International Journal of
Climatic Studies
(IJCS)

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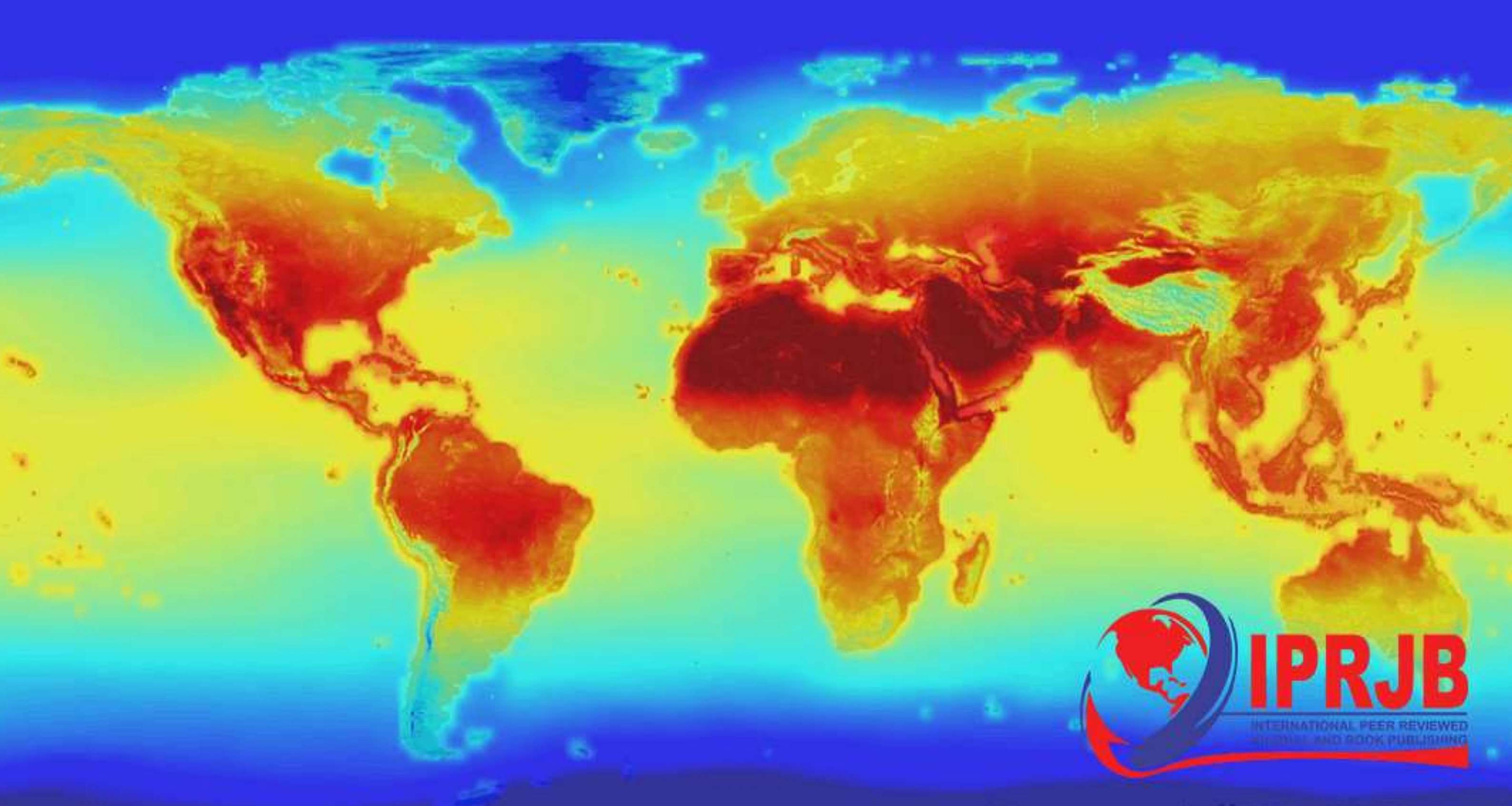

International Journal of Climatic Studies
ISSN: 2710-1061 (Online)
Vol.4, Issue 1, No.1, pp 1- 17, 2025

www.iprjb.org

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Article History

Received 15th December 2024

Received in Revised Form 19th January 2025

Accepted 28th February 2025

How to cite in APA format:

Erifeta, K. E. (2025). Sustainable Building Decarbonization in Nigeria: Challenges, Opportunities, and Policy Recommendations. *International Journal of Climatic Studies*, *4*(1), 1–17. https://doi.org/10.47604/ijcs.3249

Abstract

Purpose: This study evaluates sustainable building decarbonization in Nigeria, focusing on the challenges and opportunities in reducing carbon emissions within the construction sector. It aims to identify policy gaps and recommend strategies for effective implementation.

Methodology: A systematic literature review (SLR) was employed to analyze 80 peer-reviewed articles, government reports, and conference proceedings published between 2014 and 2025. This methodology comprehensively synthesizes existing research, identifying trends, barriers, and successful case studies in sustainable building practices.

Findings: The review revealed critical barriers to decarbonization, including high initial costs, inadequate building code enforcement, and limited public awareness. Successful policies in other Sub-Saharan countries, such as Ghana and South Africa, highlight the importance of integrated approaches and financial incentives. Key themes included the need for improved energy efficiency, integration of renewable energy, and sustainable construction materials.

Unique Contribution to Theory, Practice and Policy: Nigeria must strengthen regulatory frameworks, enhance financial incentives, and promote public awareness to achieve sustainable building decarbonization. A multi-stakeholder approach involving government, private developers, and research institutions is essential for overcoming existing barriers. By learning from global best practices, Nigeria can transition to a low-carbon built environment, contributing to broader climate goals and sustainable urban development.

Keywords: *Sustainable Buildings, Decarbonization, Renewable Energy, Energy Efficiency, Climate Resilience, Green Infrastructure*

JEL Codes of Classification: *Q52, Q54, Q42, Q48, Q54, Q58*

INTRODUCTION

Buildings contribute approximately 40% of global energy consumption and nearly one-third of greenhouse gas emissions (Osuizugbo et al., 2024). In rapidly urbanizing regions and Cities in Nigeria, the demand for residential and commercial buildings continues to rise, leading to increased carbon emissions from construction activities, material production, and energy consumption (Atedhor, G. O. (2023). Urbanization has exacerbated environmental concerns, including deforestation, increased energy demand, and inefficient waste management. These issues highlight the urgent need for sustainable building practices and policy interventions aimed at decarbonization (Abdulsalam et al, 2024).

Decarbonization refers to strategies to reduce or eliminate carbon dioxide emissions throughout the building life cycle (Akomolafe, 2023). This includes improving energy efficiency, utilizing renewable energy sources, adopting low-carbon construction materials, and enforcing green building codes (Akomolafe, et al., 2024). While global efforts have driven significant progress in sustainable architecture, Nigeria lags due to economic, regulatory, and infrastructural challenges (Onabowale, O. (2024). The lack of a cohesive national framework for sustainable construction has resulted in continued reliance on carbon-intensive practices (Barbhuiya et al, 2024). Nigeria's policy landscape for net-zero carbon buildings is highly fragmented and lacks a cohesive, overarching strategy. While various policies include provisions relevant to net-zero carbon buildings, they remain disjointed and insufficiently integrated to drive large-scale adoption. For instance, the 2017 National Building Energy Efficiency Code (BEEC) establishes minimum efficiency standards for new buildings, while the 2021 National Climate Change Policy provides guidance on retrofitting existing structures for improved energy efficiency. However, these policies function in isolation, limiting their collective impact. A review of Nigeria's 16 active policy instruments reveals that most are still in their nascent stages, implemented only on a small scale or as pilot projects. Specific gaps include: The 2021 National Environmental (Air Quality Control) Regulation prohibits the import and use of high-emission materials, and there is a federal ban on small electricity generators. However, enforcement mechanisms remain weak. Early-stage efforts on energy efficiency and embodied carbon codes exist through the BEEC, but state and local governments (LGAs) lack the necessary regulatory frameworks to support effective implementation. International organizations provide training for professionals in the built environment sector, yet LGAs lack funding to scale up these training programs and integrate them into national capacity-building efforts (Pedro de Aragão Fernandes,2023).

Addressing these challenges requires a multi-sectoral approach involving government agencies, private developers, and research institutions (Ohene, 2024). Effective policy frameworks, financial incentives, and advancements in green construction technology are necessary to facilitate a transition towards sustainable buildings (Mohammed et al., 2023). Collaboration among stakeholders is key to overcoming financial and regulatory barriers that have hindered progress in Nigeria and Sub-Saharan Africa (Iyamu et al, 2023). This review comprehensively evaluates sustainable building decarbonization in Nigeria and the broader Sub-Saharan African context (Nwankwo, 2024). It examines existing policies, technological advancements, and persistent barriers to implementation (Adebayo, 2023). The study highlights global best practices by integrating insights from 80 peer-reviewed sources and identifies pathways for Nigeria's transition to a low-carbon built environment (Balogun & Okafor, 2023). The findings will support policymakers, urban planners, and industry stakeholders in designing effective strategies for sustainable urban development (Mohammed et al., 2023). Encouraging investment in renewable energy, enforcing stricter building codes, and implementing financial incentives will be critical in achieving long-term sustainability in Nigeria's construction industry (Oguntuase & Windapo, 2021).

Problem Statement

Nigeria's construction sector significantly contributes to energy consumption and greenhouse gas emissions, exacerbated by rapid urbanization and unsustainable building practices. Despite existing energy efficiency policies, fragmented regulations, high costs of sustainable materials, weak enforcement, and low public awareness hinder the transition to low-carbon buildings. Addressing these challenges requires coordinated efforts among government, private developers, and research institutions to establish cohesive policies, financial incentives, and technological innovations for sustainable development.

METHODOLOGY

This study employs a systematic literature review methodology to analyze current trends, policies, and technological advancements in building decarbonization (Mohammed et al., 2023). Systematic literature review (SLR) methodology is a structured approach to reviewing existing research in a rigorous and replicable manner. The foundation of SLR can be traced back to the field of evidence-based medicine, with its roots in the work of Archibald Cochrane in the 1970s. Cochrane (1972) emphasized the need for systematic reviews in medical research to synthesize evidence effectively. Systematic Literature Review (SLR) allows for the exhaustive collection and synthesis of relevant literature, ensuring that all aspects of sustainable building decarbonization are considered. This methodology follows a well-defined protocol that ensures transparency and provides process clarity for researchers (Tranfield et al, 2003). It adopts a structured search strategy of inclusion/exclusion criteria, minimizing selection and publication biases, thereby enhancing the credibility of findings (Petticrew & Roberts, 2006).

Nigeria's sustainable building sector requires an in-depth synthesis of research that addresses local challenges such as policy gaps, economic constraints, and climate conditions, which SLR can systematically address (Abam et al., 2023). Kitchenham (2004) asserts that SLR is superior to traditional literature reviews because it provides a structured approach to identifying, analyzing, and synthesizing relevant studies, essential in emerging fields like sustainable decarbonization. (Moher et al. (2009) argue that SLR enhances research quality by reducing bias and ensuring that findings are based on a comprehensive and objective assessment of available studies. Siddaway et al. (2019) highlight the value of SLR in evidence-based policy-making, which is crucial for guiding sustainability strategies in developing nations like Nigeria. Despite its advantages, Greenhalgh et al (2018) argue that SLRs can be overly rigid and may exclude valuable qualitative insights that do not fit standardized inclusion criteria. Boell and Cecez-Kecmanovic (2015) contend that SLRs often emphasize quantity over quality, potentially overlooking seminal theoretical contributions that may not meet predefined methodological standards. However, SLR is considered and adopted for this review thinking that the policy gaps in Nigeria regarding building decarbonization, an SLR can provide comprehensive insights from global best practices and contextual adaptations. (Abam et al., 2023). SLR helps highlight existing gaps in the literature, which can inform future research on sustainable construction practices in Nigeria. This methodology comes in handy as it can integrate research with multiple fields such as architecture, engineering, and policy and is suitable for diverse perspectives inclusion (Abam et al., 2023)

The research is based on an extensive review of a minimum of 80 peer-reviewed journal articles, government reports, and conference proceedings published in high-impact journals. The selected sources cover diverse aspects of sustainable building practices, including energy efficiency, renewable energy, construction materials, and policy frameworks (Oyedepo, 2014). The literature search used databases such as Scopus, Web of Science, Google Scholar, and IEEE Xplore (Tomaszewski, 2021). Keywords such as 'sustainable building decarbonization,' 'green construction in Nigeria,' 'energy-efficient architecture,' and 'renewable energy integration in buildings' were used to refine search results. Only articles published within the last 11 years (2014–2025) were considered to ensure relevance to current policy and technological advancements. Focusing on articles for this period for a review on sustainable building decarbonization in Nigeria ensures relevance to evolving policies, technological advancements, and contemporary research. Recent policy shifts, such as Nigeria's National Climate Change Policy and Building Energy Efficiency Code, highlight the country's growing commitment to sustainability. Technological innovations in smart building systems, renewable energy, and low-carbon materials make older research less applicable. The increased research focus on climate change has led to valuable empirical studies addressing Nigeria's unique challenges, such as urbanization, high material costs, and weak regulations. By selecting recent literature, the review remains up-to-date, reflecting current realities and informing effective sustainability strategies. Data extraction focused on identifying major themes, recurring challenges, and successful case studies in green building development (Billanes et al, 2025). Qualitative synthesis was performed to compare global best practices with Nigeria's current state of sustainable construction. The results were analyzed to identify research gaps, policy recommendations, and potential areas for further study (Ohene, 2024).

The table below breaks down environmental impact factors in Nigeria's building construction sector based on contributions from the literature reviewed for this paper.

Table 1: Environmental Impact Factors in Nigeria's Building Construction Sector

Category	Percentage (%)	Key Findings
Energy Consumption	30%	Construction activities are energy-intensive, relying on diesel and coal.
Material Waste	20%	Significant material waste, especially concrete, timber, and metals.
GHG Emissions	25%	High emissions from material transport and on-site machinery.
Sustainable Practices	15%	Limited adoption of green building materials and renewable energy.
Regulatory Compliance	10%	Poor enforcement of environmental regulations.

Table 1 (Ohene, 2024).

Discussion

Energy Efficiency in Building Design

Energy efficiency in building design is a crucial strategy for achieving sustainability and reducing carbon emissions. Buildings contribute approximately 40% of global energy consumption and are responsible for a significant proportion of greenhouse gas emissions (Mohammed et al., 2023). The growing emphasis on green architecture and net-zero energy

International Journal of Climatic Studies
ISSN: 2710-1061 (Online)
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buildings highlights the need to integrate energy-efficient design principles at every construction and operation stage (Ofoezie et al, 2022). This review explores energy efficiency strategies, including passive and active design approaches, their implementation in Nigeria and Sub-Saharan Africa, as well as challenges and opportunities for scaling up adoption. Passive energy efficiency strategies leverage natural environmental conditions to optimize building energy performance (Okoh. & Okpanachi 2023). These techniques minimize reliance on mechanical heating and cooling systems, lowering operational energy costs (Izam et al., 2022).

Natural ventilation optimizes airflow through building orientation, window placement, and ventilated facades (Omoragbon, 2023). Studies have shown that buildings designed with cross-ventilation and stack effect cooling can reduce indoor temperatures by 5–10°C, lowering the need for air conditioning (Mpofu, 2022). In tropical climates such as Nigeria, proper orientation of buildings to capture prevailing winds can significantly enhance indoor comfort (Ogunrin, 2019). Another crucial aspect of passive design is thermal insulation. Insulating walls, roofs, and floors with high-performance materials, such as aerogels, reflective coatings, and green roofs, helps maintain indoor temperature stability (Sadineni, 2011).

In Nigeria, hydraform bricks and rammed earth have gained popularity due to their thermal mass properties, which reduce heat absorption and enhance cooling (Adegun & Adedeji, 2017). Active energy efficiency strategies involve the use of advanced technologies and systems to reduce energy consumption while improving indoor comfort (Lawal et al, 2024). These include energy-efficient HVAC systems, lighting automation, and smart grid integration. HVAC systems account for nearly 50% of a building's total energy consumption (Simpeh et al, 2022). The adoption of variable refrigerant flow (VRF) systems, heat recovery ventilators, and geothermal cooling has proven effective in reducing energy demand (Adebayo, 2023). Nigerian studies indicate that optimizing HVAC efficiency can lower energy consumption by 30% (Oyedepo, 2014). Smart energy management systems utilize IoT-based sensors and AI-driven automation to optimize electricity use (Olatunde et al, 2024). These systems can adjust lighting, cooling, and heating based on real-time occupancy data, significantly improving energy efficiency (Olatunde et al, 2024).

Studies in Sub-Saharan Africa highlight that smart automation can lead to 20–40% energy savings (John et al, 2019). Successful implementations of energy-efficient building designs across various regions include examples from Nigeria, such as the Nestoil Tower in Lagos, which showcases the potential for green architecture (Okonkwo & Agiriga, 2024). This Tower in Lagos exemplifies energy-efficient building design in Nigeria, integrating sustainable technologies that reduce its carbon footprint and serve as a model for similar initiatives nationwide. A key feature is its solar energy utilization, where installed solar panels decrease reliance on fossil fuels and lower operational costs, making it a viable solution for sun-rich regions (Nestoil Limited, 2023; Okonkwo & Agiriga, 2024). Additionally, the energy-efficient glass minimizes heat gain while maximizing natural light, reducing the need for artificial lighting and air conditioning—an approach particularly beneficial in Nigeria's urban heat-prone areas (Nestoil Limited, 2023). The tower also incorporates advanced HVAC systems that optimize energy use based on occupancy and environmental conditions, a crucial feature for densely populated cities facing high energy demand (Nestoil Limited, 2023).

The principles demonstrated by the Nestoil Tower have broad applicability across Nigeria. In urban centers like Lagos and Abuja, similar energy-efficient designs can reduce pressure on power infrastructure, while rural regions can benefit from solar energy solutions for reliable electricity access. Coastal areas, where heat and humidity are concerns, can adopt energy-efficient glass to enhance indoor comfort without excessive energy consumption. As a benchmark for sustainable construction, the Nestoil Tower highlights the importance of integrating renewable energy and efficiency-driven designs in Nigeria's building sector, supporting national goals of greenhouse gas reduction and sustainable urban development (Nestoil Limited, 2023). Additionally, global best practices, such as the Edge Building in Amsterdam, known as one of the world's greenest buildings, incorporate advanced passive design principles, smart lighting, and AI-driven climate control, providing lessons that can inform Nigeria's approach to sustainable building design (Iyamu et al, 2023). Despite the benefits of energy-efficient design, several barriers hinder widespread adoption in Nigeria and Sub-Saharan Africa, including financial constraints, lack of technical expertise, inadequate policies, and high initial investment costs. High initial investment costs prevent many developers from implementing energy-efficient systems (Adelaja, 2020). Many architects, engineers, and builders lack training in sustainable construction. Weak enforcement of building codes results in poor compliance with energy efficiency standards (Lu et al, 2022). There are limited financial mechanisms such as subsidies, tax incentives, and green financing to support the transition to low-energy buildings (Kim, 2018).

Energy efficiency in building design is a vital component of sustainable urban development (Roufechaei et al, 2014). By leveraging both passive and active design strategies, Nigeria can significantly reduce its carbon footprint and improve indoor comfort in residential and commercial buildings (Adewale et al., 2024). The Edge Building in Amsterdam exemplifies sustainable architecture, utilizing advanced technologies to reduce its environmental impact significantly. Completed in 2015, it consumes 70% less electricity than traditional office buildings through an aquifer thermal energy storage system (BREGROUP, 2023). The design maximizes natural light, reducing reliance on artificial lighting and enhancing occupant comfort (ARCHINSPIRES, 2023). Additionally, it features around 30,000 IoT sensors for real-time energy optimization and extensive solar panels that generate more energy than it consumes (ARCHINSPIRES, 2023; BREGROUP, 2023).

In contrast, Nigeria is developing its building decarbonization policies, focusing on foundational frameworks for green architecture. The Netherlands has established a robust regulatory framework that includes stringent energy efficiency standards and incentives for renewable energy (Dutch Ministry of the Interior and Kingdom Relations, 2023). Nigeria could benefit from similar frameworks to ensure compliance through audits and penalties. Furthermore, the Netherlands invests significantly in R&D for sustainable technologies, fostering innovation and collaboration (Netherlands Enterprise Agency, 2023). Nigeria should prioritize such investments to develop localized energy-efficient solutions. By adopting strategies from the Netherlands, Nigeria can enhance its approach to building decarbonization and contribute to global carbon reduction efforts.

Renewable Energy Integration

Integrating renewable energy into building infrastructure is essential for sustainability, reducing reliance on fossil fuels, and lowering greenhouse gas emissions. In Sub-Saharan Africa, particularly Nigeria, the transition to renewable energy faces financial constraints, technological limitations, and inadequate policy frameworks (Oyedepo et al., 2018). This review examines the role of renewable energy in building decarbonization, focusing on

Nigeria's adoption trends, challenges, and potential solutions, while evaluating successful global strategies.

Solar energy is Nigeria's most widely adopted renewable source due to abundant solar radiation (Adewale et al., 2023). Photovoltaic (PV) systems, solar water heating, and solar thermal cooling are commonly utilized in residential and commercial buildings. Research indicates that integrating PV systems into rooftops can supply up to 50% of household energy needs in urban areas like Lagos and Benin City (Dioha & Kumar, 2018). Wind energy also presents a viable option, particularly in coastal areas like Lagos and Port Harcourt, where wind speeds are suitable for small-scale turbine installations (Idris et al., 2020). However, high initial costs and lack of grid integration limit wind energy adoption.

Biomass energy, derived from organic waste, remains underutilized in Nigeria. Studies highlight its potential for rural electrification and waste-to-energy conversion, with biogas digesters and biomass gasification emerging as off-grid solutions (Rasheed et al., 2021). Despite government initiatives like the Rural Electrification Agency (REA) aiming to expand solar mini-grid installations (Bello, 2020), inconsistent policy implementation and a lack of investment incentives hinder progress. Countries like Germany and Denmark have successfully integrated renewable energy through feed-in tariffs, net metering, and smart grid solutions (Iqtiyani & Ilham, 2017). Nigeria's Renewable Energy Master Plan has provided a framework for sustainable energy development; however, its effectiveness has been limited by financial, regulatory, and infrastructural challenges. By learning from the successful models of Germany and Denmark, Nigeria could enhance its policy incentives and implementation strategies. This includes establishing a more robust regulatory framework, improving financial incentives, and fostering public engagement to create a conducive environment for renewable energy investments. (Adelaja, 2020; Ogunleye, 2021). To harness the potential of renewable energy in Nigeria's building sector, addressing these barriers requires policy reforms, financial incentives, technological advancements, and increased investment in research and development. Collaboration among government, the private sector, and international organizations is crucial for driving large-scale adoption of renewable energy solutions (Orikpete et al., 2023).

Sustainable Construction Materials

The construction industry significantly contributes to environmental degradation, accounting for approximately 39% of global carbon dioxide (CO_2) emissions (Ahmed et al, 2020). As urbanization accelerates, particularly in developing countries like Nigeria, the demand for construction materials rises. Traditional materials such as concrete, steel, and bricks have high embodied carbon, making the transition to sustainable alternatives crucial for mitigating climate change impacts (Arenas & Shafique, 2024). Sustainable construction materials offer environmental benefits by reducing energy consumption, enhancing resource efficiency, and minimizing waste. This review explores various sustainable materials, their adoption trends, challenges, and potential policy interventions for large-scale implementation (Nwokediegwu et al., 2024). Hydraform bricks are an environmentally friendly alternative to traditional concrete blocks. These bricks have a significantly lower carbon footprint made from compressed earth and a small percentage of cement (Ejidike, 2023). They are frequently used in Sub-Saharan Africa due to their thermal insulation properties and cost-effectiveness. Case studies in Nigeria indicate that hydraform bricks can reduce construction costs by 30% while improving indoor temperature regulation.

Bamboo is a rapidly renewable material with high tensile strength, making it suitable for structural applications. Its natural ability to absorb carbon dioxide during growth further enhances its sustainability. Studies show that bamboo can replace conventional timber in Nigeria, reducing deforestation while promoting green building practices (Goh et al, 2020). Recycling concrete reduces the demand for virgin aggregates, conserving natural resources and reducing landfill waste. Innovative technologies such as carbon curing can further enhance the performance of recycled concrete, making it a viable option for sustainable construction in Nigeria. Despite the environmental benefits, sustainable materials are not yet widely adopted in Nigeria due to high initial costs and lack of awareness (Wang et al., 2021).

Government initiatives promoting local material sourcing can help drive adoption rates. Countries like Sweden and Germany have successfully integrated low-carbon construction materials through stringent regulations and financial incentives (McInerny & Curtin, 2017). Both Sweden and Germany have implemented a range of effective policies to promote the integration of low-carbon technologies into their energy systems. In Sweden, key policies include the Carbon Tax, introduced in 1991, which incentivizes businesses and individuals to reduce carbon emissions by making fossil fuels more expensive (Swedish Ministry of Finance, 2020). Another significant policy is the Renewable Energy Certificates (RECs) system, which provides financial incentives for the production of renewable energy (Swedish Energy Agency, 2021).

Germany has also established effective policies, such as Feed-in Tariffs (FiTs) through its Renewable Energy Sources Act (EEG), which guarantees fixed payments to electricity producers from renewable sources, driving significant investment in solar and wind energy. To adapt these successful policies in Nigeria, the following strategies can be implemented: develop a Renewable Energy Certificate System to encourage investment in renewable energy projects by providing financial incentives for producers; increase investment in R&D by prioritizing funding for research and development in clean technologies to foster innovation and create localized solutions for energy challenges; and adopt feed-in tariffs to provide a stable revenue stream for renewable energy producers, attracting investments in solar and wind energy. For Nigeria to transition toward sustainable construction, policymakers must implement supportive regulations and financial incentives. Subsidies for eco-friendly materials, research funding, and mandatory green building codes can accelerate adoption. Additionally, increasing public awareness and capacity-building initiatives will enhance the skills required for sustainable construction (Agyekum et al., 2022).

Policy and Regulatory Frameworks

The transition to sustainable building practices heavily relies on effective policy and regulatory frameworks. Strong governance, clear regulations, and robust enforcement mechanisms are vital for achieving low-carbon construction and operational efficiency (Lai et al., 2017). In Nigeria and Sub-Saharan Africa, the lack of stringent building codes, inconsistent policy implementation, and financial disincentives have hindered large-scale decarbonization of the built environment (Emenekwe et al., 2024). Nigeria has several policies aimed at promoting energy efficiency and sustainability in construction. The National Building Code (NBC) outlines energy conservation standards but lacks enforcement (Oyedepo et al., 2018). The Renewable Energy Master Plan (REMP) aims to integrate renewable energy in buildings but has seen slow progress (Gungah et al., 2019). The Nigerian Energy Efficiency Policy (NEEP) promotes energy conservation across various sectors, yet gaps in monitoring and financial incentives have limited its effectiveness (Emodi & Boo, 2015). The National Environmental Standards and Regulations Enforcement Agency (NESREA) oversees environmental protection laws, but challenges like inadequate funding hinder its impact (Monyei et al., 2018). Global best practices can inform Nigeria's approach. The European Union's Energy Performance of Buildings Directive (EPBD) mandates nearly zero-energy buildings by 2030 (Sunderland & Santini, 2020). Nigeria could adopt similar energy efficiency standards tailored to local conditions. The U.S. Green Building Council's LEED certification incentivizes sustainable construction through tax credits (Ohene, 2024). Nigeria could implement comparable financial incentives to encourage green technology adoption. Despite existing frameworks, Nigeria faces critical implementation challenges. Non-compliance with building codes is widespread due to poor enforcement (Fakunle et al., 2020) and inadequate coordination among regulatory agencies. Limited financial mechanisms make green materials cost-prohibitive (MacAskill, 2021). Countries like Rwanda and Kenya provide successful models. Rwanda's green building certification program offers financial incentives (Markić, 2016), while Kenya mandates that commercial buildings integrate at least 10% renewable energy (Kazimierczuk, 2019).

For Nigeria to advance towards sustainable building, policymakers must strengthen enforcement of existing codes, introduce financial incentives for green developers, enhance inter-agency coordination, and encourage private sector participation through public-private partnerships. A multi-stakeholder approach will enable Nigeria to scale sustainable building practices and align with global decarbonization goals (Ayanrinde & Mahachi, 2023).

Challenges and Research Gaps

Sustainable building decarbonization is crucial for reducing greenhouse gas emissions and mitigating climate change. Despite advancements in technology, policy development, and research, significant challenges hinder large-scale adoption, particularly in developing countries like Nigeria (Oyedepo et al., 2018). This review explores key barriers and identifies critical research gaps in sustainable construction materials, renewable energy integration, and policy implementation, drawing insights from global best practices. One primary barrier to decarbonizing the building sector is the high initial cost of sustainable materials and renewable energy systems (Daggash & Mac Dowell, 2021). Many Nigerian developers hesitate to invest in green technologies due to long payback periods and limited access to financial incentives (Adedoja et al., 2023). The absence of subsidies and tax breaks further discourages the adoption of energy-efficient buildings. Moreover, inadequate technical expertise and limited research on region-specific innovations impede the implementation of sustainable building technologies (Garba et al., 2024). A study by Osunmuyiwa and Kalfagianni (2017) revealed that most Nigerian architects and engineers receive minimal training in green building design and energy modeling software. Challenges like poor grid infrastructure also affect the integration of renewable energy sources such as solar and wind power.

While Nigeria has a National Building Code and other environmental policies, weak enforcement mechanisms and regulatory gaps hinder sustainable construction (Sokona, 2022). Developers often bypass energy efficiency guidelines due to inadequate monitoring and corruption within permitting agencies (Timiyan, 2022). Public perception and a lack of awareness regarding the benefits of sustainable buildings further complicate matters, as many property owners prioritize short-term affordability over long-term sustainability (Ekunke et al., 2024). Changing these mindsets necessitates increased education and advocacy efforts. Most

International Journal of Climatic Studies
ISSN: 2710-1061 (Online)
Vol.4, Issue 1, No.1, pp 1- 17, 2025

research on sustainable building materials is based on temperate climates, with limited data for Nigeria's tropical environment (Ejidike, 2023). Research is needed to evaluate the thermal efficiency, durability, and lifecycle costs of locally sourced materials like bamboo and hydraform bricks. Although several policies exist to support sustainable building in Nigeria, few studies have assessed their real-world effectiveness. Future research should focus on policy evaluation frameworks to identify gaps in implementation (Balogun & Oloja-Ojabo, 2023). To bridge these research gaps, studies should conduct lifecycle assessments of alternative construction materials, explore hybrid renewable energy models, and investigate financial models that support green building investments. Promoting interdisciplinary research collaborations will also be essential. Sustainable building decarbonization offers a viable path toward reducing Nigeria's carbon footprint and achieving environmental sustainability. Addressing financial, technological, and policy-related barriers through data-driven studies and international collaborations will facilitate Nigeria's transition to a more sustainable built environment (Sokona, 2022).

CONCLUSION AND RECOMMENDATIONS

The transition to sustainable building decarbonization is crucial for mitigating climate change, reducing energy consumption, and enhancing environmental resilience (Sokona, 2022). This review identifies key challenges, including financial constraints, technological limitations, weak policy enforcement, and inadequate public awareness (Oyedepo et al., 2018; Adedoja et al., 2023). Despite these barriers, Nigeria and other Sub-Saharan African nations have significant potential to adopt sustainable building practices by leveraging renewable energy, energy-efficient materials, and innovative construction technologies (Osunmuyiwa & Kalfagianni, 2017). High initial costs and limited financing mechanisms hinder the adoption of sustainable buildings, as developers often prioritize short-term affordability over long-term sustainability (Timiyan, 2022). Nigeria's National Building Code also lacks effective enforcement, resulting in widespread non-compliance with sustainability standards (Agapiou & Yakubu, 2019). There is also a general lack of awareness regarding the benefits of sustainable construction among property owners and developers (Komolafe et al., 2020).To promote large-scale adoption of sustainable buildings, policymakers should enforce stricter compliance with the National Building Code by introducing penalties for non-compliance and incentives for adherence (Ohene, 2024). Drawing lessons from the European Union's Energy Performance of Buildings Directive (D'Orazio & Pham, 2025), the government should provide tax breaks, grants, and low-interest loans for developers integrating renewable energy and energy-efficient materials (Olumide, 2024).

Collaboration between government and educational institutions is essential to develop training programs for construction professionals focused on sustainable practices (Davies & Davies, 2017). Increased funding for research and development in local sustainable materials, such as bamboo and hydraform bricks, should be prioritized (Ejidike, 2023). Public awareness initiatives are vital to educate homeowners and developers on the long-term economic benefits of green buildings (Sokona, 2022). A multi-stakeholder approach involving government agencies, private sector players, academia, and civil society is necessary for successful implementation. Pilot programs in major urban centers like Lagos and Abuja can pave the way for nationwide scaling. By adopting stronger regulatory frameworks, financial incentives, capacity-building programs, and R&D investments, Nigeria can align with global sustainability trends and accelerate its transition toward a low-carbon built environment.

Knowledge Gaps and Recommendations for Further Research

Despite the extensive literature reviewed, several knowledge gaps remain:

Localized Research on Sustainable Materials: Most existing studies on sustainable materials are based in temperate climates, with limited data available for Nigeria's tropical environment. Research should evaluate the thermal efficiency, durability, and lifecycle costs of locally sourced materials such as bamboo and hydraform bricks.

Policy Evaluation Frameworks: Few studies have assessed the real-world effectiveness of Nigeria's existing policies on sustainable building. Future research should focus on creating frameworks to evaluate policy impacts and identify gaps in implementation.

Integration of Renewable Energy Storage Solutions: While solar energy is promoted, energy storage and grid stability challenges remain unaddressed. Investigating cost-effective battery storage solutions and hybrid renewable energy systems is crucial.

Public Perception and Awareness: Understanding public perception regarding sustainable building practices is essential for effective advocacy. Research should explore the barriers to acceptance and strategies for increasing awareness.

Future studies can address these gaps and contribute significantly to Nigeria's transition towards a more sustainable built environment.

Conflict of interest statement: The author has declared that no competing interests exist.

Data access statement: All relevant data are included in the paper.

Author Contributions: Responsible for this review paper.

International Journal of Climatic Studies
ISSN: 2710-1061 (Online)
Vol.4, Issue 1, No.1, pp 1- 17, 2025
www.iprjb.org

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