

# Integrating Renewable Design Approaches to Improve Energy Performances in High-Rise Buildings

Michael Olusegun Adamolekun<sup>1</sup>

<sup>1</sup>Department of Architecture Ambrose Alli University, Ekpoma, Nigeria

Publication Date: 2026/05/25

**Abstract:** High-rise buildings have become a defining feature of modern urban development due to rapid population growth and limited land availability in major cities. However, these structures are associated with significant energy consumption resulting from intensive use of heating, cooling, lighting, and vertical transportation systems. In response to increasing concerns about climate change, environmental sustainability, and resource efficiency, the integration of renewable design approaches has emerged as a critical strategy for improving building energy performance. This study examines the role of renewable energy systems and sustainable architectural strategies in reducing energy demand and enhancing overall building efficiency. Key approaches identified include passive design strategies and active renewable energy systems. The study further explores integrated design approaches that combine architectural planning with advanced energy management systems to optimize performance. Findings indicate that effective integration of renewable design strategies can significantly reduce energy consumption, lower carbon emissions, and improve environmental sustainability in high-rise buildings. The study highlights the need for collaborative design processes, supportive policy frameworks, and continuous technological innovation to enhance energy performance in rapidly urbanizing environments.

**Keywords:** *Curtain Walls, Glazing, Vertical Greenery, Biophilia, Fenestration, Facades.*

**How to Cite:** Michael Olusegun Adamolekun (2026) Integrating Renewable Design Approaches to Improve Energy Performances in High-Rise Buildings. *International Journal of Innovative Science and Research Technology*, 11(5), 1499-1504. <https://doi.org/10.38124/ijisrt/26may360>

## I. INTRODUCTION

Rapid urbanization is reshaping how and where people live, work, and gain access to resources, (Bodo, 2019). More than half of humanity lives in urban areas, with projections indicating this figure will rise to approximately two-thirds by the middle of the century, projecting across the world an increasing demand for high-rise buildings, particularly in densely populated cities where land availability is limited, (Byulegenova, & Turemuratov, 2023). While sourcing solutions for urban density and economic growth through high-rise buildings, there is concern with significant energy consumption and by-products. High-rise buildings require large amounts of energy for heating, cooling, lighting, and vertical transportation systems. Consequently, they contribute considerably to global greenhouse gas emissions and environmental degradation.

The increasing concerns regarding climate change and fossil fuel depletion have driven many environmentalists (architects, town planners etc.), to seek sustainable strategies to enhance building energy performance, which brought about a crucial aspect of sustainable architectural design to integrate renewable energy, (Li, Zhou, Eom, Yu, & Asrar, 2019).

Furthermore, this brings advanced challenges due to structural, technological, and environmental factors, (Chen, Huang, Yang, & Peng, 2019), (Chen, Yang, & Peng, 2019). However, advancements in building technology and design approaches have made it possible to incorporate renewable energy systems into high-rise buildings effectively.

According to Oyediran, Akinradewo, Onososen, & Koriko, (2025), high-rise buildings in Nigeria are increasingly seen as a solution to population rapid growth and urbanization, land scarcity, particularly in major cities like Asaba, Lagos, Port-Harcourt and Abuja. Historically characterized by low-rise developments, The shift towards vertical expansion is driven by the need for efficient land utilization and economic growth. Ochedi, & Taki, (2021), opined the

Contemporary Nigerian high-rise buildings often adopt design strategies from foreign nations which mostly have temperate or desert climates, with approach like fully glazed façades being not all season suited for the hot, humid conditions of cities like Lagos and Abuja. (Kalu, Ogunnaike, & O., E., 2025), thus, these designs lead to excessive solar heat gain, causing thermal discomfort due to insufficient shading and reliance on sealed envelopes that restrict airflow.

Consequently, occupants depend heavily on control of the immediate microclimate like air conditioning, increasing energy consumption and operational costs in the built environment, mostly due to inadequate supply of electricity in Nigeria. This approach neglects principles of climate-responsive architecture traditionally found in Nigerian designs, (Ayodele, Ogunjuyigbe, & Nwakanma, 2021), which utilized features to enhance natural ventilation and minimize heat gain.

A more effective strategy would integrate passive design elements and renewable systems, tailored to local climatic conditions, for energy-efficient and comfortable buildings. The purpose of this study is therefore to examine renewable design approaches and evaluate how their integration can enhance the energy performance of high-rise buildings when energy challenges associated with high-rise buildings is investigated, renewable design strategies applicable to high-rise buildings are identified and recommendations are provided.

## II. HIGH-RISE BUILDINGS

High-rise buildings are building structures characterized by their considerable vertical height and multiple floors. Although definitions vary among building codes, a high-rise building is typically defined as a structure exceeding 35 meters in height or containing more than 12 floors. The height requires special design, safety, and use conditions compared with lower buildings, (Tamošaitienė, & Gaudutis, 2013).

The energy performance in such buildings refers to how much energy a building uses to provide services like heating, cooling, lighting, hot water, and plug loads while maintaining comfort and function. (Zhao, 2023).

## III. RENEWABLE ENERGY IN ARCHITECTURE

Renewable energy in architecture refers to the incorporation of energy sources that are naturally replenished, such as solar radiation, wind, and geothermal heat, into building systems. These systems can either generate electricity or provide heating and cooling.

It looks into common building-level indicators include Energy Use Intensity (EUI), EnergyStar scores, and zero Energy Performance Index (zEPI) to compare buildings and track progress. (Gerald, & Ghisi, 2020).

It is an essential part to a functional high rise building as it also looks into sustainable designs that focuses on minimizing environmental impact through efficient resource use, reduced carbon emissions, and improved building performances overtime.

## IV. PASSIVE AND ACTIVE DESIGN SYSTEMS

Passive design strategies are initial integration of functionality of service of that a building itself offers through

architectural elements such as the building orientation, shading and shading device, and natural ventilation to reduce energy demand. Active design systems, on the other hand, involve technological systems that generate or manage energy in and around building, such as photovoltaic panels or wind turbines.

Several studies have emphasized that buildings account for nearly 40% of global energy consumption. With high-rise buildings particularly being energy-intensive due to their complex systems and high occupant density, Researchers have therefore explored various strategies to improve energy efficiency in high-rise buildings.

Renewable systems such as solar photovoltaic panels, wind turbines, and geothermal heating systems can significantly reduce reliance on fossil fuels. Additionally, passive design strategies such as optimized building orientation and high-performance façades can reduce energy demand.

Sustainable building rating systems also plays an important role in promoting renewable integration and energy efficiency. These frameworks establish performance standards and provide guidelines for environmentally responsible building design. For instance, the Leadership in Energy and Environmental Design (LEED) certification encourages energy efficiency through renewable energy integration, efficient building envelopes, and sustainable site planning. Similarly, the Building Research Establishment Environmental Assessment Method assesses buildings based on environmental performance, including energy use and renewable technologies.

Previous studies indicate that combining passive and active renewable systems yields the best results in improving building energy performance (Zhao, 2023), with difference in energy usage in traditional and high-rise building as shown in Table 1. However, challenges such as high initial costs, technological limitations, and design complexity still hinder widespread implementation.

This study is grounded in the principles of sustainable architecture and bioclimatic design. As the former focuses on adapting buildings to their local climate conditions, through utilizing natural elements such as sunlight, wind, and temperature variations to reduce dependence on mechanical systems, the latter emphasizes designing buildings that minimize environmental impact while maximizing energy efficiency and occupant comfort.

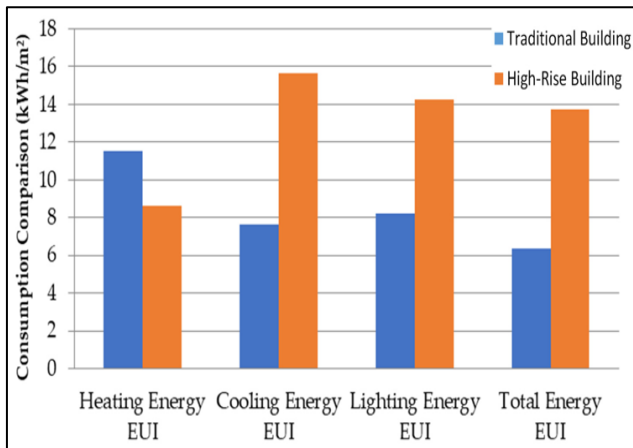


Fig 1 Expected Outcome of Heat, Energy and Lighting Energy in a Traditional and High-Rise Building. Source: MDPI, 2016

The Solar Photovoltaic (PV) Systems converts sunlight directly into electricity using the Photovoltaic Effect or Photovoltaic panels (PV Panels). When photons strike semiconductor materials (typically silicon), they excite electrons, generating a direct current (DC). Thus panels convert solar radiation into electricity and can be integrated into building façades or rooftops. Its key components are PV panels as the modules, an inverter serving as conversion from direct current to alternating current, Battery storage, rooftop array, control, building-integrated photovoltaics (BIPV) which could be façade glazing, shading devices, curtain walls.

The performance factors here depend on shading losses, efficiency of heat energy on the panel, panel orientation and solar irradiance.

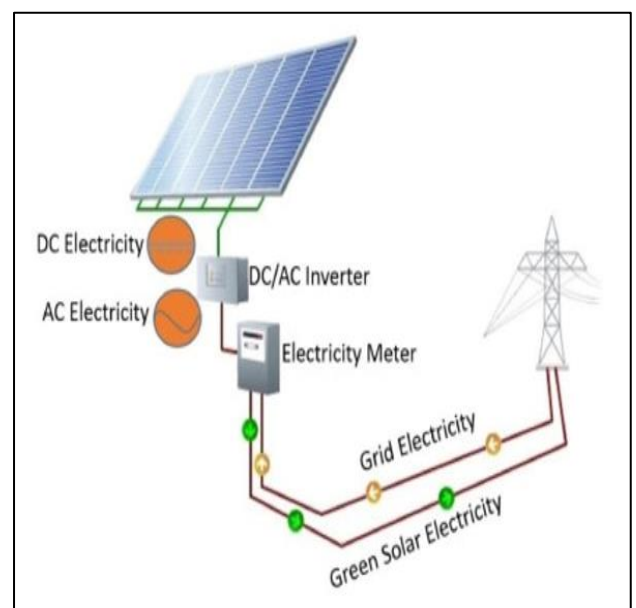


Fig 2 Solar Photovoltaic System Source: MDPI, 2016

**V. RENEWABLE DESIGN STRATEGIES FOR HIGH-RISE BUILDINGS**

➤ *Passive Design Strategies*

• *Building Orientation*

Proper orientation allows buildings to maximize natural daylight while minimizing unwanted heat gain. South-facing façades can be optimized for solar energy collection, while shading devices can reduce excessive solar heat.

• *Natural Ventilation*

Natural ventilation strategies such as courtyards, operable windows and atriums can improve airflow and reduce reliance on mechanical cooling systems.

• *Double-Skin Façades*

A double-skin façade consists of two layers of glass separated by an air cavity. This system enhances thermal insulation and improves natural ventilation.

• *Daylighting*

Designing buildings to maximize natural daylight reduces the need for artificial lighting and improves occupant comfort. This approach can be through skylight, best choice for building materials especially reflections (glass) and being aware of glare.

• *Green Roofs and Vertical Greenery*

Vegetation integrated into buildings can improve thermal insulation, reduce urban heat island effects, and enhance air quality. Greenery, courtyard system, natural plants etc., can be of great relevance in this scheme of work.

➤ *Active Renewable Systems*

• *Solar Photovoltaic Systems*

A very good example is the Edge in Amsterdam which uses rooftop and façade PV to produce significant portion of its energy demand, making it one of the most energy-efficient office buildings globally.

• *Solar Thermal Systems*

It has higher efficiency than PV for heat generation. These systems capture solar radiation as heat rather than electricity, and transferred through a working fluid as water or antifreeze solution, and used in space heating, domestic hot water (DHW) in the home, absorption cooling in advanced systems. Where solar collectors absorb heat, the collectors gives free access of the fluid as heat exchanger transfers energy to storage tank thus making hot water to be distributed within the building. A good example is the Drake Landing Solar Community in Canada that achieves over 90% of its space heating through solar thermal energy stored underground and giving a lower cost per unit of energy.

• *Wind Energy Systems*

Wind turbines integrated into high-rise structures can generate electricity using wind currents at higher altitudes. That is kinetic energy of moving air is converted into electricity by using the turbines. The consistent airflow rotates blades, driving a generator expressing power output as directly proportional to the wind speed.

This is achievable on high-rise building when small-scale turbines mounted on rooftops or slabs, on vertical-axis turbines for urban environments and integrated design to channel wind. It comes with challenges on the building like noise and vibration and also given to the fact of its high structural integration complexity. The Bahrain World Trade Center integrates three large wind turbines between its twin towers, generating part of the electricity demand of the building.

• *Geothermal Energy*

It operates on the heat transfer principle that is heat flow from warmer to cooler regions making it have stable performance regardless of weather. It utilizes the relatively stable temperature of the ground for heating and cooling via ground-source heat pumps (GSHPs), where in cooling mode, heat is extracted from the high-rise building and transferred into the ground, likewise heat being drawn from the ground into the building in heating mode. This system can either be a closed-loop system that is seen in vertical and horizontal boreholes, or open-loop system derived through groundwater. Studies shows the One Angel Square uses this system with other renewables to achieve low operational energy use. These systems are shown in the table below as;

Table 1 Comparative Insight on Active Renewable System Conversion Partway

System	Energy Source	Output Form	Efficiency Range	Best Use
Solar PV	Solar radiation	Electricity	15-22%	General power
Solar Thermal	Solar radiation	Heat	40-70%	Heating
Wind Energy	Kinetic wind energy	Electricity	20-45%	Windy sites
Geothermal	Earth's heart	Heating/cooling	COP 3-5+	HVAC

**VI. DESIGN INTEGRATION APPROACHES**

Effective integration of renewable systems requires careful planning and coordination between architectural and engineering design processes. Building-Integrated Photovoltaics (BIPV) allow solar panels to function as part of the building envelope, replacing conventional façade materials. Renewable façade systems can also incorporate shading devices and energy-generating components. Hybrid energy systems combine multiple renewable technologies, such as solar and wind energy, to enhance overall efficiency. Smart energy management systems further optimize energy use by monitoring building performance and adjusting systems automatically.

Several high-rise buildings around the world demonstrate successful integration of renewable design strategies.

The Bahrain World Trade Center is one of the first skyscrapers to incorporate wind turbines into its structure. Three large turbines positioned between the towers generate a portion of the electricity in the building.

Another example is the Pearl River Tower, which integrates wind turbines, solar panels, and advanced ventilation systems to significantly reduce energy consumption.

Similarly, the Bosco Verticale integrates vegetation into its façade, improving thermal insulation and air quality while reducing energy demand.

The Shanghai Tower incorporates multiple sustainable features including double-skin façades, wind turbines, and rainwater harvesting systems.

These analysis reveals that integrating renewable design strategies can significantly reduce energy consumption in high-rise buildings. Where passive design strategies play a crucial role in reducing initial energy demand, and active renewable systems provide sustainable energy generation.

However, several challenges remain. High initial investment costs and technological complexity can discourage developers from adopting renewable systems. Additionally, climatic conditions and urban density may limit the effectiveness of certain renewable technologies.

Despite these challenges, the long-term environmental and economic benefits of renewable integration outweigh the initial costs. As technology continues to advance, renewable systems are expected to become more efficient and affordable.

**VII. IMPLICATIONS FOR ARCHITECTURAL PRACTICE**

The vital implementation for practice includes the prioritizing of renewable energy integration during the early stages of building design by considering building orientation, façade design, and energy systems simultaneously is important by collaboration among architects, engineers, and sustainability consultants to ensure effective integration of renewable technologies. Policymakers should also provide incentives and regulations that encourage sustainable building practices.

**VIII. CONCLUSION**

High-rise buildings play a significant role in modern urban development but are also associated with high energy consumption. Integrating renewable design approaches provides an effective strategy for improving the energy performance of these structures.

This study highlights the importance of combining passive design strategies with active renewable technologies to achieve sustainable high-rise buildings. Buildings looked

into demonstrate that innovative architectural design and advanced technologies can significantly reduce energy consumption while maintaining functionality and aesthetic quality.

Future research should explore emerging renewable technologies and their potential applications in high-rise architecture, particularly in rapidly developing urban regions.

## REFERENCES

- [1]. Agboola, S., Idowu, F., Yusuf, F., & Musa, A. (2024). Barriers to Sustainable Green Building Practice in Nigeria. *Fudma Journal of Sciences*. <https://doi.org/10.33003/fjs-2023-0706-2114>.
- [2]. Ayodele, T., Ogunjuyigbe, A., & Nwakanma, K. (2021). Solar energy harvesting on building's rooftops: A case of a Nigeria cosmopolitan city. *Renewable Energy Focus*, 38, 57-70. <https://doi.org/10.1016/j.ref.2021.06.001>.
- [3]. Barber, K., & Krarti, M. (2022). A review of optimization based tools for design and control of building energy systems. *Renewable and Sustainable Energy Reviews*. <https://doi.org/10.1016/j.rser.2022.112359>.
- [4]. Bodo, T. (2019). Rapid Urbanisation: Theories, Causes, Consequences and Coping Strategies. *Annals of Geographical Studies*. <https://doi.org/10.22259/2642-9136.0203005>.
- [5]. Byulegenova, B., & Turemuratov, O. (2023). Urbanization as a global trend: causes and consequences. *BULLETIN of the L.N. Gumilyov Eurasian National University. Political Science. Regional Studies. Oriental Studies. Turkology Series..* <https://doi.org/10.32523/2616-6887/2023-142-1-37-42>.
- [6]. Chen, X., Huang, J., Yang, H., & Peng, J. (2019). Approaching low-energy high-rise building by integrating passive architectural design with photovoltaic application. *Journal of Cleaner Production*. <https://doi.org/10.1016/j.jclepro.2019.02.137>.
- [7]. Chen, X., Yang, H., & Peng, J. (2019). Energy optimization of high-rise commercial buildings integrated with photovoltaic facades in urban context. *Energy*. <https://doi.org/10.1016/j.energy.2019.01.112>.
- [8]. Dada, A., & Alibaba, H. (2023). Comparison analysis between the components of vernacular and modern architectures for sustainable housing in Niger State. *IOP Conference Series: Earth and Environmental Science*, 1210. <https://doi.org/10.1088/1755-1315/1210/1/012011>.
- [9]. Elaouzy, Y., & Fadar, E. (2022). Energy, economic and environmental benefits of integrating passive design strategies into buildings: A review. *Renewable and Sustainable Energy Reviews*. <https://doi.org/10.1016/j.rser.2022.112828>.
- [10]. Fathi, M. (2024). Sustainability and Energy Efficiency in Buildings: A Review. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*. <https://doi.org/10.1061/jladah.ladr-1110>.
- [11]. Gerald, M., & Ghisi, E. (2020). Building-level and stock-level in contrast: A literature review of the energy performance of buildings during the operational stage. *Energy and Buildings*, 211, 109810. <https://doi.org/10.1016/j.enbuild.2020.109810>.
- [12]. Kalu, G., Ogunnaike, A., & O., E. (2025). Integrating Biophilic and Passive Design Strategies in Nigerian Architecture. *African Journal of Environmental Sciences and Renewable Energy*. <https://doi.org/10.62154/ajesre.2025.019.01030>.
- [13]. Konis, K., Gamas, A., & Kensek, K. (2016). Passive performance and building form: An optimization framework for early-stage design support. *Solar Energy*, 125, 161-179. <https://doi.org/10.1016/j.solener.2015.12.020>.
- [14]. Li, X., Zhou, Y., Eom, J., Yu, S., & Asrar, G. (2019). Projecting Global Urban Area Growth Through 2100 Based on Historical Time Series Data and Future Shared Socioeconomic Pathways. *Earth's Future*, 7, 351 - 362. <https://doi.org/10.1029/2019ef001152>.
- [15]. Najjar, M., Figueiredo, K., Hammad, A., & Haddad, A. (2019). Integrated optimization with building information modeling and life cycle assessment for generating energy efficient buildings. *Applied Energy*. <https://doi.org/10.1016/j.apenergy.2019.05.101>.
- [16]. Ochedi, E., & Taki, A. (2021). A framework approach to the design of energy efficient residential buildings in Nigeria. *Energy and Built Environment*. <https://doi.org/10.1016/j.enbenv.2021.07.001>.
- [17]. Oyediran, A., Akinradewo, O., Onososen, A., & Koriko, O. (2025). Key factors contributing to construction delays in high-rise building projects: a case study of Nigeria's developing urban landscape. *Journal of Facilities Management*. <https://doi.org/10.1108/jfm-05-2024-0056>.
- [18]. Qiu, Z., Yong, Q., Wang, J., Liao, L., & Yu, B. (2024). A multi-objective optimization framework for performance-based building design considering the interplay between buildings and urban environments. *Energy Conversion and Management*. <https://doi.org/10.1016/j.enconman.2024.118793>.
- [19]. Seminara, P., Vand, B., Sajjadian, S., & Tupénaité, L. (2022). Assessing and Monitoring of Building Performance by Diverse Methods. *Sustainability*. <https://doi.org/10.3390/su14031242>.
- [20]. Sirror, H. (2024). Lessons Learned from the Past: Tracing Sustainable Strategies in the Architecture of Al-Ula Heritage Village. *Sustainability*. <https://doi.org/10.3390/su16135463>.
- [21]. Tamošaitienė, J., & Gaudutis, E. (2013). COMPLEX ASSESSMENT OF STRUCTURAL SYSTEMS USED FOR HIGH-RISE BUILDINGS. *Journal of Civil Engineering and Management*, 19, 305-317. <https://doi.org/10.3846/13923730.2013.772071>.
- [22]. Tunji-Olayeni, P., & David, S. (2024). Barriers Hindering Green Building Materials Adoption in the Nigerian Construction Industry. *The Journal of Solid Waste Technology and Management*. <https://doi.org/10.5276/jswtm/iswmaw/503/2024.577>.

- [23]. Unegbu, H., Yawas, D., Dan-Asabe, B., & Alabi, A. (2025). Advancing Sustainable Construction in Nigeria: A Critical Review of Progress, Challenges, and Future Direction. *Jurnal Pengabdian KOLABORATIF*.  
<https://doi.org/10.26623/kolaboratif.v3i2.10358>.
- [24]. Zhao, Z. (2023). Mechanical Performance and Selection Study of High-Rise and Super High-Rise Building Structural Systems. *Highlights in Science, Engineering and Technology*.  
<https://doi.org/10.54097/556pgq43>.