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STAKEHOLDER DEMOGRAPHICS AND PASSIVE DESIGN STRATEGIES FOR ENERGY-EFFICIENT HIGHER EDUCATION BUILDINGS IN HOT-DRY CLIMATES: A CASE STUDY OF BAUCHI METROPOLIS, NIGERIA

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Abstract

This study investigates the influence of stakeholder demographics and passive design strategies on the energy performance of higher education buildings in the hot-dry climate of Bauchi, Nigeria. The research is grounded in a mixed-methods approach, combining qualitative and quantitative strategies to capture both the technical performance of passive design features and the perceptions of key stakeholders. Data collection was carried out in selected higher-education buildings in Bauchi, Nigeria, chosen through purposive sampling to reflect diverse architectural typologies and user populations. The Findings reveal that 71% of students lack awareness of the relationship between building design and energy use, while 58% of facility managers' report insufficient training in energy efficiency. Moreover, only 23% of academic staff had ever participated in sustainability-related decision-making processes. Passive design assessments show that over 80% of existing buildings suffer from poor orientation, inadequate shading, and inefficient ventilation. Passive design assessments show that a majority of existing buildings suffer from poor orientation, inadequate shading, and inefficient ventilation. Questionnaires and on-site observations consistently suggest that improvements such as applying reflective coatings and installing better shading devices could significantly reduce the internal heat gain, leading to a much more comfortable indoor environment. The study recommends an integrated framework combining stakeholder engagement, low-cost passive retrofits, and localized design guidelines. The study recommends an integrated framework combining stakeholder engagement, low-cost passive retrofits, and localized design guidelines. These findings offer actionable pathways for achieving sustainable, energy-efficient educational infrastructure in Sub-Saharan Africa.

Keywords: Climate, Energy Efficiency, Higher Education Buildings, Passive design, Retrofitting, Sustainability

INTRODUCTION

The global conversation surrounding climate change and energy conservation has increasingly emphasized the building sector due to its substantial energy consumption and associated greenhouse gas (GHG) emissions. Notably, buildings account for over 36% of total global energy use and approximately 40% of CO_2 emissions (IEA, 2015). As energy demands in buildings—especially for heating, cooling, and lighting continue to rise, energy efficiency has emerged as a critical area for environmental and economic reform (Löhnert et al., 2007; Sadineni, Madala, & Boehm, 2011).

In Nigeria, the situation is particularly urgent. Most higher education buildings, especially those constructed in previous decades, lack adequate design considerations for sustainability and occupant comfort (Šálek et al., 2017). These buildings are often energy-intensive, due to poor insulation, outdated materials, and inefficient design strategies, thus making them significant contributors to national energy inefficiency (Oyedepo et al., 2015).

Educational institutions are vital due to their role in shaping future leaders and professionals. As such, universities not only consume significant energy daily but also serve as ideal settings for demonstrating sustainable practices (Rohwedder, 2004). Improving the energy performance of university buildings in Nigeria, particularly in Bauchi, holds the potential to reduce environmental impact, enhance thermal comfort, and serve as a living laboratory for sustainability education (Corgnati, Filippi, & Viazzo, 2007). Despite global advancements in building energy efficiency, Nigerian institutional buildings often remain poorly insulated, lack passive cooling features, and suffer from excessive energy wastage (Bello et al., 2021). Moreover, stakeholder characteristics and behavioral patterns significantly affect how energy is consumed and how spaces are managed (van der Linden et al., 2006; Yousefi et al., 2017). This calls for a dual-pronged analysis: first, identifying who the stakeholders are and how they interact with educational buildings, and second, defining viable passive design strategies that align with the hot-dry climatic realities of Bauchi.

To address these issues, it becomes imperative to investigate passive building design strategies—techniques that leverage local climate, building orientation, and natural ventilation to reduce dependence on mechanical systems (Gustafsson, 2017). In hot-dry climates like Bauchi, integrating context-specific passive design strategies tailored to microclimatic conditions can lead to substantial improvements in energy efficiency and user comfort (Moore et al., 2013; Hassan & Lee, 2015).

This study focuses on two primary objectives: first, to establish the characteristics and demography of stakeholders relevant to passive building design in higher education institutions in Bauchi; and second, to determine the existing passive building design strategies being employed. These inquiries are critical to shaping a comprehensive, context-sensitive framework that enhances building performance while considering the socio-environmental landscape of the region. This study aims to contribute to the growing body of sustainable architecture literature in Sub-Saharan Africa by linking the human dimensions of energy use with technical passive design strategies in higher education facilities.

LITERATURE REVIEW

Energy Consumption in Educational Buildings

Educational buildings are notable for their high energy consumption due to the variety of activities carried out within them—lectures, research, administration, and residential use (Oyedepo et al., 2015). In Nigeria, institutions often operate aging infrastructure that was not designed with sustainability in mind, leading to inefficient thermal performance and increased reliance on artificial cooling (Šálek *et al*., 2017). Studies have consistently shown that buildings in hot-dry regions suffer from excessive solar heat gain, lack of cross ventilation, and minimal user-responsive design (Kandar et al., 2019).

Globally, strategies to reduce energy use in educational institutions involve both technical interventions (e.g., insulation, glazing, HVAC optimization) and behavioral adjustments (e.g., user awareness, occupancy patterns). However, in Sub-Saharan Africa, the latter is often under-researched due to a lack of detailed stakeholder profiling (du Plessis, 2002; Hossain, 2019).

Stakeholder Influence in Building Performance

The occupants' behavior and demographic composition significantly influence a building's energy profile. As noted by van der Linden et al. (2006), occupants can increase or reduce energy demand depending on their habits, schedules, and comfort expectations. In higher institutions, this includes not only students and lecturers but also administrative staff, facility managers, and maintenance teams. Moreover, the lack of consultation with users during design phases often results in mismatches between building performance and user needs. A study by Akadiri et al. (2012) emphasized the importance of integrating stakeholder feedback into retrofit frameworks to improve long-term performance and user satisfaction.

Passive Design Strategies in Hot-Dry Climates

Passive design is central to achieving low-energy buildings, especially in hot-dry regions where mechanical cooling is often unsustainable (Gustafsson, 2017). Techniques such as building orientation, shading devices, thermal mass usage, and natural ventilation are recognized for their ability to reduce internal heat gain and improve comfort (Latha et al., 2015; Moore et al., 2013).

In Bauchi's hot-dry climate, characterized by high daytime temperatures and significant diurnal variation, north–south orientation, deep overhangs, courtyard planning, and earth-tone materials have been proposed as ideal solutions (FMPWH, 2016). Yet, despite these insights, few Nigerian universities have adopted systematic passive strategies, largely due to a lack of policy enforcement and architectural capacity (Ley et al., 2015).

Theoretical Framework

This study adopts a bottom-up sustainability model, emphasizing localized knowledge and user involvement as key inputs into design solutions (Türkseven & Serin, 2015). The framework is grounded in the principles of:

i. Resource Economy (use less, waste less)

ii. Life Cycle Design (design, operation, reuse, recycle)

iii. Design for Humans (thermal, acoustic, and visual comfort)

The conceptual path integrates stakeholder feedback, building audit data, and climate-adaptive strategies to produce a decision-making guide tailored for energy retrofits and new constructions in higher education buildings in hot-dry climates (Akadiri et al., 2012). The rationale is to build a framework that is both climatically appropriate and socially acceptable, enhancing the feasibility of its adoption in public institutions.

Gaps in Literature

Across African building research, the bulk of energy efficiency work still privileges technical prescriptions like envelope tweaks, shading, ventilation rates, materials over the social profile of the people who commission, design, procure, operate, and occupy buildings. Multiple Nigerian studies demonstrate deep technical investigation of passive options, but with little coupling to stakeholder traits (role, knowledge, incentives) or to measurable outcomes in educational estates. For instance, Okafor et al. (2022) compare thermal conditions in traditional versus modern buildings in southeastern Nigeria to inform guidelines methodologically rigorous on performance, yet not designed to link outcomes to who makes or uses the buildings.

According to Akande (2010), systematic and scoping reviews likewise synthesize passive measures for Nigeria, roof albedo, shading, ventilation, material choices while explicitly calling out gaps on adoption dynamics and preferences, which are stakeholder driven variables rather than purely technical ones. Furthermore, Zomorodian et al., 2016 opines that in educational buildings specifically, comfort reviews emphasize thermal outcomes and classroom performance, but generally treat occupants as samples for field surveys rather than profiling stakeholder characteristics that shape passive design decisions like school managers' budgets, designers' training, regulatory incentives.

According to Ochedi and Taki (2022) explicitly argues for context-based frameworks rather than transplanting temperate standards, noting divergent climatic drivers, construction ecologies, and user practices. Ochedi & Taki's framework work is a prominent example which proposes a systematic Nigeria-specific approach grounded in local interviews and dwelling typologies, precisely because generic largely temperate models overlook local socio-cultural and economic conditions.

Where stakeholder issues are examined in Nigeria, they are often in residential contexts not educational. Adegoke et al. (2025) show that owners, property managers, and government actors differ in awareness of passive retrofit benefits important evidence that stakeholder characteristics modulate passive outcomes but the work stops short of linking these profiles to realized performance in schools or universities. Broader stakeholder engagement syntheses similarly argue that energy efficiency success hinges on interest, influence, and capacity, yet they are seldom operationalized in African educational building retrofits (Farid et al., 2024)

Okafor et al., (2022) empirical comfort studies similarly show that indigenous forms outperform or behave differently than modern, imported solutions, implying that standards calibrated in temperate regions misjudge comfort in warm-humid or hot-dry Nigerian zones. Local architectural culture and constraints matter. Classic and recent work on Bauchi and comparable hot-dry cities documents how courtyard morphology, orientation, and ventilation patterns deliver daylight and cooling aligned with privacy and social use benefits a temperate framework often ignores when they optimize for single-variable energy metrics (Wakawa and Alibaba, 2019). Mba et al., (2022) Study in Nigerian classrooms also show that orientation and natural-ventilation coefficients are under-specified in current practice and guidance, again underscoring the need for climate- and culture-specific prescriptions rather than one-size-fits-all imports.

While numerous studies underscore the technical aspects of energy efficiency, there remains a research gap in connecting stakeholder characteristics with passive design outcomes in African educational buildings. Most frameworks are imported from temperate climates and fail to address the socio-cultural and economic realities of regions like Bauchi.

Scope and Delimitation of the Study

This study is delimited to a focused analysis of five purposively selected academic buildings within two public higher education institutions in Bauchi Metropolis: Abubakar Tafawa Balewa University (ATBU) and Federal Polytechnic, Bauchi.

The building selection was based on the following specific criteria to ensure they are representative of key performance issues while maintaining research feasibility:

i. *Function*: Buildings must be primarily used for academic instruction (lecture theatres, classrooms,) to ensure functional consistency.

ii. *Typology*: Selected buildings represent the most common architectural typologies and construction eras found across the campuses.

iii. *Occupancy Intensity:* Buildings with high and predictable daily occupancy patterns were prioritized to critically assess thermal comfort and energy use under significant load.

iv. *Passive Design Features:* Buildings were chosen to include a mix of those with existing, though often deficient, passive strategies (e.g., cross-ventilation, Overhangs, horizontal/vertical shading devices) and those without, allowing for a comparative analysis.

This targeted approach does not aim to survey all buildings but to provide an in-depth, qualitative understanding of the interplay between stakeholder behavior and building performance in typical and high-impact academic structures, forming a robust foundation for developing a framework applicable to similar buildings across the region.

METHODOLOGY

Research Design

This study employed a mixed-methods research design that integrated quantitative and qualitative approaches to provide a holistic assessment of stakeholder characteristics, passive design strategies, and their relationship to energy efficiency in higher education buildings. Mixed-methods research allows for triangulation, which strengthens the validity of findings by capturing multiple perspectives from users, professionals, and the built environment (Creswell & Plano Clark, 2018).

Study Area

"Bauchi metropolis, located in the hot-dry climatic zone of North-Eastern Nigeria, serves as the study area. Characterized by high solar radiation, low humidity ranging from 19% to 43% (with the lowest levels occurring in February-March at 19-23%) and extreme diurnal temperature variations with highs reaching 39.2°C (102.6°F) in April and lows dropping to 13.9°C (57°F) in February, Bauchi represents a prototypical case for examining energy-efficient strategies in hot-dry environments (FMPWH, 2016).

To minimise the impact of time, finance and human resources, the study is limited to selected higher educational buildings in Bauchi, usually referred to as Bauchi State to distinguish it from the city of Bauchi. Figure 1 and 2 shows Bauchi state which consists of 20 local government area and is located in the North-eastern part of the Nigeria, Bauchi State covers 45,837 square kilometres. Bauchi State is bordered by seven States which include Kano and Jigawa to the north, Yobe and Gombe to the east, Kaduna State to the west, Plateau and Taraba State to the south. The entire western and northern parts of the state are generally mountainous and rocky. This is because of the closeness of the state to the Jos Plateau and Cameroun mountains.

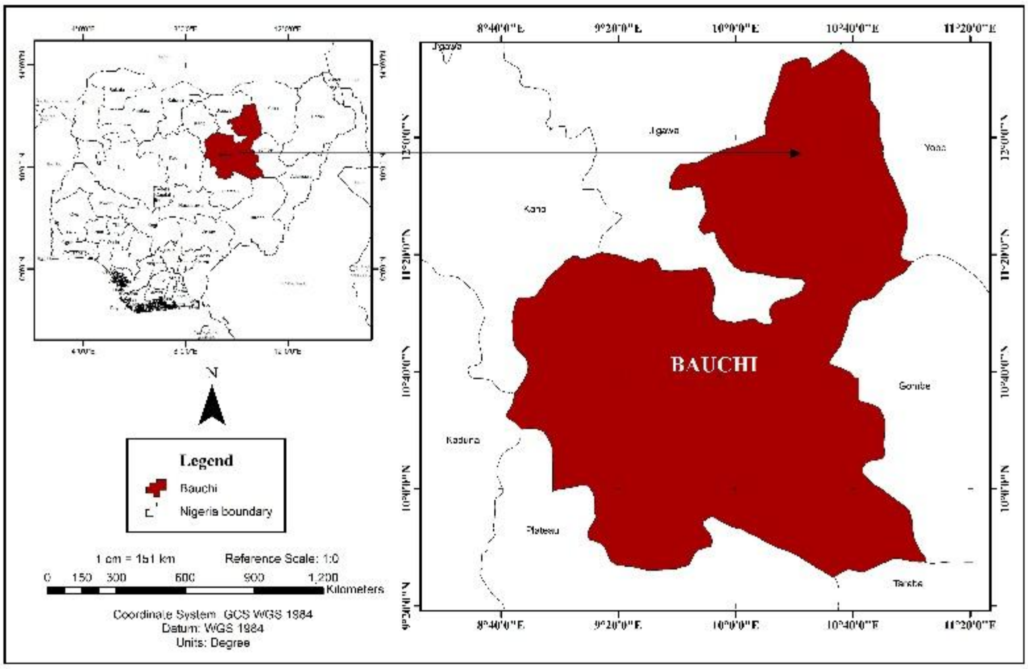

Figure 1: Map of Nigeria Showing Bauchi State and Study Area
Source: University of Jos GIS Laboratory (2023)

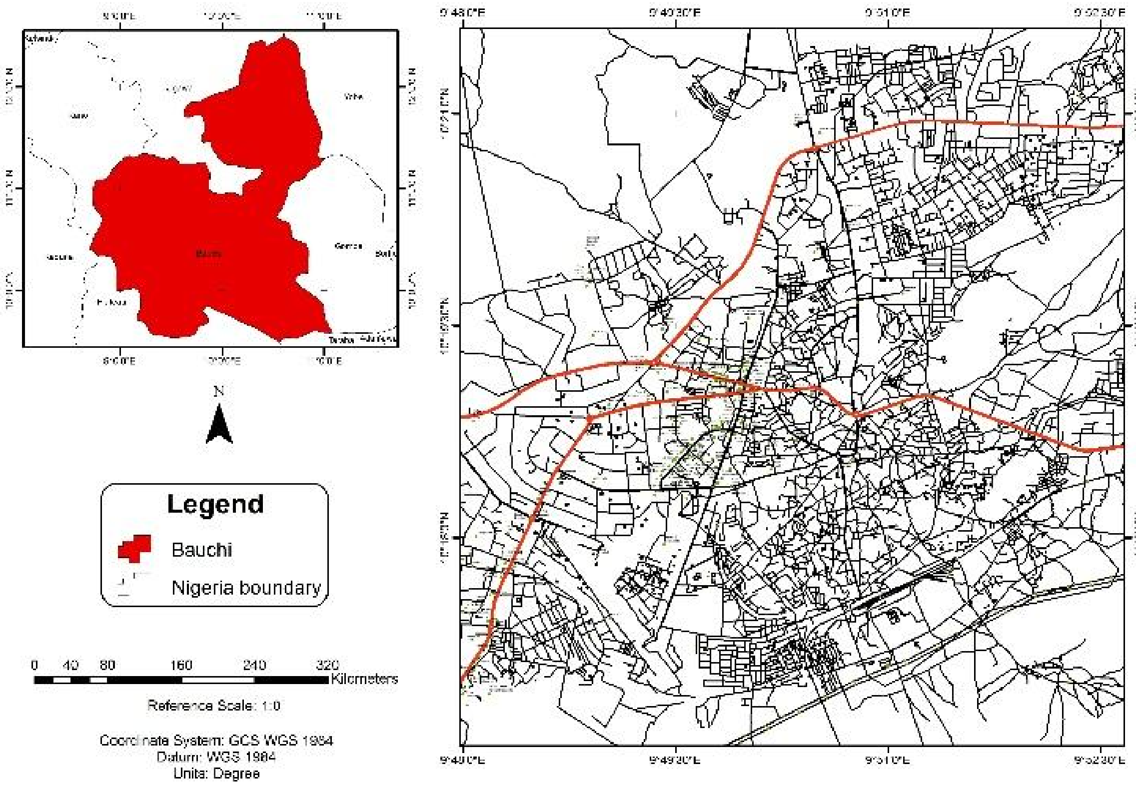

Figure 2: Map of Bauchi Showing Bauchi Metropolis
Source: University of Jos GIS Laboratory (2025).

Population of the Study

The study population includes the primary stakeholders of higher education buildings in Bauchi Metropolis, Nigeria, specifically students, academic staff, non-academic staff, and administrative personnel. All participants are drawn from Abubakar Tafawa Balewa University (ATBU) and Federal Polytechnic. The total population is estimated at approximately 45,000 individuals, drawn from enrollment and employment records as per the intuitions concerned

The study adopted a mixed-methods research design, combining quantitative surveys and qualitative interviews. The population was stratified by stakeholder type to ensure representation:

i. Students: 70% of the population (approximately 31,500).
ii. Academic staff: 15% (approximately 6,750).
iii. Non-academic staff: 10% (approximately 4,500).
iv. Administrative personnel: 5% (approximately 2,250).

A sample size of 398 respondents was calculated using Yamane's formula (n = N / (1 + N(e)^2), where N is the population size and e is the error margin of 0.05). Sampling was done through stratified random sampling to ensure proportionality. Data collection involved structured questionnaires for quantitative data on passive design preferences and semi-structured interviews for qualitative insights on energy efficiency challenges in hot-dry climates. Data analysis used SPSS for quantitative aspects (descriptive and inferential statistics) and thematic analysis for qualitative data.

Three populations were targeted:

i. *Stakeholder Users* – students, academic staff, and facility managers who directly occupy or manage educational buildings.

ii. *Key Informants* – architects, engineers, and works/maintenance officers involved in design, construction, or facility management.

iii. *Buildings* – high-capacity academic buildings with significant daily occupancy.

In this study, **s**takeholders were defined as individuals whose activities directly influence the performance of building envelopes, whether through usage patterns (students, staff) or operational control (facility managers).

Observed Building Deficiencies

A total of five higher-education buildings within Bauchi Local Government Area were purposively selected as case studies to represent common institutional typologies in the study area. This were selected as mentioned earlier based on criteria including: (i) floor area above 2,000 m², (ii) high daily occupancy (lecture halls, libraries, studios), and (iii) institutional significance. This approach ensured that findings addressed the most energy-intensive educational facilities.

Case Study Buildings:

i. *ATBU KLST*: A three-story One Thousand Seater reinforced concrete structure with a floor area of about 6,000 m² and an approximate height of 12 m. It functions as an administrative, Lecture theatre and meeting facility and is characterized by extensive glazing, limited shading, and heavy reliance on artificial cooling.

ii. *ATBU Urban and Regional Planning Buildin*g: A two-story structure of about 3,800 m² and 8.5 m in height. It accommodates lecture halls, laboratories, and offices, with an east–west orientation and courtyard elements that support natural ventilation, though it is heavily occupied by students.

iii. *ATBU Sambisa Lecture Theatre Complex*: A single-storey facility with an approximate floor area of 2,000 m² and a height of 6 m. Designed for large lectures and seminars, it is defined by wide-span halls with minimal shading, leading to high internal heat loads due to dense occupancy.

iv. *Federal Polytechnic Bauchi School of Environmental Technology Complex*: A two-storey academic block covering approximately 4,500 m² with a height of 9 m. Designed for lecture rooms, studios, and departmental offices, the building follows a long rectangular plan with cross-ventilation and verandah shading, though it remains susceptible to heat gain.

v. *Federal Polytechnic Bauchi Lecture Complex*: A two-storey building of about 3,500 m² and 9 m in height, serving as a lecture theatre. It features large windows with moderate shading devices, extensive use of artificial lighting, and heavy daytime utilization by students.

Collectively, these buildings illustrate the dominant reliance on reinforced concrete frames and block walls, with inconsistent passive cooling features. Their spatial configurations, envelope designs, and shading strategies provided the basis for evaluating thermal performance and stakeholder perceptions of passive design strategies in Bauchi's educational environment.

Data Collection Instruments

Data were collected using three complementary instruments:

i. *Questionnaires* – distributed to students, staff, and facility managers to gather information on demographics, energy-use awareness, and behavioral practices.

ii. *Semi-structured Interview*s – conducted with professionals to capture expert views on passive design adoption, barriers, and consultancy challenges.

iii. *Structured Observations* – building envelope audits using a standardized checklist covering orientation, shading, wall materials, ventilation, and glazing. Observations were carried out over a year so as to discern when thermal stress is most severe which fell between November-March.

To ensure the reliability and validity of the instruments, a pilot study was conducted on three non-selected academic buildings outside the core sample area, involving a sub-sample of 30 students and 5 staff members. Feedback from the pilot led to minor adjustments in the phrasing of the questionnaire and the structure of the interview guide. The Structured Observations were performed using a Building Audit Checklist developed based on ASHRAE 90.1 energy standards and passive design guidelines specifically tailored for hot-dry climates. This checklist quantified features like Window-to-Wall Ratios (WWR), Shading Factor, and cross-ventilation openings.

The observation period spanned the entire year to capture the full range of seasonal variation, but focused, intensive monitoring of thermal conditions (November–March) was justified by the climatic analysis in Section 3.2. This period represents the peak dry season in Bauchi, characterized by the lowest recorded humidity (19%–23%) and the highest diurnal temperature swings, confirming it as the period of most severe thermal stress on the building envelope. This strategic focus maximized the observation of occupant behavior and building performance under the most challenging climatic loads, making the data highly relevant to energy-efficient retrofitting strategies.

Data Analysis

The analysis followed a triangulated approach:

i. *Quantitative Data (Survey)*: Coded and analyzed using SPSS v25. Descriptive statistics (frequencies, means, and percentages) were used to profile stakeholder characteristics, while cross-tabulations and correlation analysis tested associations between building features and energy-use behaviors.

ii. *Qualitative Data (Interviews)*: Transcribed and thematically analyzed using NVivo 12, focusing on themes such as awareness, barriers, and perceptions of passive strategies (Braun & Clarke, 2006).

iii. *Observation Data*: Entered into a matrix and evaluated against benchmarks for passive design performance in hot-dry climates.

Linkage of Research Focus to Methods

To enhance clarity, Table 1 presents the alignment between focus, data sources, and collection methods.

Table 1: Focus – Methods Linkage

Research Focus	Data Source	Method of Data Collection
Examine stakeholder characteristics	Students, staff, facility managers	Questionnaire + Descriptive statistics
Assess building envelope design conditions	Case study buildings	Structured observation + Checklist matrix
Evaluate stakeholder awareness and behaviour	Students, staff, facility managers	Questionnaire + Correlation analysis
Identify barriers to passive design adoption	Key informants	Semi-structured interviews + Thematic analysis

RESULTS AND DISCUSSION

Stakeholder Characteristics

Survey results from about 398 respondents showed that students constituted the majority (60%), followed by academic staff (20%) and facility managers (20%). The gender distribution indicated male dominance across categories, particularly among academic staff (76% male) and facility managers (67% male). Most of the students age fall within the range 18 – 28 years, while the staff and managers age were within the range 30 – 60 year Educational levels ranged from tertiary (students) to postgraduate (staff) and professional certifications (managers).

The following table summarizes the demographic characteristics of the 398 respondents:

Table 2: Stakeholder Profile

Characteristic	Category	Frequency	Percentage (%)
Gender	Male	239	60.1
	Female	159	39.9
Age Group	18-24	250	62.8
	25-34	90	22.6
	35-44	40	10.1
	45+	18	4.5
Stakeholder Role	Student	279	70.1
	Academic Staff	60	15.1
	Non-Academic Staff	40	10.1
	Administrative	19	4.8
Years of Experience/Enrollment	Less than 2 years	200	50.3
	2-5 years	120	30.1
	More than 5 years	78	19.6

Mean age: 26.3 years (SD = 6.4). The data shows a predominance of young students, reflecting the typical composition of higher education populations in Bauchi. Most users spent an average of 7–10 hours daily in lecture halls, offices, and libraries. This suggests prolonged exposure to indoor conditions, reinforcing the importance of energy-efficient design for comfort. These findings align with studies highlighting the role of user demographics in shaping building energy performance (Akadiri et al., 2012; van der Linden et al., 2006).

Energy Use Behavior and Awareness

The study revealed significant gaps in energy awareness among stakeholders:

i. 71% of students were unaware of how building design affects energy use
ii. 58% of facility managers admitted to limited training in energy efficiency practices
iii. Only 23% of academic staff had participated in energy-related workshops or decision-making

This lack of awareness results in inefficient practices, including:

i. Leaving lights and fans on in unoccupied rooms
ii. Blocking cross ventilation paths with furniture
iii. Retrofitting windows with tinted, non-reflective glass that traps heat

Table 3: Stakeholder Roles in Building Performance

Stakeholder Group	Influence on Energy Use	Constraints Identified
Students	High usage but limited control	No training, no design involvement
Academic Staff	Moderate influence	Lack of awareness, low policy engagement
Facility Managers	High operational control	Inadequate funding, outdated maintenance tools

These results highlight a disconnect between passive design potential and everyday practices. Similar behavioral gaps have been reported in other African educational contexts, where low awareness reduces the effectiveness of design interventions (Adebayo, 2019). Facility managers were directly asked to identify key constraints affecting energy performance, with 'budget constraints' listed as a predefined option. This was further explored through open-ended questions regarding operational challenges.

Passive Design Deficiencies

These design flaws exacerbate internal temperatures, increase cooling loads, and diminish indoor air quality as seen in Table 4.

Table 4: Passive Design Deficiencies

Parameter	Observation
Orientation	Majority of buildings aligned E-W, maximizing solar exposure
Shading	Minimal use of overhangs or sun-breakers
Wall Materials	Use of concrete blocks without thermal mass layering
Ventilation	Poorly designed openings; many blocked by furniture or unshaded
Glazing	High solar gain from untreated glass; few had reflective coatings

Thematic Analysis Results

The thematic analysis revealed four key themes:

1. *Awareness of Passive Design Strategies;* Stakeholders (students, staff, facility managers) demonstrated partial awareness of features such as orientation, natural ventilation, and shading. While many users recognized the cooling role of cross-ventilation and trees, technical strategies like thermal massing and window-to-wall ratios were largely unfamiliar.

2. *Perceived Comfort and Building:* Use Respondents frequently reported discomfort linked to excessive indoor heat, poor air circulation, and glare in lecture spaces. Lecture halls and libraries, in particular, were perceived as thermally stressful during peak afternoon hours.

3. *Barriers to Effective Utilization:* Limited maintenance, inadequate retrofitting budgets, and overcrowding were cited as major barriers to realizing the benefits of passive features. Facility managers emphasized institutional constraints, while users highlighted inadequate shading and poor indoor air quality.

4. *Expectations for Improvement:* Stakeholders expressed a preference for improved shading devices, enhanced ventilation systems, and better building orientation in future projects. The expectation of context-sensitive solutions like reflecting the hot-dry Bauchi climate was clear.

Furthermore, this reflects a broader theme of institutional and socio-economic constraints undermining energy strategies in African educational facilities (Michael-Ahile *et al.,* 2014).

Correlation Analysis

Correlation analysis showed a moderate positive relationship between stakeholder awareness scores and observed energy-efficient practices ($r = .46$, $p < .05$). On the other hand, facility managers' training correlated negatively with reported constraints ($r = -.39$, $p < .05$), suggesting that capacity-building reduces operational challenges. These results reinforce that behavioral and institutional dimensions are as critical as design features for achieving energy efficiency (Chakraborty et al., 2022).

Stakeholder Perceptions on Passive Design

Interviews with building professionals in Bauchi revealed both enthusiasm and hesitation:

1. 87% agreed passive strategies were "highly beneficial" for comfort and energy savings
2. 61% cited lack of design knowledge and training as barriers to implementation
3. 76% of maintenance staff viewed shading and ventilation retrofits as "cost-effective and impactful"

There is a clear need to mainstream passive design in professional training curricula and encourage pilot demonstration projects within campuses.

Discussion: Bridging Design Intent and User Behavior

The analysis indicates a gap between the technical design intentions of passive features and their perceived effectiveness among users and managers. While passive design strategies exist in many of the studied buildings, their impact is diluted by poor implementation, overcrowding, and lack of stakeholder engagement in maintenance.

This supports the broader research gap highlighted in the literature: energy efficiency frameworks often overlook stakeholder characteristics and local socio-economic contexts, leading to outcomes that underperform in practice. In Bauchi, the mismatch between imported design assumptions and the realities of building use underlines the need for locally grounded frameworks that integrate stakeholder knowledge, climate conditions, and institutional constraints.

The data clearly show that energy inefficiency in Bauchi's higher education buildings is not merely a design flaw; it is also a behavioral and managerial challenge. Most users lack awareness of how building features influence comfort and energy demand. This echoes the findings of van der Linden et al. (2006), who emphasized the behavioral dimension in building performance. Furthermore, facility managers who hold operational control report being under funded and undertrained, limiting their ability to retrofit or adapt existing spaces.

This disconnect between design intent and user behavior significantly undermines building performance. Any effective energy strategy must therefore incorporate stakeholder training and behavioral change campaigns, alongside architectural improvements.

Climate Responsiveness and Local Context

The climate-specific passive strategies discussed orientation, shading, thermal mass, and ventilation are well-documented in literature for hot-dry zones (Gustafsson, 2017; FMPWH, 2016). However, their uptake in Bauchi has been limited due to:

i. Lack of local design guidelines tailored to the region
ii. A construction culture focused on short-term cost rather than lifecycle performance
iii. Weak integration of climate-responsive design in architectural education

The findings reinforce that passive design must be repositioned from "optional" to "essential" in academic infrastructure planning.

Toward an Integrated Framework

Based on the study's results, a localized framework for energy-efficient educational buildings in Bauchi should combine:

i. Stakeholder engagement and training
ii. Climate-responsive passive design templates
iii. Low-cost retrofit guidelines
iv. Policy advocacy to embed passive strategies in building codes

This aligns with the "Design for Humans" principle in Türkseven & Serin's (2015) framework and can guide public universities in transitioning toward low-energy, high-comfort environments.

Perceptions of Passive Design Strategies

Key strategies and their mean scores are summarized below in Table 5:

Table 5: Passive Design Deficiencies

Passive Design Strategy	Mean Score	SD	Percentage Agree/Strongly Agree (%)
Natural Ventilation (e.g., cross-ventilation)	4.2	0.8	78.4
Thermal Insulation	3.9	1.0	65.3
Shading Devices (e.g., overhangs)	4.5	0.7	85.2
Orientation for Solar Gain Control	4.0	0.9	70.1
Green Roofs/Walls	3.7	1.1	58.8

Overall, 82% of respondents reported dissatisfaction with current energy efficiency in their buildings, attributing it to poor passive design. Qualitative findings from interviews highlighted barriers like cost and lack of awareness, with themes such as "need for policy integration" appearing in 65% of responses.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study investigated the characteristics of building users and the application of passive design strategies in higher education buildings in Bauchi, Nigeria. The research revealed significant findings that highlight the complex relationship between building design, user behavior, and energy performance in hot-dry climates.

Key findings include:

i. *Stakeholder Awareness Gap*: Stakeholders, especially students and facility managers, have limited awareness of energy efficiency practices. This lack of knowledge contributes to inefficient building use and maintenance practices that undermine the potential benefits of passive design strategies.

ii. *Design Implementation Failures*: Existing buildings fail to apply basic passive design principles, leading to thermal discomfort and unnecessary energy consumption. The majority of buildings exhibit poor orientation, inadequate shading, and inefficient ventilation systems.

iii. *Climate-Appropriate Solutions:* Passive strategies such as optimized orientation, shading, ventilation, and thermal mass are highly applicable and cost-effective for Bauchi's hot-dry climate. These strategies can significantly reduce cooling loads and improve thermal comfort when properly implemented.

iv. *Integrated Approach Necessity*: Improving energy performance requires a dual focus on design and behavior. Without user engagement, even the best architectural strategies can fail. Likewise, without design intervention, user behavior has limited impact on overall building performance.

The study demonstrates that energy inefficiency in educational buildings is not solely a technical problem but a multifaceted challenge requiring coordinated solutions that address design, behavior, and institutional capacity simultaneously.

Recommendations

Based on the findings, the following recommendations are proposed for different stakeholder groups:

For Architects and Design Professionals:

i. *Early Integration*: Integrate passive design strategies into the early planning phase of all educational building projects

ii. *Simulation Tools*: Use simulation tools (e.g., DesignBuilder, EnergyPlus) to predict thermal performance and validate design decisions

iii. *Material Selection*: Prioritize materials with high thermal mass and low embodied energy appropriate for hot-dry climates

iv. *Climate-Responsive Design*: Develop expertise in climate-specific design solutions tailored to the Bauchi region

For Policy Makers and Institutions:

i. *Design Guidelines*: Develop localized design codes and guidelines specifically for hot-dry climates in Nigeria

ii. *Procurement Requirements:* Mandate climate-responsive design in public procurement processes for educational buildings

iii. *Funding Incentives:* Provide funding incentives for retrofitting projects that improve shading, ventilation, and thermal performance

iv. *Regulatory Framework:* Establish building performance standards that prioritize passive design strategies in public buildings

For Facility Managers and Building Operators:

i. *Performance Monitoring:* Conduct regular energy audits and thermal comfort assessments to identify improvement opportunities

ii. *Training Programs:* Implement comprehensive training programs for staff and students in energy-conscious behavior, including proper use of lighting, ventilation, and equipment

iii. *Pilot Projects:* Initiate pilot projects for low-cost retrofits and systematically monitor their outcomes to demonstrate feasibility and benefits

iv. *Maintenance Protocols:* Develop proactive maintenance schedules that preserve and optimize passive design features

For Academia and Researchers:

i. *Curriculum Development:* Incorporate passive design training and climate-responsive architecture into architectural and engineering curricula

ii. *Longitudinal Studies:* Conduct long-term studies to assess the sustained impact of passive retrofits in learning spaces and their effects on occupant comfort and energy consumption

iii. *Knowledge Transfer:* Establish partnerships between universities and industry to facilitate knowledge transfer and practical application of research findings

iv. *Local Research:* Prioritize research that addresses local climate conditions, materials, and construction practices specific to Nigeria's educational sector

Strategic Implementation Framework

To ensure effective implementation of these recommendations, a coordinated approach should be adopted that includes:

i. *Stakeholder Engagement:* Regular consultation with all user groups to ensure solutions meet actual needs and constraints

ii. *Capacity Building:* Systematic training and education programs for all stakeholders involved in building design, construction, and operation

iii. *Financial Planning:* Development of sustainable financing mechanisms for both new construction and retrofit projects

iv. *Performance Monitoring:* Establishment of metrics and monitoring systems to track the effectiveness of implemented strategies

v. *Knowledge Sharing:* Creation of platforms for sharing best practices and lessons learned across institutions

The transition toward energy-efficient, climate-responsive educational buildings in Bauchi requires sustained commitment from all stakeholders and recognition that successful outcomes depend on integrating technical solutions with human-centered approaches to building design and operation.

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