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Carbon-Neutral Design Strategies for Net-Zero Energy Buildings: A Comparative Study of Different Design Approaches in Eti-Osa Local Government Area, Lagos, Nigeria

Ogunnaike Adekunle (O.)[1]; Dayomi Abiodun (M.)[2]; Odebiyi Ezekiel (A.)[3]; Osunkoya Oyewole (O.)[4]; Ozomaro Julius (U.)[5]; Rabiu Olumide (O.)[6]

[1;2;3;4;5;6]Department of Architecture, College of Environmental Science and Management, Caleb University, Imota, Ikorodu, Lagos, Nigeria

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Abstract: Several cities have set carbon neutrality targets. This paper aims to assess various approaches for a progressive city to achieve carbon neutrality in building design, construction and occupancy. The study explores various carbon-neutral design strategies and its effectiveness applicable to net-zero energy buildings. Provide recommendations for implementing sustainable design practices in Lagos, Nigeria. The research outlines the carbon neutrality design strategies using credible sources, concepts and existing case studies. The findings reveal that most carbon neutrality strategies are achievable and that its widespread adoption in Lagos will enhance its sustainability target. The incorporation of passive design strategies, including natural ventilation, shading devices, and insulation, with active systems, such as energy-efficient lighting and HVAC systems. Notably, there are a few incentives for the adoption of smart systems by some financial institutions and this a step towards better implementation of carbon neutral design strategies. Implementing such with governmental incentives would substantially enhance control over its carbon neutrality efforts. Consequently, it is suggested that cities striving for carbon neutrality should consciously encourage and advance the passive and active design strategies in achieving carbon-neutral buildings in Nigeria, irrespective of design constraints, as a fundamental strategy for achieving their goals.

Keywords: *Sustainability, Carbon Neutral Design, Smart Systems, Life Cycle Assessment, Passive and Active Design Strategies*.

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I. INTRODUCTION

➢ *Background*

As revolutionary as the construction sector may seem nowadays, it currently accounts for nearly 40% of the world's carbon dioxide emissions, 11% of which are a result of manufacturing building materials such as steel, cement, and glass (Dima Stouhi, 2022). The global push towards sustainability has placed significant increase in carbon emissions and achieving energy efficiency in the built environment. This sector has been so dynamic and revolutionary that it currently accounts for nearly 40% of the world's carbon dioxide emissions, 11% of which are a result of manufacturing building materials such as steel, cement, and glass. Buildings account for a substantial portion of global energy consumption and greenhouse gas emissions, making them a critical area for achieving carbon neutrality. The concept of net-zero energy buildings (NZEBs) has emerged as a viable solution, aiming to balance energy consumption with renewable energy production. In Nigeria, where rapid urbanization and energy challenges coexist, adopting carbon-neutral design strategies is both a necessity and an opportunity.

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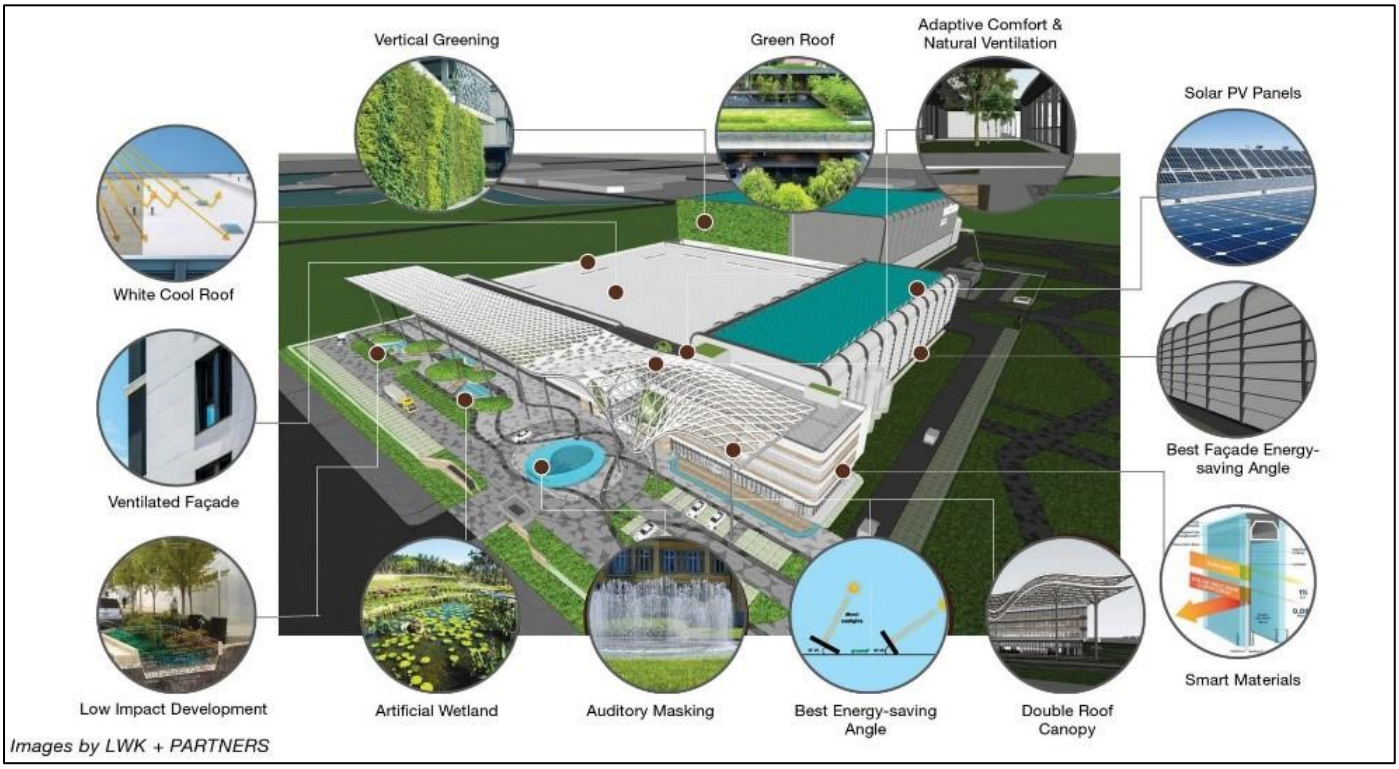

Fig 1 Low Carbon Features of the Carbon-Neutral Building Design (Lwk+Partners, 2022)

Emissions are produced by the building with its interaction with the environment, before construction – when raw materials fabricate into building materials, during their construction – excavation and transportation of materials, emissions from water and waste, after construction – operations including mechanical equipment (Sahithi Ch, 2024). Despite the growing awareness of sustainable building practices, the implementation of carbon-neutral design strategies in Nigeria faces numerous challenges. These include limited access to renewable energy technologies, high initial costs, and a lack of local expertise. Furthermore, the diverse climatic conditions across the country necessitate tailored design approaches that address regional needs while maintaining energy efficiency. A comparative study of different design strategies is essential to identify the most effective solutions for achieving net-zero energy buildings in Nigeria. This study aims to:

- Explore various carbon-neutral design strategies applicable to net-zero energy buildings.
- Compare the effectiveness of these carbon-neutral design strategies in the Eti-Osa L.G.A, Lagos, Nigeria.
- Provide recommendations for implementing sustainable design practices in Eti-Osa L.G.A., Lagos, Nigeria.

This research contributes to the growing body of knowledge on sustainable architecture and energy-efficient building design. By focusing on Nigeria, it addresses a critical gap in the literature and provides practical insights for architects, engineers, policymakers, and other stakeholders. The findings will support the development of context-specific solutions that promote environmental sustainability and energy independence.

Fig 2 Carbon Neutral and Energy Efficiency Principles (Herbert Post, 2024)

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The preliminary assessment reveals that Lagos primarily relies on the state and private sector to implement the necessary measures for achieving carbon neutrality. When these scope allocations are reconsidered, the city's potential for carbon neutrality increases significantly, enabling broader carbon offset initiatives across various sectors.

II. LITERATURE REVIEW

➢ *Carbon Neutral Design Elements*

Buildings and construction account for nearly 40% of global carbon dioxide emissions, making residential design choices critical for addressing climate change (PJ Hutter, 2025). Designing a building according to the climate zone is one of the essential elements in Carbon-Neutral Architecture (Dima Stouhi, 2022).

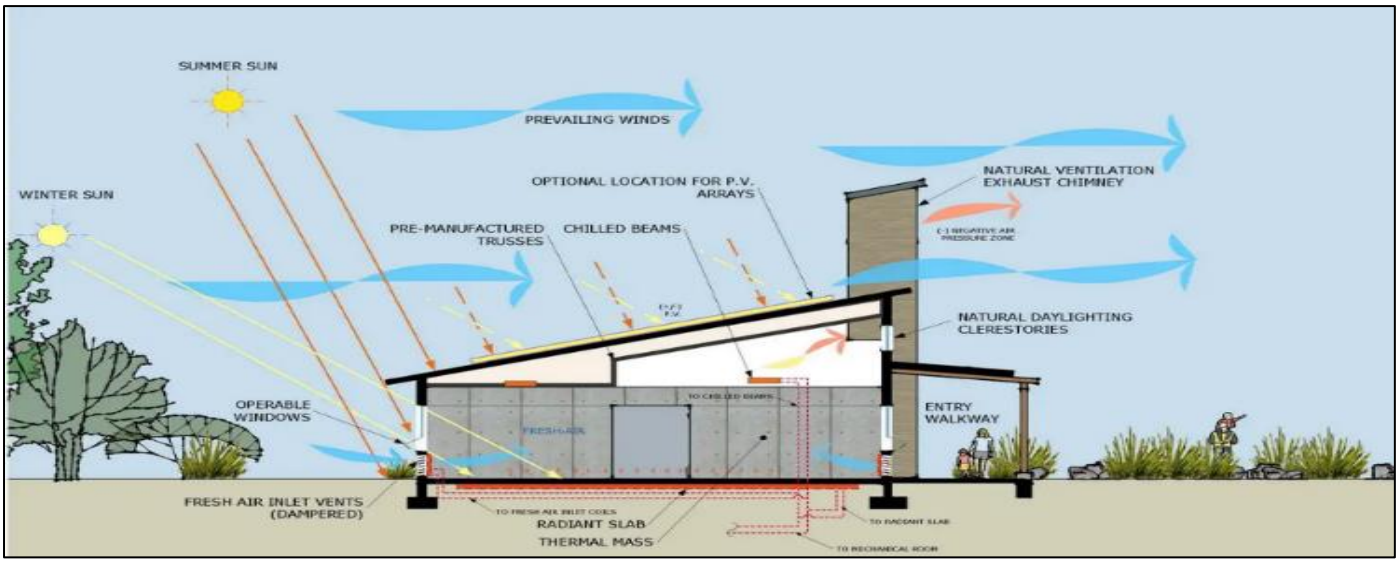

Fig 3 Carbon Neutral Home Design Strategy (Sahithi Ch, 2024)

➢ *Life Cycle Assessment*

A Life Cycle Assessment (LCA) enables the identification of solutions that yield the greatest benefits throughout the building's life span, considering the specific characteristics of the building. Conducting an LCA at an early project stage and evaluating various emission reduction strategies can guide projects towards more sustainable outcomes (Wiktor Kowalski, 2025).

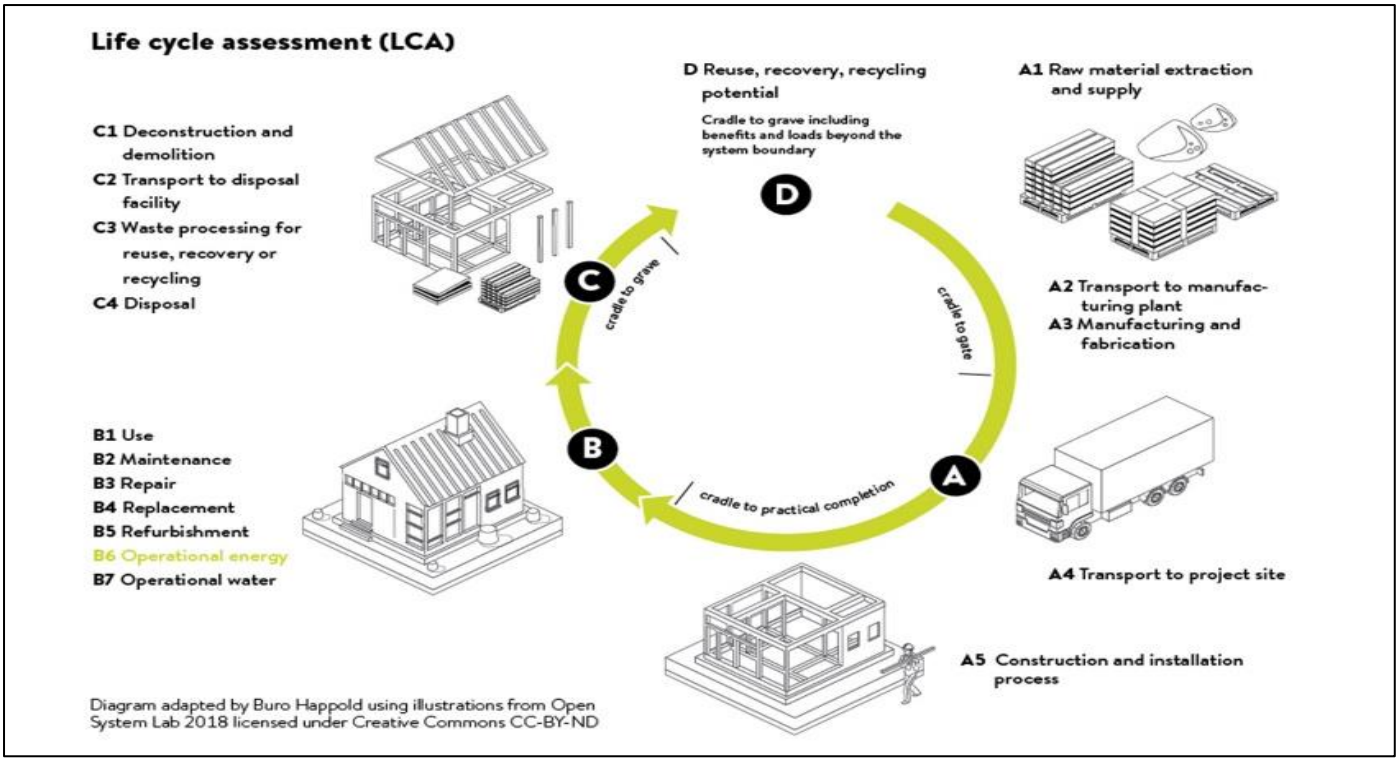

Fig 4 Life Cycle Assessment (LCA) Details (Wiktor Kowalski, 2025)

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- *Operational and Embodied Carbon Reduction*

Operational carbon refers to emissions from your day-to-day energy use – heating, cooling, lighting, and all those appliances that make modern life comfortable. Embodied carbon encompasses emissions from manufacturing, transporting, and installing building materials. According to the World Green Building Council, embodied carbon will be responsible for half of the entire carbon footprint of new construction between now and 2050 (PJ Hutter, 2025).

Reducing embodied carbon in buildings is critical to achieving net zero and carbon neutral construction targets (Asha Ramachandran, 2024).

Embodied carbon is less tangible than operational carbon. This concept includes carbon emissions from the harvest of materials to manufacturing, construction, repairs, and finally demolition and disposal. As buildings become more efficient and our energy generation becomes more renewable, greenhouse gas emissions associated with building energy consumption are reduced and the embodied carbon becomes a higher priority (Adrian Welch, 2021).

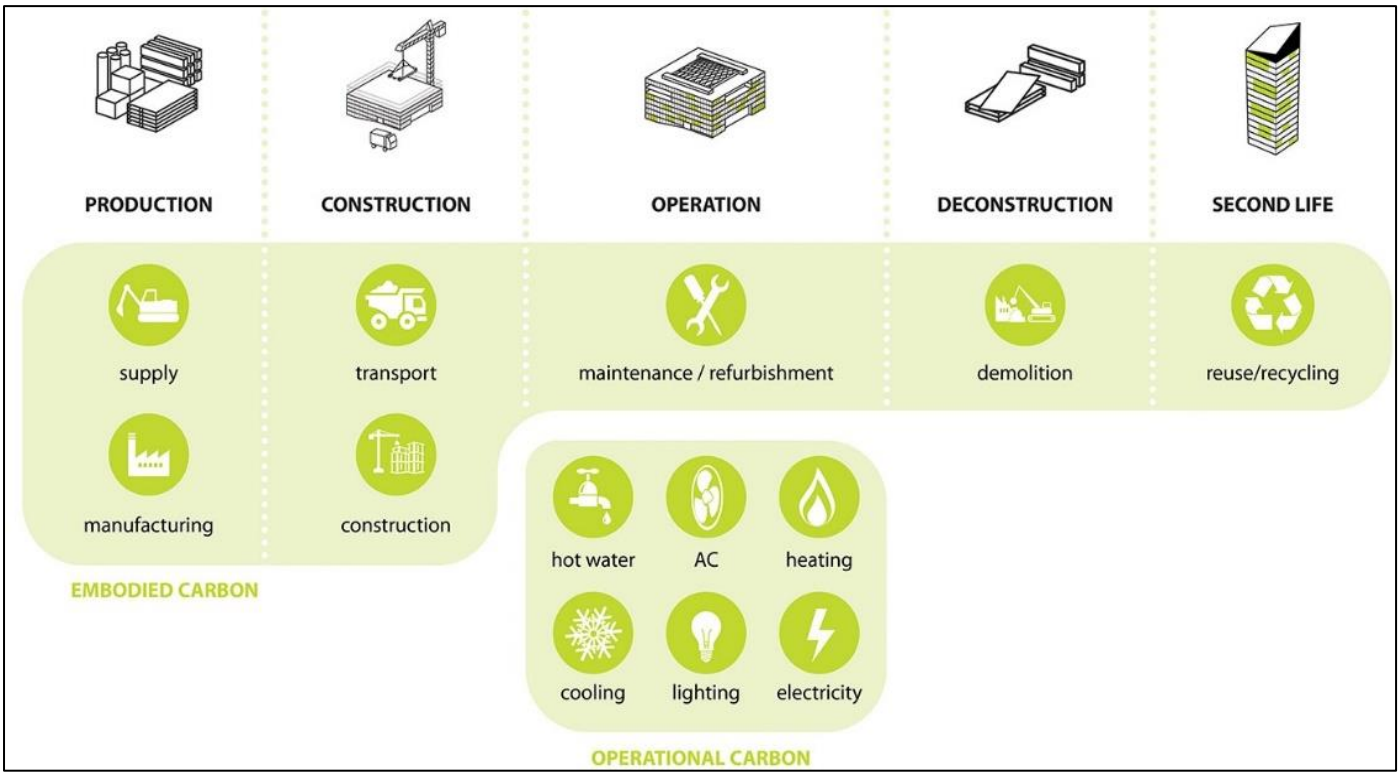

Fig 5 Disparity of Embodied Carbon and Operational Carbon (Wiktor Kowalski, 2025)

➢ *Renewable Energy Fusion*

The incorporation of renewable energy sources into building design is a crucial step towards green buildings and environmental preservation in an era where sustainability is a need rather than an option (Jack Portley, 2024). As we face escalating energy demands and environmental challenges, the integration of renewable energy sources such as solar, wind, and biomass in commercial buildings becomes crucial. This approach not only mitigates the environmental impact of energy consumption but also enhances the energy resilience and economic performance of commercial properties (Herbert Post, 2024).

Different renewable energy sources each have a unique contribution towards making buildings more sustainable. Of the total energy consumption in buildings worldwide, 17 % is allocated for lighting. Proper architectural design can harness up to 70 % of this lighting requirement directly from sunlight. Furthermore, incorporating solar energy and photovoltaic technologies can increase a building's renewable energy use to 83 %, while reducing overall energy demands by 48%. Wind energy also plays a critical role in reducing carbon emissions and the use of non-renewable energy (Nidhi Dhull, 2024).

➢ *Smart Building Design*

Smart Building Systems have emerged as a game-changer in the construction and management of modern buildings. These systems integrate cutting-edge technology and advanced automation to create intelligent structures that can optimize energy consumption, enhance security, and improve occupant comfort (Alex Tabibi, 2024).

There is a significant reduction of installation costs due to the elimination of expensive standalone building management network infrastructures, a growing implementation of environmental initiatives in accordance with drive to net zero, such as reducing carbon emissions alongside decreased energy costs, as well as enhanced safety and security thanks to using data from sensors and controls to coordinate access control and improve fire safety (Billy Marigold, 2023).

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Fig 6 Chart of Building Automation Systems (Alex Tabibi, 2024)

III. METHODOLOGY

A mixed-methods approach was employed, combining literature review, case studies, and simulations. Two case studies of net-zero energy buildings in Nigeria were selected, and their design strategies were analyzed. Simulations were also conducted using building information modeling (BIM) software to evaluate the energy performance of different design approaches.

A. Case Studies

Here are some case studies of existing Net-Zero Energy Buildings in Eti-Osa LGA, Lagos Metropolis, Nigeria:

➢ *Case Study 1: The Nigerian Institute of International Affairs (NIIA) Building.*

- Location: Kofo Abayomi Road, Victoria Island, Eti-Osa LGA, Lagos.
- Building Type: Office Building

Fig 7 Facade of the NIIA Building (Michael Olugbode, 2023)

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- Design Approach: The NIIA building features a unique design approach that incorporates a combination of passive design strategies, including natural ventilation, shading devices, and insulation, with active systems, such as solar panels and energy-efficient lighting.
- Energy Performance: The building has achieved a net-zero energy status level.

➢ *Case Study 2: The Pan-Atlantic University Building.*

- Location: Km 22, Lekki-Epe Expressway, Eti-Osa LGA, Lagos.
- Building Type: Educational Building

Fig 8 Facade of the Pan-Atlantic University Building (Chris Oyeoku Okafor, 2024)

- Design Approach: The Pan-Atlantic University building features a design approach that incorporates a combination of passive design strategies, including natural ventilation, shading devices, and insulation, with active systems, such as energy-efficient lighting and HVAC systems.
- Energy Performance: The building has achieved a net-zero energy status level.

IV. FINDINGS

The study revealed that carbon-neutral design strategies can be achieved through the integration of passive and active design approaches. The results of the simulation analysis showed that:

- Passive design strategies, such as building orientation, natural ventilation, and insulation, can reduce energy consumption by up to 35% (Adeyemi A.A. & Ogbonna C., 2022).
- Active design strategies, such as renewable energy systems, energy-efficient appliances, and energy storage systems, can reduce energy consumption by up to 60% (Ajao A.M & Oyedele L., 2022).
- A holistic approach, integrating both passive and active design strategies, can achieve net-zero energy consumption (Agency I.E, 2022).

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V. DISCUSSION

This publication paper shows the breakdown of carbon neutral design strategies for net zero energy buildings and its implementation showing different design approaches in Nigeria.

To minimize or eliminate greenhouse gas emissions throughout the entire building lifecycle, from construction to operation and eventual demolition, by focusing on energy efficiency, renewable energy, and low-carbon materials in Nigeria. Minimizing construction waste and maximizing material reuse or recycling contributes to a lower overall carbon footprint. Prioritizing low-carbon materials with a reduced embodied carbon footprint is crucial in Nigeria. Lower operating and maintenance costs, better resiliency to power outages and natural disasters, and improved energy security. Unify programming models. Be factored and extensible. Integrate with Web standards and practices.

The study's findings highlight the importance of considering both passive and active design strategies in achieving carbon-neutral buildings in Nigeria. The results also underscore the need for policymakers and building professionals to adopt a holistic approach to building design, integrating energy efficiency, renewable energy, and sustainable materials.

The study's findings are consistent with previous studies, which have shown that passive design strategies can significantly reduce energy consumption (Kadiri K.O & Momoh O., 2022).

The study's findings also support the use of active design strategies, such as renewable energy systems, to achieve net-zero energy consumption (NBRRI, 2022).

VI. RECOMMENDATIONS

➢ *Based on the Study's Findings, the Following Recommendations are made:*

- Policymakers should adopt a holistic approach to building design, integrating energy efficiency, renewable energy, and sustainable materials.
- Building professionals should consider both passive and active design strategies in achieving carbon-neutral buildings.
- Researchers should conduct further studies on carbon-neutral design strategies specifically in Nigeria.
- The government should provide incentives for building owners and developers to adopt carbon-neutral design strategies.

VII. CONCLUSION

This study demonstrates that carbon-neutral design strategies can be achieved through the integration of passive and active design approaches. The study's findings highlight the importance of considering both passive and active design strategies in achieving carbon-neutral buildings in Nigeria.

The study concludes that a holistic approach, integrating both passive and active design strategies, is essential for achieving net-zero energy consumption in Nigeria. The study's findings have implications for policymakers, building professionals, and researchers seeking to promote sustainable building practices in Nigeria.

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