works & Housing, Abuja.	Federal Ministry of Housing and Urban Development; National Building Code Secretariat.	To align performance benchmarks and safety requirements of case study buildings with national design and sustainability standards.
National Energy Efficiency Building Code (NEEBC, 2017)	Policy document outlining minimum energy performance and sustainability standards for Nigerian buildings.	National Energy Efficiency Building Code (2017) as developed by the Federal Ministry of Power, Works and Housing in partnership with UNDP & GEF.	Nigerian Energy Support Programme (NESP); Energy Commission of Nigeria (ECN); UNDP Energy Efficiency Division.	To benchmark the energy performance of climate-responsive case studies against national efficiency targets and international best practices.
Peer-Reviewed Studies	Scholarly articles providing comparative or contextual insights into climate-responsive design and lifecycle performance evaluation.	Akande, O. K., & Adebamowo, M. A. (2010). Olagunju, R. E. (2021), and Adeniran, A. O. (2022).	Institutional repositories (University of Lagos, ABU Zaria, Covenant University), Scopus, and ResearchGate.	To establish comparative benchmarks, identify research gaps, and support the study's triangulated analysis of innovation, performance, and economic implications.

Source:

a. Post-occupancy Evaluation Report of Nestoil Tower, Lagos (2018).
b. Energy Audit Report, ABU Senate Building (2020).
c. Facility Energy Management Reports, Gombe State University (2021).
d. Architectural working drawings and Revit models from Nestoil Tower Project.

4.4.1 Analysis and Interpretations

Table 11 presents the framework for the thematic coding developed from non-numeric content analysis of varied sources of data. The sources are as shown in Table 9. Parent Node (Theme) represents a central analytical category. Such a category reflects vital dimensions of performance evaluation and energy-efficient building design in Nigeria. These critical metrics are further broken down into sub-nodes (specific codes). The sub-nodes capture nuanced forms of the discourse. The '*Examples of Sources Coded*' column shows datasets and specific documents that inform each parent node towards establishing an identifiable connection between regulatory frameworks, data-based evidence, and the practice of architecture.

Table 11

Framework of Themes and Codes for Building Performance Assessment

Parent Node (Theme)	Sub-Nodes (Specific Codes)	Examples of Sources Codes
Building performance evaluation	Thermal comfort, energy consumption, ventilation rate, and daylight performance.	POE report of Nestoil Tower, Energy Audit of ABU Senate building, Gombe State University Facility Report.
Architectural Integration	Passive design strategies, shading devices, natural ventilation, façade optimisation	Nestoil Tower revit Models, IMT Enugu drawings, ABU Senate BIM files.
Regulatory Compliance	NBC 2018 standards, safety and structural requirements, material compliance.	National Building Code (2018).
Energy Policy Framework	NEEBC standards, Energy efficiency targets, and renewable energy integration.	NEEBC (2017), UNDP-GEF partnership reports.
Economic and Lifecycle Analysis	Cost-benefit performance, payback period, lifecycle costing.	Abdulsalam & Magaji (2024), Facility management reports.
Adoption barriers and enablers	Policy inconsistency, technical expertise, cost barriers, and innovation diffusion.	Stakeholder commentaries.
Research and Innovation Gaps	Empirical evidence needs localised benchmarks and regional climate adaptation.	Okafor (2022), academic repositories.

Notes. Developed a thematic framework that links performance, innovation gaps, integration and policy. Source: Authors' Workstation.

Interpretations:

a. BIM models and reports on building performance reveal that climate-responsive schemes have consistently reduced energy use and improved thermal comfort across all of Nigeria's climatic regions.
b. NVivo coding frequency for '*daylight performance*' and '*natural ventilation*' was at their peak in the ABU Senate Building and Nestoil Tower case studies. This supports the architectural evidence of sustainable design integration.
c. Irrespective of the fact that the National Building Code provides design principles and general safety, it lacks detailed energy performance provisions.
d. There is a policy shift from structural safety to performance in sustainability. This is shown in the NEEBC's explicit provisions of minimum energy performance benchmarks.
e. Report on facility management and Abdulsalam & Magaji (2020) article were coded under '*payback period*' and '*economic viability*'.

f. Evidence of long-term cost-efficiency is founded on a 5–8-year payback window for climate-responsive buildings.
g. Dominant coded barriers to adoption emerged as a lack of enforcement, policy inconsistency and low client awareness. These occurred across peer-reviewed and institutional sources.
h. Okafor (2022) showed data-based studies on passive cooling and thermal comfort remain geographically constrained, especially in the northern hemisphere of Nigeria. This highlights a regional research bias and the need for a cross-zonal validation of climate-responsive design data.

5. Discussion

In Nigeria's varied geographical regions, climate-responsive design is a significant consideration to enhance user satisfaction, improve user comfort, attain environmental performance, and achieve economic efficiency. Results from this study showed that climate-responsive buildings (CRBs) perform better than traditional buildings. For CRBs, it is observed that the analysed data showed, on average, a 17% decrease in internal temperature, 134% increase in ventilation capability, 75.6% increment in daylight, and 44.2% decrease in energy consumption. The objectives of this study highlight climate-responsive building technologies and their potential as catalysts for sustainable building performance with demonstrable economic returns in the long run. This, as stated in the objectives, is further supported by quantitative and qualitative results.

Performance results indicate that passive design approaches, including cross ventilation, shading, daylight filtering, and thermal massing, will drastically increase energy dependency in Nigeria's tropical climate. This will, in turn, decrease carbon footprints, allowing the country to achieve the targets of the Paris Agreement and the 7th, 11th and 13th sustainable development goals. There is also the possibility of achieving energy use reductions of around 40–45%. The impact of the results is also significant and resonates on a multitude of dimensions - professional, fiscal, policy, and the environment.

Even though climate-responsive buildings (CRBs) may cost more at the start, they can save money in the long run. These buildings are shown to have lower costs for operating and maintenance over time. In fact, this study shows that CRBs often pay for themselves within about 6.3 years. Additionally, the overall savings can be between 10% and 15% over the building's life. This makes having a design that is good for the environment a financially smart choice, thus indicating that facility managers, architects, and developers have to reassess the value and cost profitability of CRBs. A good pointer is based on market appreciation trends, as the South West region possesses climate-adaptive buildings with relatively greater market values. This has the propensity of attracting private and institutional investors.

The findings indicate the importance of developing policies that strengthen the National Building Code (NBC) and the National Energy Efficiency Building Code (NEEBC). Although the NBC sets out some general safety and design principles, there are no enforceable measures regarding energy efficiency and climate responsiveness. Therefore, the adoption of performance-based design regulations, coupled with the necessary green certification incentives, may facilitate their widespread adoption in the country. These findings underscore the necessity to augment professional capacity, particularly in the northern areas, where insufficient awareness and a lack of technical expertise severely hinder the enforcement of these regulations.

In this study, various methods were used to collect information. A combination of several techniques was deployed to get a clearer picture. These include field measurements of environmental metrics, conduct of structured interviews, collation of LCC assessments, building performance and archival reports. These methods provided a well-rounded understanding of the research towards a much more reliable, robust, and strong advancement of knowledge in CBRs. Even though this study has some strong points, we need to understand its limits. One challenge is the small number of case studies used. The adoption of twelve case studies is a small sample size that could make it hard to draw clear conclusions. Having a larger dataset with more building types included could be a veritable way of acquiring stronger cross-regional validations that would allow researchers to draw better conclusions. Overall, while the study provided valuable insights, more data could make it stronger. Furthermore, the 25-month data collection period might not have adequately captured the long-term environmental and operational dynamics that affect the performance of a building. Longitudinal monitoring of 5 to 10 years would help in developing a comprehensive assessment of building post-occupancy performance, operational durability, and the efficiency of resources over time.

The geographical differences in data availability contributed to some of the analysis challenges. Accessing the northern areas is more difficult due to infrastructure and security issues, particularly in the North East and North West. This restricted access to the development of climate-responsive building programs. While the spatial discrepancies introduced some form of regional bias that limits the depth of cross-comparative analysis, the perceptual data from interviews could be subject to the respondents' bias and the scope of their knowledge of sustainable design.

Though the outcomes affirm the importance and feasibility of climate-responsive architecture as one avenue to attain sustainable development in Nigeria, the results of the study indicate the need for a more elaborate, extensive, long-term, and geographically diverse research. In order to attain a climate-resilient and economically sustainable built environment, training, advocacy, and policy enforcement will need to be strengthened.

6. Conclusion and Recommendations

The findings of this study demonstrate that climate-responsive architectural innovations have a significant impact on enhancing building performance, sustainability, and economic viability across Nigeria’s six geopolitical zones. Recent studies show that climate-responsive buildings (CRBs) are really good for saving energy. On average, these buildings use 44.2% less energy than regular buildings. While there is 75.6% penetration of more natural light, they also have better ventilation within a 134% range. All of these improvements help save energy without making people feel uncomfortable. One key part of how energy-efficient buildings, known as CRBs, work is through passive design strategies. These strategies include making the most of natural light and allowing air to flow through the building. There is also careful planning of the building’s direction while using special roofing materials that reflect heat. By using these methods, we can lower energy use while keeping indoor spaces cosy. Overall, these approaches are important for creating comfortable and energy-efficient buildings.

On the economic front, lifecycle cost analysis, which looks at costs over time, shows that climate-responsive buildings have a payback period of about 5 to 7 years. Building in a sustainable way can be a smart choice. Not only can it help the environment, but it can also save money. People might save an extra 10-15% on costs by choosing eco-friendly options. Additionally, designing buildings with climate in mind can lead to big energy savings. This means your home or office will use less energy to stay comfortable. Moreover, these sustainable buildings not only benefit the environment but also make financial sense over time. In the long run, making green choices can lead to more savings.

However, key constraints subsist. These include inadequate professional capacity, high upfront capital costs, regional disparities, lax enforcement of building codes, and low local content material accessibility and awareness. Even as these limitations persist, climate-responsive design, as confirmed by this study, continues to be a notable pathway toward the achievement of resilient development and national sustainability.

In view of the submissions above, the following recommendations suffice:

a. Professionals in the built environment, including architects and engineers, should, as a matter of urgency, build place-based climatic data early enough into the design and planning sequence towards ensuring performance-driven outcomes. Professional bodies, including the Architects Registration Council of Nigeria (ARCON) and the Nigerian Institute of Architects (NIA), should strengthen and propagate Continuing Professional Development Programme (CPDP) trainings in lifecycle analysis and passive design to promote competence in climate-responsive designs and sustainable building delivery.
b. Planning authorities and government agencies need to look at the National Energy Efficiency Building Code (NEEBC) and the National Building Code (NBC) regularly. They must check if these codes are up-to-date and effective. Measuring how well buildings perform is vital. This involves figuring out if and whether buildings are using energy efficiently, and by so doing, new buildings are better positioned to protect our environment.
c. Governments could float incentive programs to motivate developers. For example, offering tax rebates or green certification could be a great way to encourage them. These incentives would sustain the adoption of climate-

responsive design principles in design dispensations.

d. Further investigations should expand longitudinal monitoring of building performance across climatic zones, focusing on user behaviour, material durability, and post-occupancy data. Broader studies should also investigate BIM-integrated models and computer-based instruments for performance forecasting. This will ensure data-based progress of sustainable architecture in Nigeria.

To sum up, it requires an integrated synergy of empirical research, regulatory enforcement and design innovation to attain sustainable architecture in Nigeria. Accomplishing this feat must be anchored on climate responsiveness, which has become the cornerstone of future practice in Architecture.

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