

# Exploring Eco-Friendly Design Principles for Residential Design

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## Abstract

This study investigates the integration of eco-friendly design principles in residential building design in Nigeria, with an emphasis on sustainable development and environmental impact reduction. It explores key principles including energy efficiency, water conservation, waste reduction, the use of sustainable building materials, indoor air quality, and livability. The study adopts a qualitative research approach by reviewing existing literature on sustainable residential building projects in Nigeria and comparable global contexts. Findings are expected to provide a comprehensive understanding of eco-friendly design principles and highlight the benefits of their adoption, such as reduced environmental degradation, lower long-term costs, and improved occupant health and well-being. The research further aims to identify best practices and offer practical recommendations to guide architects, urban planners, and policymakers in promoting sustainable residential design across Nigeria. The study contributes to the growing discourse on green architecture and sustainable housing solutions in developing economies.

**Keywords:** *Eco-Friendly Design, Sustainable Development, Residential Buildings, Occupant Well-Being, Indoor Air Quality.*

## I. INTRODUCTION

The construction industry has been shifting towards sustainable practices, particularly in the residential sector, in response to increasing environmental concerns. (Oladokun, Isang & Emuze, 2020) Eco-friendly residential design aims to minimize the negative environmental impact of buildings through energy efficiency, responsible material selection, water conservation, and improved indoor environmental quality. (Yu, 2024). The core objective is to reduce the ecological footprint of housing while enhancing occupant well-being and promoting long-term economic viability. Ochedi, E., & Taki, A. (2021).

According to Ibitoye, Solomon, Afolabi & Oyewole (2022), residential architecture plays important role in achieving symbolism, broader sustainability goals, as housing represents a substantial portion of global energy consumption and carbon emissions.

The International Energy Agency (IEA), pointed that residential buildings account for approximately 30% of total energy used worldwide and contributes significantly to greenhouse gas emissions. This highlights the urgent need for architects and other building allied-professionals to adopt environmentally conscious practices in the residential sector.

The relevance of sustainable design in residential architecture is not only environmental but also social and economic. (Saidu & Yeom, 2020).

Eco-friendly residential designs offer better thermal comfort, natural lighting, and air quality, improving health and quality of life. Energy-efficient systems and water-saving technologies reduce utility costs, making sustainable housing more cost-effective.



Fig 1 The Concept of Eco-Friendly Design  
Source: Pinterest (2020)

## II. RESIDENTIAL DESIGN

The origin of shelter is as early as human existence, highlighting the need for protection from environmental invasion and leading to the development of rudimentary forms of housing, that is simplest way to build house. Initially, humans relied on natural shelters like caves, trees branches as shades or rock overhangs. (Bourdier & Probst, 2015). As styles of domestication and family settlement idea increases, George, Guthrie, & Orr (2022) further analysed that sheltering emphasizes the process of provision through object production like a building, considering the long-term effects on a host communities and the environment. Man started constructing more permanent shelters using materials like tharsh, wood, leaves, stone, and animal skins. The Neolithic Revolution around 10,000 years ago marked a significant turning point, leading to the construction of more durable and stable shelters, defining originality, vernacular architecture (Olukunle, 2022) and over time, shelter evolved from simple structures to more complex and diverse buildings.

Among the numerous provisions shelter stands for is the residential building. A residential building is a structure designed to provide living space for individuals or families, ranging from single-family homes to multi-story apartment complexes. These buildings serve as the primary space for people to live, sleep, eat, and carry out daily activities. (Prystuplyuk, 2024). They differ from

commercial or industrial buildings in their function of providing shelter and a comfortable environment. They are designed with the needs of their occupants in mind, ensuring comfort, privacy, and safety. (Pranveer, & Kumar, 2025). It involves the systematic planning, design, and construction of residential buildings. (Odum, & Ezezue, 2020).

The modern typologies in residential building varies, having deep historical values with one another types of building and still serving as the a benchmark for distinguishing each building from the other. Bogachenko, M., & Yermuraki, O. (2023).

### ➤ *Elements of Building*

Elements of a building are the fundamental components that form every structure, functionality, and usability uniquely in a building. It works regardless of how magnificent or not the building is. (Condotta & Zatta, 2021). They are crucial in architectural design and construction, ensuring stability, safety, aesthetics, and comfort.

According to Olusola, Olubola, Onajite, & Akintayo, (2012), the elements of building includes foundation, plinth, walls, floors, roof, doors, ramps, lifts, building services, finishes, and structural frame. Foundation transfers loads to the ground, while plinth protects the building from ground moisture. Walls support structural loads and divide interior spaces. Floors

provide horizontal surfaces and meet structural, thermal, and acoustic requirements. Roofs protect the building from weather elements, while doors and windows allow access, ventilation, and light. Building services include plumbing, electrical, HVAC, fire safety, and communication systems.

➤ *Benchmark for Residential Design*

Human-centered design prioritizes occupant comfort, privacy, and functional requirements in residential spaces. Natural light and ventilation are strategically integrated to enhance well-being and minimize energy consumption. Thermal comfort is achieved through insulation, shading, and climate-appropriate materials. Safety and security measures are crucial, including secure access points and emergency escape routes. Sustainability in residential design involves using eco-friendly materials, renewable energy systems, and water-saving mechanisms to reduce environmental impact and contribute to building resilience in climate challenges. Hollberg, A., Lützkendorf, T., & Habert, G. (2019).

Residential design evaluation involves other benchmarks such as functionality, aesthetics, structural integrity, energy efficiency, sustainability, cost and affordability, user comfort and well-being, cultural and contextual relevance, flexibility and future adaptability, and regulatory compliance. These criteria ensure that the design meets practical needs, appeals to occupants, and is compliant with engineering standards. (Ubayi, Abubakar, Ahmad, Dulawat, Ibrahim, Ibrahim & Garko, 2024).

The effect should also be cost-effective, user-friendly, and adaptable to changing family needs and technology. Additionally, the design should meet building codes, zoning laws, and environmental regulations. (Buba & Tanko, 2017).

### **III. ENERGY CONSUMPTION IN RESIDENTIAL BUILDING**

According to Uyigue, E. U. E. (2015), Residential buildings are primarily energy-intensive, with HVAC systems accounting for the majority of energy consumption. Water heating systems, such as electric or gas, are used for showers, dishwashing, and laundry. Lighting, both interior and exterior, consumes electricity, with LED lights being an energy-saving alternative. Kitchen appliances, such as refrigerators, freezers, electric cookers, ovens, blenders, and microwaves, are also energy-intensive. Laundry equipment, such as washing machines, electric irons, and clothes dryers, can significantly increase energy usage, especially in large households. Entertainment and personal electronics, such as televisions, home theatres, computers, and chargers, also contribute to energy consumption. Standby power usage, such as devices like decoders, and microwaves, is also a significant energy consumption. Water pumps and borehole systems consume electricity in areas without constant water supply.

In Nigeria, residential electricity consumption exhibits notable variation across regions, particularly between urban and rural settings. On average, individuals consume about 27 kilowatt-hours (kWh) of electricity per month nationwide. Urban dwellers tend to use more energy, averaging approximately 39 kWh per person monthly, whereas rural residents typically consume around 17 kWh per person. These differences highlight disparities in appliance ownership, access to electricity, and broader patterns of energy use across the country. (Olaniyan, McLellan, Ogata & Tezuka, 2018).

It is important to note that these consumption levels are influenced by factors such as the availability and reliability of electricity supply, the types of appliances used, and socioeconomic conditions. For instance, households with access to more electrical appliances like air conditioners and refrigerators will naturally have higher energy consumption. Conversely, in areas with limited access to electricity or fewer appliances, consumption rates are lower. (Onisanwa, Akinbobola, & Olowookere, 2020).

➤ *Building Orientation*

Building orientation is a crucial eco-friendly design principle in residential architecture, influencing energy performance, indoor comfort, and sustainability. It refers to the positioning of a building relative to the sun's path, prevailing winds, and surrounding landscape. (Olusola & Daramola, 2021). It is expected building obeys the rule of thumb in building orientation that is, in tropical and hot climates like Nigeria, the best building approach is to use the north-south axis for the longer side and the east-west axis for the shorter side. This orientation allows for more controlled exposure to sunlight, optimizing daylight and passive ventilation without overheating the building. (Fadeyi, John, Uduma-Olugu & Adebamowo, 2024). This was further emphasised that the shorter side, that is the east and west sides receive intense, low-angle sunlight, reducing solar heat gain and improving indoor comfort and energy efficiency. This orientation also maximizes cross ventilation, improves passive solar design efficiency, and helps in strategic placement of solar panels on south-facing roofs. A visual representation of this is provided below in fig. 2.

The objective is to maximize natural light and ventilation while minimizing heat gain or loss. Building orientation is important for passive solar heating and cooling, natural daylighting, cross ventilation, solar panel efficiency, and shading and glare control. Proper orientation allows buildings to capture heat during cooler seasons and avoid it during hotter periods, reducing reliance on mechanical heating and cooling. Strategically placing windows and glazed surfaces along certain facades enhances daylight penetration, decreasing dependence on artificial lighting. Cross ventilation allows natural airflow through the interior, improving indoor air quality and reducing the need for fans or air conditioners. Proper orientation also helps control solar glare and provides shading, especially for west-facing windows in hot climates.

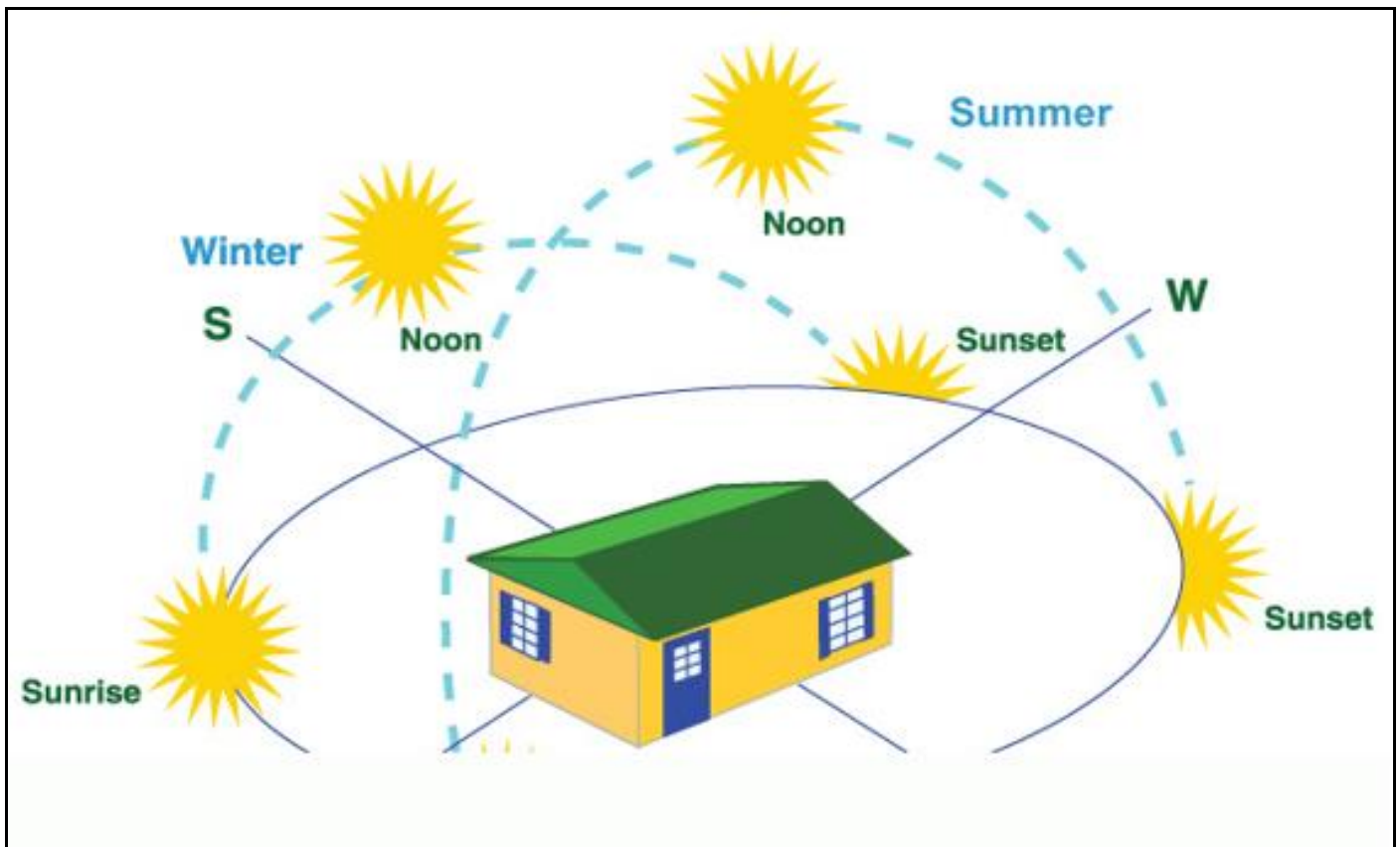


Fig 2 The Concept of Building Orientation  
Source: Google (2017)

#### ➤ Daylighting

A well-structured approach to achieving effective daylighting and glare control in a building involves strategic separation of view and light functions within the glazing system. (Beltran, Lee & Selkowitz, 1997). This means the usage of high-transmission, clearer glazing at high levels to admit ample daylight and lower-transmission glazing at the eye level to minimize glare and improve human comfort in a residential building. Reflective elements such as glass blocks or light shelves can enhance daylight penetration into deeper areas of a room, promoting diffuse reflection and reducing harsh contrasts and glare. Specialized prisms and light-redirecting devices can also be applied to bounce sunlight towards ceilings or far corners of a room, extending natural light distribution without increasing heat gain. When combined, these strategies reduce dependence on artificial lighting, improve indoor visual comfort, and increase energy efficiency. (Tian, Lin, He & Jonsson, 2021).

Climate change and environmental degradation are causing a significant shift towards sustainable architectural design. The built environment contributes to global energy consumption and greenhouse gas emissions, necessitating a paradigm shift towards energy-efficient and environmentally responsible building practices. Architects play a pivotal role in this transformation, as decisions made during the design phase significantly influence the building environmental performance throughout its lifecycle. (Yu, Gu, & Ostwald, 2022).

Integrating sustainability principles from the onset can lead to substantial reductions in energy use, resource consumption, and environmental impact. Strategies such as passive design, renewable materials utilization, and energy-efficient systems can be implemented.

Trebilcock, M. (2011), emphasized the importance of embedding sustainable practices into architectural education and professional practice, advocating for a holistic approach considering environmental, social, and economic factors. Amado & Feria, (2019) proposed frameworks that guide architects in evaluating and implementing sustainable strategies effectively. These tools and guidelines have been developed to assist architects in assessing the sustainability of their designs, ensuring sustainability is a fundamental component of the design process. By adopting such methodologies, architects can contribute to the creation of energy-efficient and sustainable buildings. (Amado *et al*, 2019).

#### ➤ The Buildme Tool in Relation to Nigeria Residential Houses

The Build ME tool is a building-stock modelling and energy/material-use assessment framework developed for the Middle East and North Africa region (MENA). It helps stakeholders, proponents estimate material use, energy consumption, carbon emissions, and life-cycle impacts of buildings using a bottom-up archetype modelling approach.

Eco-friendly design principles for residential designs means the usage of sustainable design in implementing on basic elements of building.

This study aims to estimate the energy and material use of Nigeria's residential buildings, focusing on achieving a net-zero building sector with a rapidly growing population. By developing bottom-up archetype also, it calculates baseline energy and material use of Nigeria's residential building stock using the Build ME tool and converts this data into CO<sub>2</sub> emissions using a life-cycle assessment. Nigeria's residential dwellings use approximately 0.3 kg of material per dwelling over a lifetime of 50 years and 2404 kWh/yr of energy per dwelling. Annually, dwellings emit 2500 kgCO<sub>2</sub>-eq per dwelling due to material and energy use. To meet Nigeria's emissions targets, scenarios proposed for sustainable housing include improved energy efficiency, a shift in construction materials, and decarbonisation of grid electricity. The study also highlights the potential benefits of a policy switch to materials such as timber, earthen blocks, adobe bricks, and clay, which could significantly reduce construction-related emissions. These changes could improve the quality of life for households, combat climate change globally, and bring economic advantages to Nigeria. (Nwagwu, Akin & Hertwich, 2024)

By applying Build ME in Nigeria, researchers can simulate retrofit scenarios, passive design improvements, and policy interventions to reduce emissions and improve sustainability in residential architecture. This is relevant for residential design professionals interested in eco-friendly or sustainable design principles, as it quantifies how design decisions affect energy use and material consumption. It can also make data-based recommendations for design improvements, such as switching materials, improving insulation, optimizing windows, and reducing embodied carbon. The Build ME concept in this thesis and further project helps strengthen arguments with quantitative evidence, not just qualitative design statements

#### IV. ECO-FRIENDLY DESIGN PRINCIPLES

##### ➤ *Energy Efficiency*

Energy efficiency is crucial in residential buildings, as 30% of global energy consumption is in residential buildings. Factors such as heating, cooling, and lighting contribute to this. To achieve energy efficiency, building orientation, insulation, window design, passive solar design, renewable energy systems, energy-efficient appliances, and smart home technologies are essential. Building orientation maximizes natural daylighting and passive solar heating and cooling, while insulation and air tightness reduce heat loss. Passive solar design harnesses solar energy for heating and cooling, while on-site renewable energy systems generate clean energy and reduce grid reliance. Energy-efficient appliances, lighting, and HVAC systems also reduce energy consumption. Energy-efficient buildings can command higher property values and rental rates, making them a valuable investment for in residential usage.

##### ➤ *Water Conservation*

Water conservation is a crucial aspect of eco-friendly design in residential buildings, especially in regions like Nigeria, where water scarcity is a significant issue. With a growing population and urbanization, The Nigeria water demand is increasing, straining existing resources. Contributing to water conservation efforts, residential buildings can incorporate design principles and technologies that reduce water consumption.

With strategies like installing low-flow fixtures, collecting and storing rainwater for non-potable (eating or drinking) uses, treating and reusing greywater for irrigation, installing water-efficient appliances like dishwashers and washing machines, using drought-resistant plants and efficient irrigation systems, and installing water meters and monitoring systems to detect leaks and optimize water usage. These measures can help reduce water consumption and reduce demand on municipal water supplies, ultimately contributing to a more sustainable and efficient living environment.

##### ➤ *Indoor Air Quality*

In Nigeria with its unique climatic region, indoor air quality (IAQ) is a crucial aspect of eco-friendly residential design. Poor IAQ can lead to health issues such as respiratory issues, allergies, and cardiovascular diseases. The tropical climate of Nigeria leads to high indoor temperatures and humidity, fostering mold growth and volatile organic compound emissions. Outdoor air pollution from vehicular emissions, industrial activities, and waste burning can compromise IAQ, while indoor sources of pollution from cooking fuels, cleaning products, and building materials can further degrade IAQ.

Improving indoor air quality for residential buildings and reducing indoor pollutant concentrations are achieved when air filtration systems remove pollutants, non-toxic building materials minimize indoor pollution, proper ventilation design like cross ventilation accounts for residents density, activity levels, and pollutant sources, indoor plants purify air, and smart home technologies monitor and control IAQ for real-time feedback and optimization.

##### ➤ *Sustainable Building Materials*

Studies shows that the building sector in Nigeria is a major contributor to environmental degradation, resource depletion, and greenhouse gas emissions. Sustainable building materials are crucial in reducing these impacts, with Nigeria facing unique environmental challenges such as deforestation, resource depletion, and climate change. Sustainable building materials can address these issues, thereby promoting energy efficiency in buildings, reducing energy consumption. Additionally, enhancing indoor air quality, thereby promoting occupant health.

These are done through using locally sourced materials such as earth, stone, and clay to reduce transportation, energy emissions and support local economies. The usage of recycled materials, such as reclaimed wood and glass, conserve resources.

### ➤ *Waste Reduction*

Waste reduction is a crucial aspect of eco-friendly residential building design. The construction industry generates significant waste, contributing to environmental degradation, pollution, and resource depletion. Highlighting and intergrating waste reduction strategies in residential building design can minimize waste, reduce environmental impact, and promote sustainable development. Nigeria faces unique environmental challenges such as inadequate waste management, resource depletion, and environmental pollution. Waste reduction in residential building design can help mitigate these issues by minimizing waste generation during construction and occupancy, conserving resources, and reducing environmental pollution. By designing buildings with waste reduction in mind, the architects, can minimize waste generation, conserve resources, and promote sustainable development. Strategies as designing for deconstruction, selecting materials with minimal packaging, developing waste management plans, incorporating recycling and reuse strategies, and implementing efficient construction practices like prefabrication and modular construction.

### ➤ *Liveability*

Liveability is a vital concept that includes adaptability which refers to building ability to accommodate changing occupant needs and environmental conditions. Design strategies for adaptability include flexible floor plans, universal design, and future-proofing.

Again liveability involves longevity that is when a building has the ability to endure and remain functional over time through its durable materials, quality construction, and low-maintenance design.

Lastly, site responsiveness is important in the study of buildings liveability. This includes include careful orientation and layout, landscaping that promotes biodiversity, and climate-responsive design.

## V. CONCLUSION

The importance of incorporating eco-friendly design principles into Nigerian residential architecture to reduce environmental impact, enhance energy efficiency, and improve living standards cannot be overemphasized. This documentation had importantly suggested that passive strategies, renewable energy use, sustainable materials, and water conservation can significantly reduce resource consumption, offering a sustainable path for resilient, cost-effective housing in the Nigerian society, worth emulation.

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