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Assessment of energy efficiency strategies in mid-rise office building in Lagos State

Olamilekan A Yussuff [1*], Bibitayo T Oluwasina [2], Daniel O George [3]

[1-3] College of Postgraduate Studies, Department of Architecture, Caleb University Imota Lagos State, Nigeria

* Corresponding Author: **Olamilekan A Yussuff**

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Abstract

The assessment of energy efficiency strategies in mid-rise office buildings in Lagos addresses the pressing need to mitigate energy consumption and greenhouse gas emissions in urban environments. As commercial buildings, including mid-rise offices, continue to expand in Lagos, there's a growing urgency to adopt sustainable practices to curb energy demand. This study focuses on identifying and evaluating energy efficiency strategies in mid-rise office buildings within Lagos, Nigeria, considering factors such as building orientation, envelope design, and renewable energy utilization. Two case studies, Nestoil Tower and Number One Building, were selected using non-random purposive sampling based on specific criteria. The research methodology primarily employed qualitative techniques, including observation and structured interviews. Findings reveal that both buildings implement passive measures and technological integrations to enhance energy efficiency, such as efficient building spatial orientation, effective lighting and ventilation systems, and integration of smart building automation systems. However, disparities exist in the availability and efficiency of certain technologies, highlighting the need for further improvement. Nestoil Tower excels in solar energy integration, while Number One Building demonstrates potential for enhancement in renewable energy utilization. Despite these variations, both buildings prioritize low energy consumption appliances and equipment. Based on these findings, recommendations are proposed to enhance renewable energy integration, improve smart technology integration, and promote a culture of energy efficiency in mid-rise office buildings in Lagos. By implementing these recommendations, stakeholders can contribute to the reduction of energy consumption and greenhouse gas emissions, fostering a sustainable built environment in Lagos and beyond.

Keywords: energy efficiency, mid-rise office building and Lagos State

1. Introduction

Globally, buildings are significant contributors to energy consumption and greenhouse gas emissions. This is particularly true for urban areas, where commercial buildings, including mid-rise offices, play a crucial role in energy usage. Lagos, being one of the largest and fastest-growing cities in Africa, faces unique challenges related to energy supply, infrastructure, and sustainability. The demand for energy in commercial buildings is escalating due to economic growth and urbanization. Mid-rise office buildings are prevalent in urban landscapes, representing a significant portion of the commercial real estate sector. Their energy usage patterns and efficiency can have a substantial impact on overall energy consumption in a city. Energy efficiency involves the optimization of energy use through a combination of passive solar design, energy-efficient equipment, and renewable energy sources (Gupta & Chakraborty, 2021) [12]. It involves various optimization of energy use throughout a building's lifecycle, from construction to operation and maintenance (Anna *et al*., 2019) [3].

In most office building the use of Building envelope systems, building orientation, integration of renewable energy sources and day lighting design strategies were most implemented in office buildings as a means of energy efficiency system (Aderonmu *et al*., 2019) [1].

And also the use of as well as the use of sustainable technology to limit heat loss and gain, improve ventilation, and increase daylight availability (Erebor *et al*., 2021) [9]. The energy efficiency percentage in building as cited by Erebor *et al*., (2021) [9] revealed that office buildings exhibit a concerning 36% level of energy use and consumption which is more than non-residential buildings which consuming approximately 27.5% of the overall energy. Thus, the construction of an energy-efficient building necessitates an initial focus on design, emphasizing the importance of adopting an appropriate approach. In mid- rise office building, the need for a better energy strategies design which can reduce the total energy consumption in these building arises. Several studies have suggested the need for greater adoption of energy efficiency strategies in mid and high-rise office buildings, particularly in the areas of building orientation, envelope design, and renewable energy use. That mid-rise office building (Ezema & Maha, 2022) [10]. Mid-rise office buildings come in various architectural styles and designs. Common types include contemporary glass facades, modernist structures, and mixed-use buildings that combine offices with retail spaces. These building which naturally utilized high energy consumption because of it high number of floors such as in 5 to 10 storey building uses a lot of energy. Energy-efficient solutions in sustainable office buildings can positively impact employee well-being and performance (Kozusznik *et al*., 2019) [15]. The increase in energy demand with the simultaneous complication and rise in the cost of energy production have made energy conservation and energy efficiency the most important development areas in many countries of the world (Sekisov, 2021) [19]. However, the Increased in natural ventilation and other architectural design parameters can also increase energy efficient in building (Kamal & Ahmed, 2023) [14].

Energy-efficient buildings are required to fulfill additional design objectives, such as improving the well-being of occupants, optimizing their utilization of water, energy, and other resources, and mitigating the significant environmental impacts of the building. Consequently, numerous countries are formulating building codes that prioritize design solutions for energy efficiency. Many of these codes acknowledge the adoption of bioclimatic design concepts and principles, integrating various measures to save energy (Erebor *et al*., 2021) [9]. Lagos state which is a home to most mid-rise building in Nigeria, because of its available economy hubs and it economy population serves as a study area and a case study for this study with a study focus on only mid-rise office building within the state. A lot of energy efficiency strategies method have been identified by several studies such as (Aderonmu *et al*., 2019; Erebor *et al*., 2021; Ezema & Maha, 2022) [1, 9], however strategies to mod-rise office building in the study area have not been extensively identified and analyze. Therefore, these study focuses on the identification of the available energy efficiency strategies in mid-rise office building in Lagos, and assess the most suitable energy efficiency strategies for mid-rise building in Lagos state.

2. Literature Review

2.1. Building Energy Efficiency

Enhancing energy efficiency plays a crucial role in the worldwide initiative to decrease CO_2 emissions. The objective is to decrease primary energy consumption by 11% to 20% within the next decade and by 30% to 41% by the year 2050 (Erebor *et al*., 2021) [9]. Energy efficiency in buildings involves minimizing energy waste and reducing overall consumption of primary energy resources (Bhattarai *et al*., 2019). It can also be link energy consumption pertains to the quantity of energy utilized for heating, ventilation, and lighting within structures (Chegut *et al*., 2019) [6]. Energy efficiency serves as an approach to attain environmentally friendly design by diminishing greenhouse gas emissions, leading to cost savings and a decrease in the overall life-cycle expenses of a building. This is commonly accomplished through the incorporation of advanced technological manufacturing processes in designing materials, equipment, or appliances. These processes aim to curtail energy consumption or demand, or by employing established strategies to minimize energy loss or wastage (Ezema & Maha, 2022) [10]. An energy-efficient building balances all aspects of energy use in a building by providing an optimized mix of passive solar-design strategies, energy-efficient equipment, and renewable sources of energy (Gupta & Chakraborty, 2021) [12]. Energy efficiency first emerged in the EU energy policy agenda in the 1970s (Marina *et al*., 2020) [16]. The design with energy-efficient measures and renewable energy systems was found to be economically attractive for residential sector in most climate (Al-Badi & Al-Saadi, 2020) [2].

A building is considered energy-efficient if it effectively utilizes energy resources to meet its operational needs while minimizing waste and environmental impact. Key characteristics of energy- efficient buildings include: Optimal Insulation which Proper insulation helps regulate indoor temperatures, reducing the need for excessive heating or cooling, High-Efficiency HVAC Systems such as Heating, ventilation, and air conditioning (HVAC) systems designed for energy efficiency minimizing energy consumption., Energy-Efficient Lighting with the use of LED or other energy-efficient lighting technologies helps reduce electricity consumption, Smart Building Controls with Automated systems for lighting, temperature control, and other building functions help optimize energy usage based on occupancy and usage patterns, Renewable Energy Integration such as renewable energy sources such as solar panels or wind turbines contributes to the overall energy efficiency of a building. Energy-Efficient Windows and Doors that help in controlling heat gain or loss, improving overall energy performance. Also advanced Building Materials with high thermal mass or other advanced properties contributes to the energy efficiency of a structure, Energy-Efficient Appliances and Equipment throughout the building further reduces overall energy consumption, Water Efficiency Measures and Thoughtful architectural design and proper orientation of the building can enhance natural lighting, reducing the need for artificial lighting and improving overall energy efficiency.

2.2. Energy Efficiency Strategies in Office Building

Design strategies for energy efficiency pertain to the measures and characteristics embedded during the initial design phase of buildings to enhance their effectiveness in utilizing energy for lighting, heating, and ventilation. These strategies may be incorporated into building projects from the outset or introduced during the renovation of older structures. According to Erebor *et al*, (2021) [9], the adoption of energy-efficient design strategies, especially in office buildings, has gained prominence due to existing building codes and corporate policies that prioritize environmental protection. A range of strategies have been identified to improve energy efficiency in buildings. Erebor (2021) [9] highlights the importance of design, planning, and construction phases, with a focus on building envelope systems, orientation, and renewable energy integration. Passive measures in the design features of the building envelope can help reduce the overall energy consumption of the building without compromising the occupants' comfort level (Gondal *et al.*, 2019) [11]. The impact of passive renovation suggestions, such as orientation and insulation material, in achieving significant energy savings in existing buildings (Salah & Tuna Kayili, 2021) [18]. In office building energy efficiency strategies is summarized in the table below.

Table 1: Building energy efficiency strategies is summarized

S.N.	Categories of Energy Efficiency	Strategies
1	Passive Measures	Building Spatial Orientation
		Ventilation system
		Building location
		Building Material
		Thermal insulation
		Landscape design
		Façade and shading device
		Building shape and form
2	Technologies Integration	Smart Building Automation Systems (BAS) such as door, lightning and HVAC
		Occupancy Sensors
		Energy Management Systems (EMS)
		Smart Blinds and Shades
		Digital Signage such Interactive and dynamic displays used for wayfinding, announcements, and information sharing within the building.
		IoT (Internet of Things) Connectivity
		Voice-Activated Assistants and Facial Recognition Systems
3	Renewable Energy Integration	Solar energy (Photovoltaic cells)
		Wind energy
		Bio-Fuel
		Hydro energy
		Geo-thermal energy
4	Energy Appliance	Low energy consumption appliance and equipment

Source: (Erebor *et al.*, 2021; Ezema & Maha, 2022) [9, 10]

2.3. Factors influencing energy efficiency in mid-rise office buildings

Several factor influences the energy efficiency usage and optimization in in building, these factor include architectural, natural, technology and human factor also Building characteristics, equipment and technologies, and occupant's behaviors are key influencing factors on energy efficiency design in mid-rise office buildings (Chen *et al.*, 2020) [7].

1. Architectural Factors

The design and orientation of the building significantly impact its exposure to natural light, heat gain, and airflow. Careful consideration of insulation and the building envelope, including walls, roof, and windows, is essential for regulating internal temperatures and minimizing energy demand for heating and cooling(Chen *et al.*, 2020) [13]. Window design and glazing choices influence natural lighting, heat transfer, and overall energy efficiency. The efficiency of the HVAC system, encompassing both design and technological aspects, is crucial for maintaining optimal indoor conditions while minimizing energy consumption. Additionally, the integration of renewable energy sources and the selection of energy-efficient building materials contribute to the overall sustainability and energy performance of the structure. Influential factors in architectural design affecting the light and heat environment of office buildings should be considered for optimized energy-saving design (Ding & Guo, 2021) [8].

2. Human Factors

Human factors are integral to the energy efficiency of mid-rise office buildings. Occupant behavior plays a crucial role as habits and practices influence energy consumption patterns (Chen *et al.*, 2020) [7].

Educating and raising awareness among occupants about energy-efficient practices contribute to responsible energy use. Social-psychological and contextual factors influence occupants' intention to conform to the norms of sharing environmental control features, which significantly influence building energy consumption (Chen *et al.*, 2020) [13] The implementation of occupancy sensors and controls, coupled with proper training for building management and maintenance staff, ensures that energy- efficient systems are operated effectively. Additionally, collaborative workspace design that promotes shared resources and efficient use of space can positively impact energy usage. Occupant personality types, control feature accessibility, and group dynamics are the three most influential factors determining human-building interactions in shared offices (Hong *et al.*, 2020) [13].

3. Technology Factors

Technology factors help enhancing the energy efficiency of mid-rise office buildings. Smart building automation systems (BAS) enable comprehensive control and optimization of various building functions, including HVAC, lighting, and security. Energy management systems (EMS) leverage software platforms to monitor, analyze, and optimize energy consumption data, providing valuable insights for informed decision-making. The integration of Internet of Things (IoT) devices allows for real-time monitoring and control, fostering energy-efficient operations. Smart grid integration enables adaptive energy consumption based on real-time demand and pricing, contributing to overall efficiency. The Smart Integrated

Workspace Design (SIWD) framework, integrating IoT technology into the Value Engineering process, resulted in an 18% improvement in building energy performance and quality (Berawi *et al*., 2023) [4]. The implementation of energy-efficient appliances, renewable energy technologies, and advanced lighting controls further leverages technology to minimize energy consumption. Building energy monitoring systems continuously track energy usage, providing occupants with real-time feedback to encourage responsible energy use.

4. Natural Factors

Natural factors are essential contributors to the energy efficiency of mid-rise office buildings. The local climate and microclimate conditions significantly influence the heating and cooling needs of the building, impacting overall energy demand. The availability and utilization of natural daylight play a major role in reducing reliance on artificial lighting and positively affect energy consumption. Wind patterns, when considered in design, can enhance natural ventilation opportunities, potentially reducing dependence on mechanical HVAC systems. The solar exposure of the building site and its orientation affect heating, cooling, and the potential for integrating solar energy generation technologies. Thoughtful landscaping and greenery around the building contribute to shading, insulation, and overall energy efficiency. Embracing natural ventilation opportunities through well- designed spaces with operable windows further enhances the energy performance of the building. Geographical location influences the availability of renewable energy resources and informs considerations for sustainable building practices Therefore there is need to maximize the use of daylighting and natural ventilation systems to reduce energy consumption (Rahim & Quraisy, 2021) [17].

3. Methodology

The study only adopted the use of qualitative research method in evaluate the energy efficiency measure put in place within the selective case study. The study primarily focus on observation and structural interviews as a means of research techniques. In choosing the respective case study, non-random purposive sampling method was utilized. The selective case-study was choose using selected criteria such as building height, umber of floors, accessibility to the building environment, and the type of occupancy within the office building and it relationship with LEED Certification. Ethical constraint was also put in place when conducting the study within the case study. For this study two selected mid-rise building were chosen as the case study, which include

1. Nestoil Tower, Victoria Island Lagos state.
2. Number One (IMB Plaza) Victoria Island, Lagos, state.

4. Study Finding

The result to the study finding is summarized below, with each of the respective finding been analyzed from the study observation guild as expressed in table 1 below

4.1. Nestoil Tower, Victoria Island Lagos state

Nestoil tower is a fifteen-storey building located in Victoria Island Lagos, Nigeria, it was completed in the year 2016 and is owned by Nestoil Ltd, an indigenous Nigeria Oil and Gas Company. The tower has a total floor space of 21,000 square meter and is one of the mid-rise buildings in Lagos, it is an energy conserved building and has been awarded Leadership in energy and environment design (LEED) gold certificate. For its sustainable design feature, the tower has modern design with a glass façade and an open plan interior layout. It also has won several awards for it architectural design. It unique architectural features include unique architectural Feature: Sleek and Modern design, Helix- shaped design, Sky gardens, Vertical landscape, distinct Diamond- pattern glass façade and the employment of green technologies, It is a mixed-use building mainly for recreational activities, play and plug internet facilities, office spaces, multi storey parking facilities and for residential purposes.

***Source*:** Nestoil group

Fig 1: Exterior view

***Source*:** field survey

Plate 1: Interior view

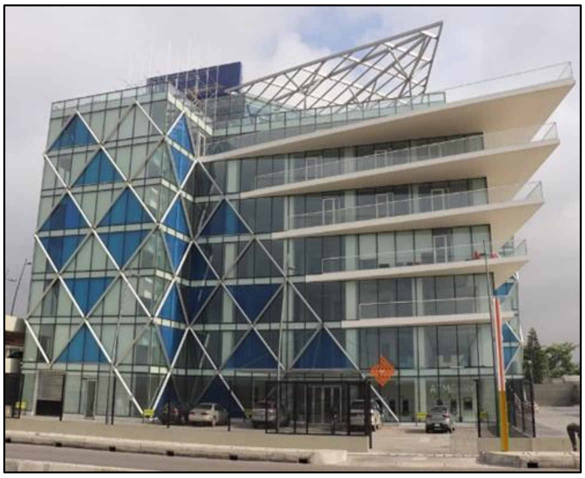
Observation and interview finding on Nestoil Tower

Table 2: The available energy strategies are indicated with ✓ while non-availability is indicated with ●

Categories	Strategies	Availability	Observe efficiency comment
Passive Measures	Building Spatial Orientation	✓	Efficient proper wall per wall space
	Lightning and Ventilation system	✓	High and efficiency ventilation with the use of both natural ventilation with a lot of widows opening aiding lightnings
	Building Material	✓	Highly efficient building material such as glass facade
	Thermal insulation	✓	High efficiency thermal insulation
	Landscape design	✓	Better landscape design with sky view
	Facade and shading element	✓	Efficient facade and shading element
	Building shape and form	✓	excellent building shape and form
Technologies Integration	Smart Building Automation Systems (BAS) such as door, lightning and HVAC	✓	High-Efficient BAM with availability of smart door and smart lightning system and proper HVAC system
	Occupancy Sensors	✓	Lass efficiency occupancy sensor
	Energy Management Systems (EMS)	✓	Efficiency energy management system
	Smart Blinds and Shades	●	Non-availability of smart blind and shade
	Digital Signage such Interactive and dynamic displays used for way finding, announcements, and information sharing within the building.	✓	Less efficiency digital signage within the facilities
	IoT (Internet of Things) Connectivity	✓	High efficiency in internet of things network
	Voice-Activated Assistants and Facial Recognition Systems	●	Non-availability of voice- activated assistant and facial recognition system
Renewable Energy Integration	Solar energy (Photovoltaic cells)	✓	High efficiency in solar energy system
	Wind energy	●	Non-availability of wind energy system
	Bio-Fuel	●	Non-availability of bio-fuel
	Hydro energy	●	Non-availability of hydro-energy
	Geo-thermal energy	●	Non-availability of Geo-thermal energy
Energy Appliance	Low energy consumption appliance and equipment	✓	Highly efficient energy appliance which lead to reduction in waste energy

4.2. Number One (IMB Plaza) Victoria Island, Lagos, state

Number one building formerly known as IMB Plaza is a mid-rise six stories building located at Victoria Island Lagos state. The building occupied a total floor space of 11,261 sqm of Gross Built Area and approximately 8,700 sqm of Gross Lettable Area. The building houses several office buildings which include: Broll Property Services Limited, Access Bank, Kaly Restaurant on the last floor, and Amazon Web Services. The building is fully equipped with smart door, smart lighting system with the combination of natural ventilation and lightning. It also has two-floors 5,000sqm parking building, installation of a new MEP system and security equipment. Its architectural building includes efficient lighting system, Adequate natural lightning, proper building insulation and orientation better energy efficient heating, ventilation and air conditioning system, (HVAC).



Source: Crane burg

Fig 2: Exterior view

Source**:** Crane burg

Fig 3: Interior view

Table 3: Observation and interview finding on Number One Building

Categories	Strategies	Availability	Observe efficiency comment
Passive Measures	Building Spatial Orientation	✓	Efficiency and better spatial orientation and wall to wall ratio around corridor.
	Lightning and Ventilation system	✓	Highly efficient ventilation and lightning system within the building.
	Building Material	✓	Better building material
	Thermal insulation	✓	Efficient thermal insulation mechanism
	Landscape design	✓	Better building landscape design
	Façade and shading element	✓	Highly efficient faced and shading element
	Building shape and form	✓	Excellent building shape and form
Technologies Integration	Smart Building Automation Systems (BAS) such as door, lightning and HVAC	✓	Highly-efficiency BAS with highly secure doors and security system with proper HVAC mechanism
	Occupancy Sensors	✓	Efficient occupancy sensor
	Energy Management Systems (EMS)	✓	Better EMS system
	Smart Blinds and Shades	✓	Highly efficient smart Blinds and shade
	Digital Signage such Interactive and dynamic displays used for way finding, announcements, and information sharing within the building.	✓	Efficient digital signage and interactive display.
	IoT (Internet of Things) Connectivity	✓	Better connectivity between IoT
	Voice-Activated Assistants and Facial Recognition Systems	✓	Efficient voice-activated assistant with less facial recognition systems
Renewable Energy Integration	Solar energy (Photovoltaic cells)	✓	Efficient solar energy system
	Wind energy	•	Non- availability of wind energy
	Bio-Fuel	•	Non-availability of bio-fuel
	Hydro energy	•	Non-availability of Hydro-energy
	Geo-thermal energy	•	Non-availability of geo-thermal energy
Energy Appliance	Low energy consumption appliance and equipment	✓	Highly efficient energy appliance which lead to reduction in waste energy

4.3. Discussion of Finding

The findings from the observation and interviews conducted at both Nestoil Tower and Number One Building shed light on various factors influencing energy efficiency in mid-rise office buildings. Both buildings exhibit a range of passive measures and technological integrations aimed at enhancing energy efficiency. In terms of passive measures, both buildings demonstrate efficient building spatial orientation, effective lightning and ventilation systems, and utilization of high-quality building materials, thermal insulation, landscape design, facade, and shading elements. Additionally, they integrate advanced technologies such as Smart Building Automation Systems (BAS), Energy Management Systems (EMS), and IoT connectivity to optimize energy usage and enhance operational efficiency. However, discrepancies exist in the availability and efficiency of certain technologies. Nestoil Tower boasts a highly efficient smart lighting system and a robust solar energy integration, whereas Number One

Building excels in smart blinds and shades integration and efficient digital signage. Both buildings prioritize low energy consumption appliances and equipment. While renewable energy integration varies, with Nestoil Tower embracing solar energy and Number One Building demonstrating potential for improvement in wind, bio-fuel, hydro-energy, and geo-thermal energy systems. Overall, the findings show the importance of a comprehensive approach that combines passive design strategies with advanced technologies to achieve optimal energy efficiency in mid-rise office buildings.

5. Conclusion

The assessment of energy efficiency strategies in mid-rise office buildings in Lagos highlights several key findings. Both Nestoil Tower and Number One Building exhibit commendable efforts in integrating passive measures and advanced technologies to enhance energy efficiency. These include efficient building spatial orientation, effective lightning and ventilation systems, utilization of high- quality building materials, and integration of Smart Building Automation Systems (BAS) and Energy Management Systems (EMS). However, discrepancies exist in the availability and efficiency of certain technologies, such as smart blinds and shades and renewable energy systems. While Nestoil Tower excels in solar energy integration, Number One Building demonstrates potential for improvement in wind, bio-fuel, hydro-energy, and geo-thermal energy systems. Nevertheless, both buildings prioritize low energy consumption appliances and equipment. The following are the Recommendation derive from the study.

1. Enhance Renewable Energy Integration: Both buildings should explore opportunities to further integrate renewable energy sources such as wind, bio-fuel, hydro-energy, and geo-thermal energy. This would diversify energy sources, reduce reliance on conventional energy, and enhance sustainability.
2. Improve Smart Technology Integration: Address the gaps in smart technology integration, particularly in areas such as smart blinds and shades, occupancy sensors, and digital signage. Implementing these technologies can optimize energy usage and improve occupant comfort and experience.

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