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Strategy for Energy Efficiency Utilization in Public Buildings in Nigeria-A Critical Review

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ABSTRACT

Energy efficiency in public buildings constitutes a vital and mostly unexploited opportunity to substantially decrease operating expenses, alleviate environmental repercussions, and improve indoor comfort and productivity for inhabitants in Nigeria. Achieving substantial and sustained reductions in energy consumption requires a comprehensive and integrated approach that begins at the architectural design stage, extends through the retrofitting and upgrading of existing building stock, and is reinforced by continuous energy auditing, monitoring, and management throughout the building life cycle. Although national policy frameworks such as the Nigeria Building Energy Efficiency Code (BEEC) have been established to promote efficient energy use, their practical adoption and enforcement within public infrastructure remain limited and inconsistent. This review synthesizes recent empirical findings and policy-oriented studies to critically assess the current state of energy efficiency in Nigeria's public buildings, examining prevailing strategies, implementation gaps, institutional barriers, and emerging opportunities. Particular emphasis is placed on the roles of bioclimatic design principles, renewable energy integration, systematic energy auditing, and administrative and regulatory challenges, as well as the associated economic and environmental implications. Ultimately, the review identifies practical and policy-driven pathways for accelerating the widespread adoption of effective energy-efficient building practices across Nigeria's public sector.

Keywords: Strategy, Energy Efficiency, Utilization, Public Buildings, Nigeria, Architectural Design

Aims Research Journal Reference Format:
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1. INTRODUCTION

Public buildings in Nigeria, including administrative offices, schools, hospitals, and government-owned facilities, consume a substantial share of institutional energy due to high electrical loads, frequent use of air-conditioning equipment, lighting systems and reliance on backup power generators (Abu *et al,* 2021). Energy inefficiency raises operational costs and increases greenhouse gas emissions, posing challenges to sustainable development and climate resilience (Wei Chen *et al*, 2024). Understanding energy efficiency strategies within these buildings is essential for addressing national energy challenges. The study shows how bioclimatic tools and climate analysis directly influence architectural form and design strategies to suit specific climate conditions. These approaches are particularly relevant for public buildings in hot climates, where cooling constitutes a major portion of energy use. This review synthesizes recent research and policy insights into the status, challenges and prospects for energy efficiency in Nigeria's public buildings.

1.1 Building Energy Consumption Patterns and Inefficiency
Nigeria's electricity sector exemplifies inefficiency on a national scale. Chronic under-generation, obsolete transmission infrastructure, frequent load shedding, and unreliable distribution are the critical factors that keep the grid supplies far below required levels. These factors compelled many households, public buildings, and firms to rely on petrol/diesel generators, resulting in higher economic and environmental costs. The inability to translate generation capacity into delivered energy illustrates inefficiency stemming from both infrastructure and governance constraints (Ekong *et al,* 2021). Studies have consistently shown that many public buildings in Nigeria exhibit inefficient energy use patterns. A qualitative assessment of public-school buildings in Lagos observed heavy reliance on grid electricity and diesel generators due to frequent outages, with limited incorporation of renewable or efficiency-oriented technologies in retrofits (Isidore *et al*, 2022). Research focusing broadly on building energy performance in Nigeria highlights that factors such as poor envelope integrity, lack of insulation, and inefficient HVAC (heating, ventilation and air conditioning) systems significantly contribute to higher energy usage. While many academic studies focus on residential or mixed-use buildings, their findings are relevant for public buildings due to shared design and climatic challenges.

The Nigerian Building Energy Efficiency Code (BEEC) was established to provide minimum energy performance requirements for new construction and renovations. The BEEC prescribes bioclimatic design principles and compliance pathways such as prescriptive and performance approaches, intended to reduce energy consumption through optimized building orientation, envelope design and climate-responsive measures. However, enforcement remains limited, and actual compliance varies significantly. Although BEEC provides a critical regulatory foundation, research consistently shows that adoption and enforcement are weak, and public buildings often fail to meet even basic efficiency standards due to institutional, economic, and technical barriers (FMPW&H, 2017).

2. DESIGN AND TECHNOLOGICAL STRATEGIES FOR ENERGY EFFICIENCY

Energy efficiency seeks to maximize useful output per unit of energy input—reducing consumption without sacrificing service levels. Effective strategies are inherently multi-layered, combining design principles, advanced technologies, and management systems to reduce demand and improve performance across sectors. In buildings, for example, passive design forms a first line of defense by reducing inherent loads through climatic and architectural responses, significantly lowering energy requirements before technology is applied (Jorgensen *et al,* 2025).

2.1 Bioclimatic and Sustainable Architectural Design
Recent studies highlight bioclimatic design principles that adapt building form and materials to local climate conditions (Francisco *et al*, 2015). It is a highly effective method for reducing energy demand in tropical regions like Nigeria. Features such as solar shading, controlled window-to-wall ratios, and optimized ventilation reduce cooling loads and electric consumption (Adedayo *et al*, 2013). Designing for optimum thermal comfort using bioclimate simulation and analysis as an urban architectural design and educational support tool was carried out by Bouthaina *et. al.,* (2022). Other sustainable Bioclimatic architectural designs are:

i. **Passive Architectural Design Strategies:** Passive design measures focus on minimizing loads through building form, orientation, shading, natural ventilation, and daylighting, thereby reducing heating, cooling, and lighting energy. Such strategies harness environmental forces instead of relying on mechanical systems. Integrated passive strategies can yield 20–40% reductions in thermal loads and high reductions in lighting demands when combined with high-performance envelopes and shading devices (Jorgensen *et al,* 2025). Traditional passive measures—e.g., thermal mass and orientation—remain central to green building performance (Ifechukwu *et al,* 2022).

ii. **Early Design Phase Approaches:** Research highlights that the early stages of architectural design present the greatest opportunities for energy efficiency gains, with energy performance simulation tools enabling informed decisions unconstrained by later design commitments (Aviruch *et al,* 2024). By simulating thermal comfort and consumption patterns early on, architects and engineers can optimize design parameters (e.g., solar orientation, envelope properties, daylighting) before construction begins.

3. ACTIVE TECHNOLOGIES ADVANCED PERFORMANCE SMART BUILDING SYSTEMS .

Emerging research suggests that smart building technologies, including energy management systems (EMS), automated HVAC, and efficient lighting controls, can enhance operational efficiency in buildings. Advanced HVAC systems, energy-efficient lighting and renewable energy technologies (especially solar photovoltaic arrays) are frequently recommended in the literature to enhance performance. Blending renewable energy technologies, such as photovoltaic (PV) panels, with conventional systems provides on-site generation that can partially or wholly supplant grid energy, therefore boosting energy efficiency by reducing net consumption (Jorgensen *et al,* 2025*).* Integration of these technologies in public buildings can lower energy costs, improve reliability (especially in off-grid scenarios) and reduce dependency on diesel generators. Such integration is especially effective in net-zero energy building designs where renewable generation meets or exceeds total operational consumption.

Smart control systems can further optimize these systems, responding dynamically to real-time conditions and habit patterns to avoid waste. While specific case studies on Nigerian public buildings are limited, related research in the country's building sector demonstrates that implementing smart systems yields measurable energy savings, operational cost reductions, and improved comfort (Baalah *et al*, 2024). Figure 1 gives the strategic hierarchy for efficient energy utilization in public buildings.

3.1 Retrofit and Optimization Strategies:

Candi *et al.* (2024) observed that retrofitting existing infrastructure is essential since new construction alone cannot meet global efficiency goals. A comprehensive review shows that key retrofit strategies include:

a) Improving envelope insulation (adding insulation to walls/roof, window upgrades- double/ triple low energy glazing, which directly reduces heat gains/losses,
b) Cool roofs and shading systems to reduce heat gain in a hot climate,
c) Upgrading HVAC and lighting systems, and
d) Integrating renewable sources where possible

Retrofitting deployed globally has demonstrated significant reductions in energy use and environmental impact, particularly in commercial and institutional buildings. However, retrofit programmes are affected by complex dynamic processes. The interactions between various influencing factors indicate that even small changes can have a significant effect. As the age of existing buildings increases, energy consumption intensifies, forcing the expansion of the scale of building energy-saving renovation, as well as the enhancement of energy-saving awareness of the residents who are willing to invest in residential building energy consumption problems, and then enterprises in the energy-saving projects are involved in the process of economic benefits of recovery. Invariably, the market subsystem feedback loop indicates: Enterprises' willingness to develop (+) → market demand and supply (+) → scale of renovation (+) → economic returns (+) → owners' awareness of energy conservation (+) → enterprises' willingness to develop, as shown in Figure 2 (Siqi *et al,* 2025).

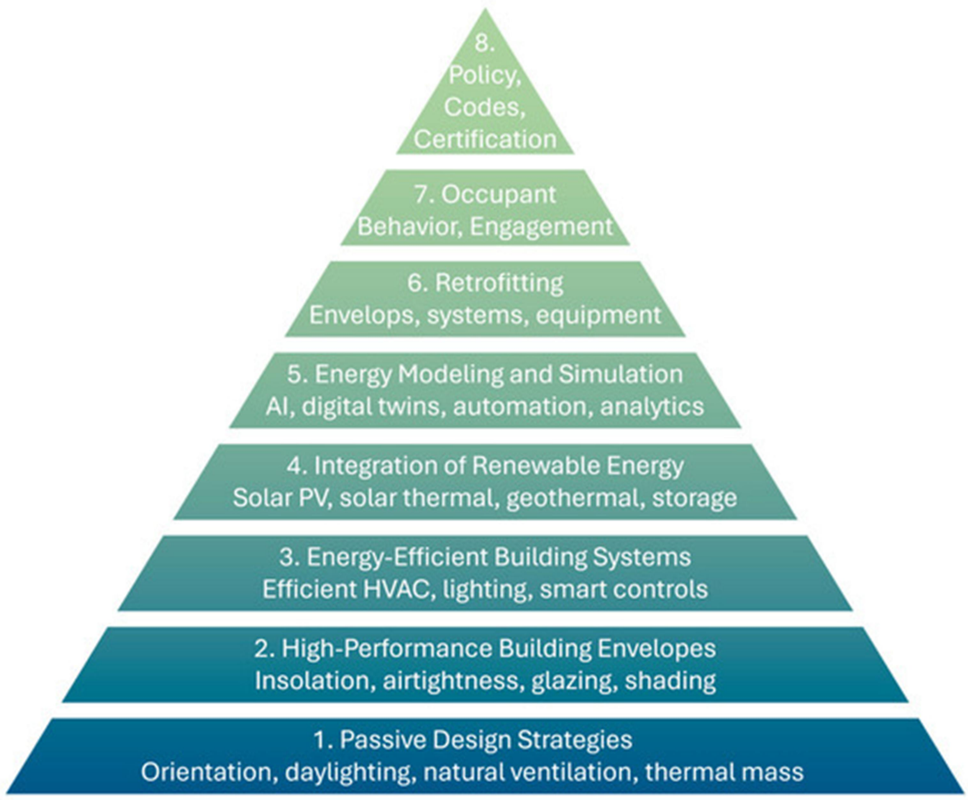

Figure 1: Strategic Hierarchy for Efficient Energy Utilization in Public Buildings
Source: Jorgensen et al, 2025

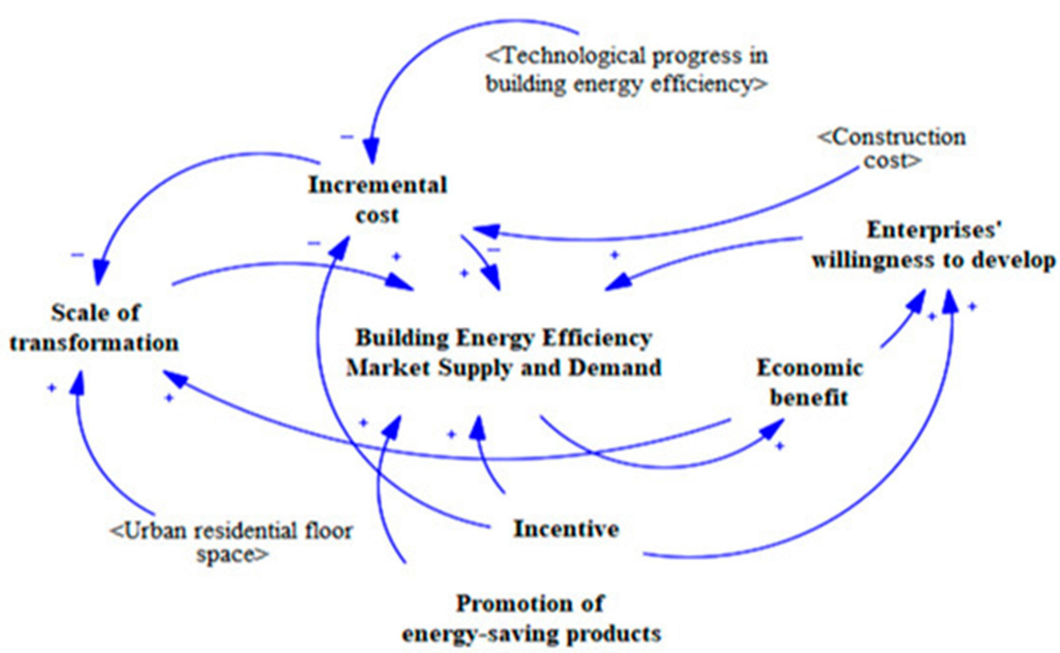

Figure 2: Market subsystem feedback loop
Source: Siqi *et al,* 2025

3.2 Economic and Environmental Benefits

Energy efficiency plays a crucial role in environmental performance. A 2025 empirical time-series study found that increasing energy efficiency significantly reduces CO_2 emissions in Nigeria in both the short and long run, validating its role in climate mitigation strategies. For example, studies in Rivers State found that implementing energy efficiency strategies reduces energy costs, increases productivity and decreases greenhouse gas emissions. However, these studies also note that current energy use patterns remain unsustainable due to high fossil fuel dependence and slow technology uptake (Nathan Udoinyang 2025).

3.3 Annual Audit and Continuous Performance Assurance

Energy Audits are systematic ways and means of uncovering inefficiencies and defining retrofit priorities. Audit types and methodologies include:

i. Preliminary audits or target quick wins with minimal measurement,
ii. Comprehensive audits involve sub-metering system diagnostics and modelling, and
iii. Investment-grade Audits support financial and retrofit decision-making with Return on Investment (ROI) analysis.

Advanced methodologies now integrate Building Energy Management System (BEMS) data with analytic tools to produce granular temporal profiles and performance benchmarks for year-round improvement. The outcomes of energy audits enable identification of energy- intensive systems and inform prioritized retrofit measures. Audit results in real building studies have led to substantial electrical energy savings, emission reduction, and financial returns. Annual audit cycles should be used not only to verify compliance but also to adapt to occupant behaviour changes, evolving use patterns and equipment ageing (Figure 3).

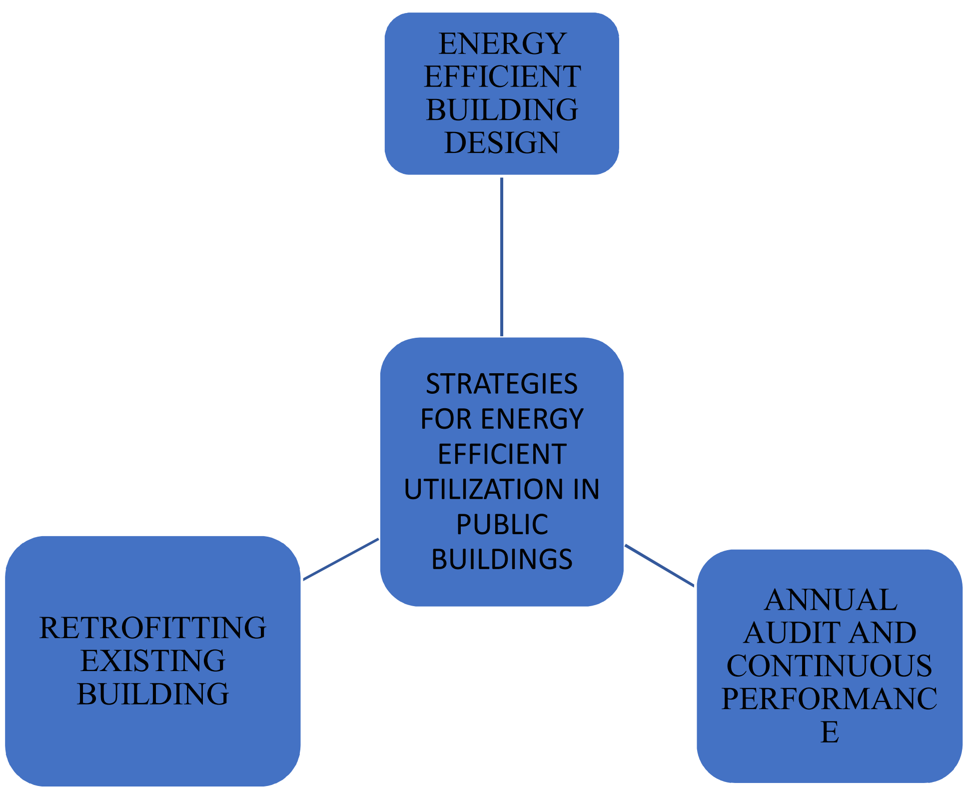

Figure 3: Strategies for Efficient Energy Utilization in Public Buildings

Integrated frameworks of design-retrofit-audit loop begin with low energy demand design, continue through evidence-based retrofit and are finally sustained by regular audits to maximize efficiency gains. Evidence shows substantial potential for operational energy reductions, emission mitigation, occupant comfort improvements and favorable economic payback when these strategies are deployed coherently across building lifecycles.

4. MANAGERIAL AND INSTITUTIONAL BARRIERS

Nathan Udoinyang (2025) observed a strong theme across recent research in the persistence of barriers that constrain energy efficiency adoption in public buildings:

i. **Technical and Institutional Gaps:** Research shows low enforcement of energy codes and insufficient technical capacity to implement efficiency protocols in public projects. Many professionals lack training in design and compliance with energy-focused standards.
ii. **High Upfront Costs and Financing Constraints**: Energy-efficient systems often require higher initial expenditures, deterring adoption in budget-constrained public sectors
iii. **Low Awareness and Weak Policy Enforcement**: Despite the existence of BEEC, actual adoption of energy-efficient design elements remains low due to limited awareness, weak regulatory enforcement, and a lack of incentives for public building owners.
iv. **Economic, regulatory and socio-institutional obstacles:** These barriers align with broader findings in the Nigerian built environment literature that point to economic, regulatory and socio-institutional obstacles hindering sustainable architecture adoption.

5. OPPORTUNITIES AND FUTURE DIRECTIONS

Addressing energy efficiency in public buildings requires integrated strategies that combine design innovation, policy enforcement, financing mechanisms and capacity building:

i. **Strengthening BEEC Implementation**: Enhancing regulatory enforcement and expanding mandatory compliance measures will provide clearer standards for public buildings (Irene *et al*, 2023).
ii. **Technological Innovation:** Combining passive measures with active systems and digital management tools to achieve adaptive optimization (Mert *et al,* 2024).
iii. **Integrated Design Thinking:** Aligning architecture, system engineering and energy performance analysis from the onset(Jorgensen *et al,* 2025) .
iv. **Capacity Building and Professional Training**: Training architects, engineers, and facilities managers on energy-efficient design and operations will help mainstream best practices.
v. **Fiscal Incentives and Green Financing:** Offering incentives, tax relief, and access to affordable financing can lower barriers to adopting energy-efficient technologies (Okezie *et al,* 2025).
vi. **Renewable Integration**: Promoting hybrid systems combining solar and efficiency improvements can mitigate reliance on unreliable grid power and reduce operating costs (Aisha Tokunbo Ajia, 2025)
vii. **Digitalization and Reporting**: Capturing of energy data digitally, as well as the use of software (**AI-based Prediction and Optimization Models**) for monitoring and targeting real-time energy usage, will assist energy auditors to guide retrofit decisions under data constraints during the auditing process (Parisa *et al,* 2022).

6. CONCLUSION

Energy efficiency in Nigerian public buildings is a significantly underutilised yet strategically essential tool in the country's overarching goals of sustainable development, climate resilience, and long-term energy security. Although the Nigerian Building Energy Efficiency Code establishes an important policy and regulatory foundation for improving building performance, its impact has so far been constrained by persistent institutional weaknesses, limited technical capacity, inadequate financing mechanisms, and weak enforcement structures. Evidence from empirical studies clearly demonstrates the substantial economic, environmental, and social benefits achievable through the adoption of bioclimatic design principles, high-performance building systems, systematic energy auditing, and the integration of renewable energy technologies. However, translating this potential into widespread practice requires more than policy statements; it demands strengthened regulatory enforcement, targeted capacity building, increased stakeholder awareness, and the deployment of innovative and accessible financing instruments.

By strategically addressing these interrelated barriers through coordinated multi-sector collaboration and continuous policy refinement, Nigeria can accelerate the transition toward an energy-efficient public building stock that delivers enduring economic savings, reduces environmental impacts, and improves occupant comfort and productivity. This review therefore emphasizes the urgent need for a harmonized and sustained commitment among government institutions, built-environment professionals, energy managers, and development partners to mainstream energy efficiency into public infrastructure planning, delivery, and operation. Such a coordinated approach is essential for unlocking the full potential of energy efficiency as a cornerstone of Nigeria's sustainable development and energy transition agenda.

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