EVALUATION OF BIOCLIMATIC PRINCIPLES IN DESIGN OF TROPICAL HIGH-RISE DWELLINGS – CASE STUDIES FROM AFRICA

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Abstract

High-rise dwellings provide a unique solution for maximizing urban land use. With the increase in climate consciousness and the demand for energy-efficient buildings globally, saving the environment is the most vital issue that humankind must address today; thus designing ecologically is crucial. The bioclimatic approach to high-rise building design has been put forward as a vehicle for achieving energy-efficient and climate considerate tall buildings. However, a lot is yet to be understood regarding the performance of existing high-rise building stock. The aim of this study was to conduct a pilot survey to evaluate the application of bioclimatic design principles in high-rise residential buildings in the hot-humid tropical climate of Nigeria through a participatory survey of the stakeholders in three high-rise building complexes. Primary data was collected for the study by physical observation, field measurement and interviews of the residents and management. Secondary data was obtained from existing literature published by the estate management as well as literature already in the public domain. Results showed that building envelope and orientation, solar shading, and indoor air quality were the most provided while Energy efficiency and heating/cooling and sustainable landscape were the least provided in the three studied complexes. Eko Atlantic Towers (Black pearl and Champagne pearl), showed the highest mean weighting of 1.27 (38%) compared to the #4 Bourdillon 1.18 (35%) and Eko-Court towers 0.93(27%) respectively. Eco court tower had the least provision for bioclimatic design principles. With a collective mean weight value of 1.13 (low provision), the study reveals that the design of high-rise residential buildings in the study area did not fully take into cognizance the application of bioclimatic principles. The study recommends active legislative action toward enacting and implementing bioclimatic design principles in the design of future high-rise buildings in the study area.

Keywords: bioclimatic, climate, high-rise dwellings, tropical design

INTRODUCTION

Tall buildings are resource-intensive due to the excessive scale and complexity of design (Parker & Wood, 2013). Different research have shown the energy performance of high-rise buildings to be higher than that of low and mid-rise buildings of similar floor dimensions in similar locations (Wood & Ruba, 2013). The studies further reveal that the increase in energy consumption of high-rise structures is linkable to the increased use of heating, ventilation, and air-conditioning (HVAC) systems.

Scholars suspect this is due to the increased energy demands to transport and pump materials and services up the building's floors working against gravity, additional energy consumption for the mechanized movement of people up and down its elevators and increased use of air conditioning to sustain ventilation and air quality on higher floor levels.

The design, building, and operation of high-rise buildings today continue to grow more complex and increasingly technology-intensive in all ramifications. Supertall buildings are now equipped with adaptive design and technology to help them withstand impact of the natural elements such as wind as they tower into the sky. Smart adaptive facades have been developed to shield, track and harness solar energy for supporting the building's energy use for example; the AL Bahr tower in UAE (Attia, 2017). Energy conservation has indeed become non-negotiable in today's high-rise buildings, as no one wants tall buildings that are too costly to maintain or that depend solely on fuels that damage the ozone layers.

In response to this, bioclimatic skyscrapers are designed to employ design strategies that help make sure buildings adapt to their local climate in terms of form, shape, materials, and orientation as well as adopt the local flora of the site for improved ventilation (Yeang, 2000). When it comes to the issue of high-rise buildings in the tropics, of notable significance is the work by Asian Architect Ken Yeang, who is renowned for his interests in ecological architecture and the climate of the tropics. His involvement in design and construction of commercial high-rise building typology has accorded him the opportunity to gather great experience on the subject, which he has crystallized and published as a set of guiding principles with which he designs tall buildings, globally.

His work, Solaris, located in Singapore, exemplifies how a high-rise building can go up literally with the local flora of the site thus providing the occupants at the higher floors with fresh air and a cooling effect made possible through the interaction between plants and the residents. He further posits that the idea of the tropical high-rise should be a tall building whose built forms design and planning have responses to and take advantage of the climatic and ecological factors of the locality (Yeang, 2000).

Yeang (1996), cited in Cook (1997), summarizes the guiding principles for designing a truly tropical high-rise building. This includes; the presence of open-to-air ground floor areas, the use of multi-storey atria that are open or semi open at the top or corners, the adoption of the building core at the east and west sides of the buildings, placement of curtain walls on the north and south faces, the use of recessed sun spaces and use of environmentally interactive walls.

When a skyscraper is referred to as "bio-climatic" it is expected to have a number of indicators that point to this. In other words, the indicators of bio-climatism should be observably evident in such building. The word bio-climatic or bio-climatism is formed with two syllables, which are biology and climate. "Bio" in this case refers to the humans, plants and animals of the place while "climatic" refers to the elements of the local weather (and by extension, climate) of the place. Hence, for a building to be truly bio-climatic, it must be done in a manner that is sustainable for the indigenous people, plants and animals as well as it must be in agreement with the local climate of the place. Some of Yeang's bio-climatic towers are shown in Figure 1.

Figure 1: Cross-section of some bio-climatic towers by Ken Yeang

Source: (Yeang & Powell, 2007)

Top left: BIDV-Tower-Vietnam, Top center and down left: Chong Qing Tower China, Top right: Solaris tower Singapore, Down center: Eco-Bay Complex Abu Dhabi, Down right: K-Tower-Kuwait.

The key ecological concepts applied in the buildings shown in Figure 1 include;

i. Deep sun-shading louvres to block direct sunlight during the hot months of the year.
ii. Roofs are covered in vegetation to prevent rooftop solar heat gain.
iii. Long and narrow floor plates to create optimal conditions for natural ventilation.
iv. Vertical gardening, evaporative cooling, green atriums and roof gardens.
v. A combined system of natural ventilation, evaporative cooling and shading systems.
vi. Use of wind walls and operable windows.
vii. Form modifications to adapt to wind.
viii. Solar energy use (photovoltaic panels) and sun-shading devices.
ix. Rainwater harvesting and recycling.
x. Use of wind funnels, eco cells, sky courts.
xi. Application of the loose-fit design philosophy.

According to Sarkar (2010), as well as Folaranmi , Philip, Stephen, and Buhari (2013), the major indicators of bio-climatism include building envelop and orientation, energy source, sun shading device, passive design, indoor air quality, heating and cooling, landscape and thermal mass. It is important to evaluate the application of these bioclimatic principles in existing high-rise dwellings in order to appreciate the extent of implementation and thus determine future trends.

In the African context, Africa as a region has featured its share of tall buildings across different countries. However, bibliometric analysis of research articles relating to energy efficiency in high-rise buildings reveals that Africa contributes far fewer studies in this field when compared to Asia, America, and Europe (Adedayo, Adio , & Oboirien, 2021). Hence, there seems to be a shortage of literature relating to energy use in high-rise residential buildings from the African sub-continent.

Figure 2 depicts African buildings that stand at least 120m (394 ft.) tall. This shows that Egypt and South Africa have the most buildings taller than 120m in the African continent. Nigeria which is the largest African country in terms of population size (worldpopulationreview.com, 2022) has only four. It is, therefore, necessary to conduct a post-occupancy study on the existing high-rise buildings in order to understand the peculiar social, economic and environmental factors affecting living and management of such buildings in Africa.

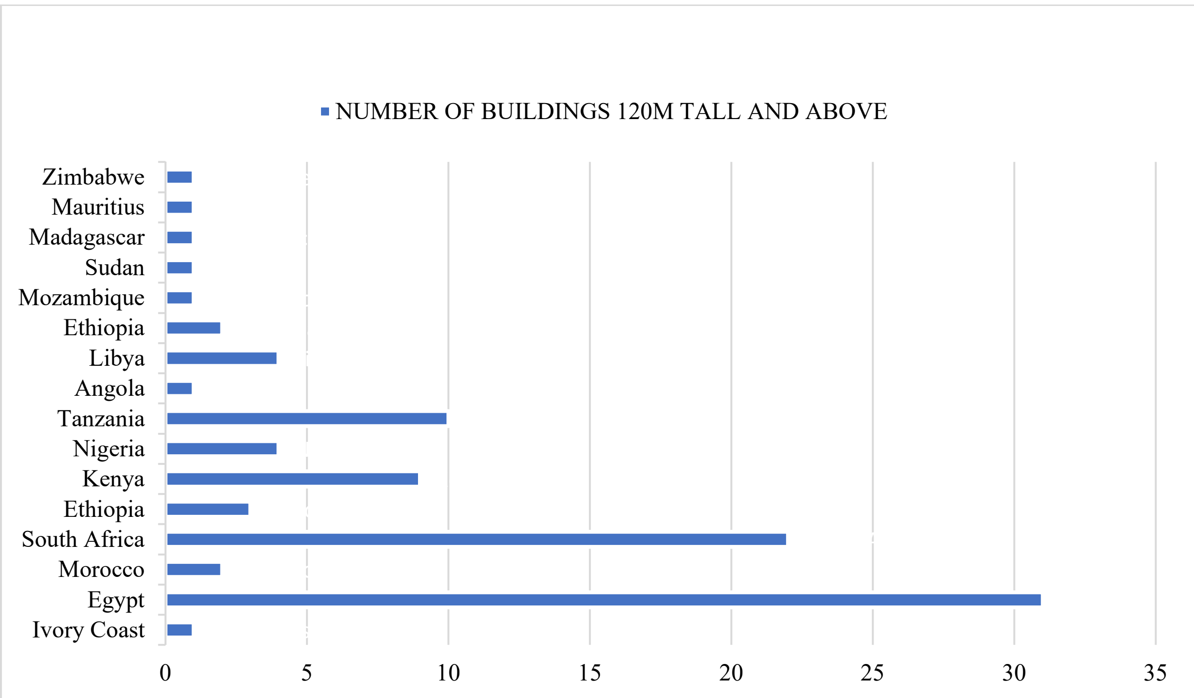

Figure 2: Distribution of high-rise buildings in Africa
Source: Adapted from (Wood & Ruba, 2013)

Figure 3 depicts graphical representation of tall buildings in Nigeria. The coastal city of Lagos hosts the most number of tall buildings with four (4) of them being above 120m tall. Lagos State, Nigeria, which is situated in the tropical climatic region (National Geographic Society, 2022), being the economic seat of the country attracts and houses multi-national corporations that provide huge amounts of foreign direct investment compared to other states of the country. This in part is responsible for the high concentration of tall buildings in the city and hence the ability of the upper class to afford this building typology irrespective of its energy-intensive nature. When it comes to residential high-rise buildings, the four (4) main tallest buildings in Lagos include the Champagne Pearl Tower 134m, Black Pearl Tower 112m, 4 Bourdillon 102m and Eko courts 88m (emporis.com, 2022).

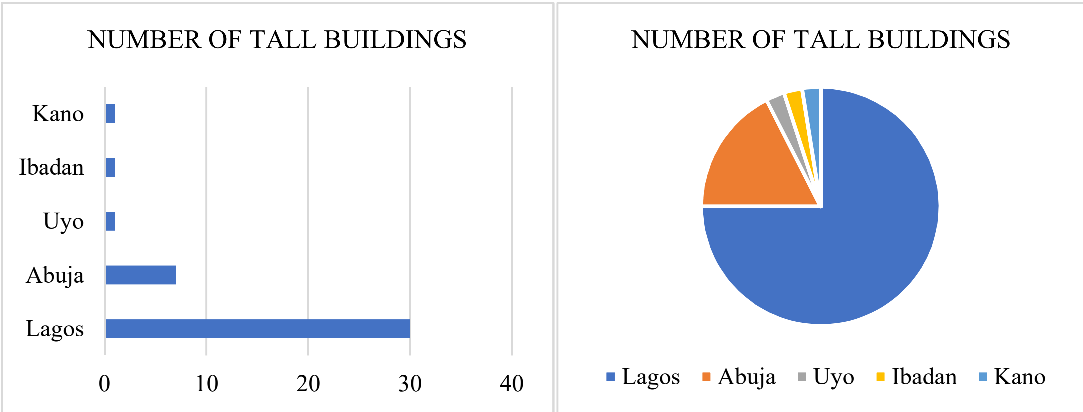

Figure 3: Distribution of high-rise buildings in Nigeria.
Source: Adapted from (Wood & Ruba, 2013)

The general mentality of the people in Nigeria towards high-rise building is that it is an elitist luxury that is associated with the bourgeoisie of the society. Most residents of urban areas prefer to find accommodation in low and mid-rise buildings that charge cheaper rent and maintenance fees. Because of this sharp difference in spending ability, only the upper class members of society are able to pay the high costs of living in high-rise buildings with the accompanying high-energy bills.

Aim of the Study

The aim of the study was to conduct a pilot survey to evaluate the application of bioclimatic principles in high-rise residential buildings in the hot-humid tropical climate of Nigeria through a participatory survey of the stakeholders in three high-rise building complexes in Lagos, Nigeria. The focus was to identify what bioclimatic principles were implemented in the existing high-rise dwellings with a view to measuring performance and success, better communicate these results, build momentum through communication and participation, and enable a culture of evidence-based design. This will provide lessons that can be used to improve design and development of future projects.

METHODOLOGY

A purposive sampling technique was adopted for the study. The purposive sampling method falls under the non-probability sampling techniques in which units are selected based on the judgement of the researchers because they believe that such units have characteristics needed in the sample. This means, units are selected "on purpose" in purposive sampling (Dolores & Tongco, 2007). According to literature (Bernard, 2002; Lewis & Sheppard, 2006) a researcher decides what needs to be known and sets out to find people who can and are willing to provide the information by virtue of knowledge or experience. In line with this, the most recently completed high-rise residential buildings in the study area were selected. These were a symbolic representation of the state-of-the-art structures in this category in the country.

Primary data was collected from field surveys using interviews, checklists, photographs, sketches and notes. Three high-rise building complexes were adopted for this study based on climatic zone of the building, scope of the building and the function of the building as criteria. Secondary data was obtained from existing literature published by the management of the estates and other scholars in the public domain. The major indicators of bio-climatism and their determinant variables form the data required for this study. They include: building envelop and orientation, energy source, sun shading device, passive design, indoor air quality, heating/cooling and landscape with details given in the Table 1;

Table 1: Indicators of Bio-climatism

S/N	MAJOR INDICATORS	VARIABLES
1.	Building envelop and orientation	• Using materials that reduce heat gain and loss • East-West Orientation • Adaptive building form • Smart facades
2.	Energy Efficiency	• Photovoltaic panels • Wind or Hydro energy • Inverters • Occupancy sensor controls
3.	Solar Shading	• Windows overhang • Operable shading Devices • Façade recesses • Internal Shading
4.	Passive Design	• Natural Ventilation (size, type and position of windows), ceiling height and natural lighting • Use of Courtyards/atriums/sky courts and use of wind walls • Rain water harvesting • Application of the loose-fit philosophy
5.	Indoor Air Quality	• Use of ventilation control system • Operable windows • Plant(green) elements in the interior • Vertical landscaping

6.	Heating and Cooling	• Green roofs • Use of evaporative cooling • Solar heating • Low – energy appliances eg Inverter ACs
7.	Sustainable landscape	• Integration, preservation or creative inclusion of natural flora • Use of recycled water for watering plants • Retention or adaptive use of natural water bodies • Vertical landscape

Source: Adapted from (Abdullahi , 2020)

Data collected were analyzed using a four-point, forced-choice Likert scale rating with weighted values ranging from 0 to 3 where: **0** = No provision, **1** = Low provision, **2** = Moderate provision, **3** = Standard provision. The four (4) point Likert scale is basically a forced Likert scale. In the four-point likert scale there is no safe 'neutral' option. The respondents are forced to form an opinion. Market researchers ideally employ this to get specific responses on a particular subject matter. In the four point likert scale, The two sides to satisfaction which is satisfied and dissatisfied will be interlinked with other answer options without a neutral answer option (Formplus, 2022). The mean weight values (MWV) was then calculated by finding the averages of the weighted scores of variables.

CASE STUDIES

Six high-rise residential buildings in three complexes in the Island area of Lagos State, Nigeria was covered under this study. The Eko Atlantic complex (comprising the completed Black pearl and Champagne towers (see Figure 4)), the single tower at #4 Bourdillon avenue and the Eko court complex (Blocks A, B and C).

Eko Atlantic Complex

Figure 4: Champagne Pearl (Right) and Black Pearl (left) Towers, Victoria Island, Lagos

Source: Fieldwork, 2022

The Eko Atlantic complex (coordinates 6.4098°N 3.4120°E) is a private development situated downtown, Eko Atlantic, Lagos State, Nigeria. According to a statement on the official website, It is originally designed to comprise five (5) residential towers namely Eko Black Pearl, Eko White Pearl, Champagne Pearl, Indigo Pearl, and Aqua Pearl (ekopearltowers.com, 2016).

As at date only the Black pearl (completed 2016) and Champagne pearl towers (completed 2017) have been occupied. It was designed by the Lebanese Architecture firm Tabet Atelier d'Architecture (TAA). See Figure 5.

The Black Pearl Tower

Figure 5: Site plan and Elevation of the Eko Atlantic Towers

Source: (ekopearltowers.com, 2016)

The Black pearl tower consists of thirty (30) residential floors with four apartments on each floor. It is oriented in the NE – SW position. With an average floor area of 190sq.m, the floor plan varied in shape and area as the tower rises. See Figure 6.

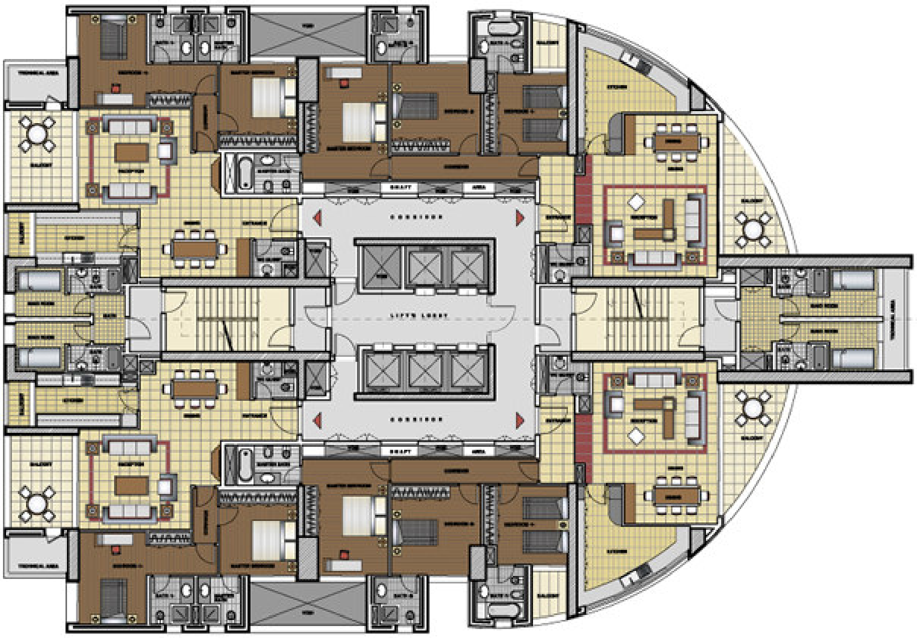

Figure 6: Typical floor-plan of the Black Pearl - Eko Atlantic Towers.

Source: (ekopearltowers.com, 2016)

The apartments are of five (5) variants ranging between two to three bedrooms per apartment. The mode of fenestration is single façade with simple glazed openable windows, which sometimes run floor to lintel. Decentralized air-conditioning system is employed and each apartment has a dedicated electricity meter that measures and records the amount of energy supplied per month. The main source of energy for the towers is provided from soundproof diesel generator sets placed at the basement floors. This provides about 65% of the daily energy requirement of the building while the public supply caters for about 35%. Average electricity bill per apartment per month is N490,000 (USD 1,178.45/mo.).

Despite the seemingly high level of awareness of energy conservative technologies by the staff of the management team, energy conservative technology such as solar lighting or use of inverters are not employed in the building. The residents who were interviewed had no problems paying the exorbitant energy bills which are about three (3) times higher than the average household pays in a low or mid-rise building in the same locality. Amenities provided include; a private health club, meeting room and lounge.

<u>The Champagne Pearl Tower</u>

The Champagne Pearl is a thirty-three (33) floors residential tower standing beside the Black Pearl tower with very similar design attributes. The Champagne tower benefits from the common garden terrace at the top of the podium and has a private health club, a meeting room, and a lounge (see Figure 7).

Figure 7: The Champagne Pearl Tower (color) - Eko Atlantic Towers

Source: (ekopearltowers.com, 2016)

There was a common commitment on the part of the estate managers to provide steady power supply even when it meant outsourcing the responsibility to a third-party energy contractor who provides an alternative source of power to the national grid. This alternative source of power is usually diesel-powered generator sets, which run as backups to cater to the energy requirements of the tall buildings. An assessment of the application of Bioclimatic Architecture Principles in the Design of Eko Atlantic Towers is shown in Table 2.

Table 2: Application of Bioclimatic Architecture Principles in Design of Eko Atlantic Towers

S/N	MAJOR INDICATORS	VARIABLES	WEIGHT SCORE	MEAN WEIGHT SCORE
1.	Building envelop and orientation	• Using materials that reduce heat gain and loss • East-West Orientation • Adaptive building form • Smart facades	2.00 2.00 2.50 1.00	1.88
2.	Energy Efficiency	• Photovoltaic panels • Wind or Hydro energy • Inverters • Occupancy sensor controls	0.00 0.00 0.00 2.00	0.50
3.	Solar Shading	• Windows overhang • Operable shading Devices(exterior) • Façade recesses • Internal Shading	3.00 0.00 3.00 2.00	2.00
4.	Passive Design	• Natural Ventilation (size, type and position of windows),ceiling height and natural lighting • Use of Courtyards/atriums/sky courts and use of wind walls • Rain water harvesting • Application of the loose-fit philosophy	3.00 0.50 0.00 1.00	1.13
5.	Indoor Air Quality	• Use of ventilation control system • Operable windows	2.00 3.00	1.75

		• Plant(green) elements in the interior • Vertical landscaping	1.00 1.00	
6.	Heating and Cooling	• Green roofs • Use of evaporative cooling • Solar heating • Low – energy appliances eg Inverter ACs	0.00 0.00 0.00 1.50	0.38
7.	Sustainable landscape	• Integration, preservation or creative inclusion of natural flora • Use of recycled water for watering plants • Retention or adaptive use of natural water bodies • Vertical landscape	2.50 1.00 0.00 1.50	1.25

Source: Fieldwork, 2022

#4 Bourdillon Drive Tower

The tower at #4 Bourdillon (coordinates 6.44512, 3.43386) is a twenty-five (25) floor high-rise building located on the corner of Bourdillon and Thompson Road, Ikoyi, Lagos comprised of forty-one (41) apartments. The units range between three (3) and four (4) bedroom flats and 5-Bedroom Duplex Flats and Duplex Penthouses. The building was designed by architects Design Group Nigeria, P&T group. The project is a joint venture between Kaizen Properties and El-Alan Group. The construction of the tower commenced in 2015 and completed in early 2020. With an average floor area of 833sq.m, the floor plate varies in shape between the two wings. The building is L-shaped with one leg in the EW position and the other in the NS orientation (See Figure 8, and Figure 9).

Figure 8: The Tower at #4 Bourdillon Drive – Ikoyi, Lagos

Source: (N4 Bourdillon IT, 2016,)

Figure 9: Typical floor plan, Right Wing, Tower at #4 Bourdillon Drive – Ikoyi, Lagos.

Source: (N4 Bourdillon IT, 2016,)

The mode of fenestration is single façade with simple glazed operable windows, which sometimes run from floor to lintel. It has deep projecting waving edge horizontal fins that serve as sun-breakers for the corresponding floors. The main source of energy for the towers is provided from the national grid about 62% and is supported by three (3) nos. 650kva soundproof diesel -generator sets which provide about 38% of the daily energy requirement of the building. Decentralized air-conditioning system is employed. Each apartment has a dedicated electricity meter that records the amount of energy supplied per month. Average electricity bill per apartment per month according to response by occupants was approximately N644,651 (USD 1,550/mo.). An assessment of the application of Bioclimatic Architecture Principles in Design of #4 Bourdillon Avenue Tower is shown in Table 3.

Table 3: Application of Bioclimatic Architecture Principles in Design of #4Bourdillon Avenue Tower

S/N	MAJOR INDICATORS	VARIABLES	WEIGHT VALUES	MEAN WEIGHT VALUE
1.	Building envelop and orientation	• Using materials that reduce heat gain and loss • East-West Orientation • Adaptive building form • Smart facades	2.00 2.50 2.50 1.00	2.00
2.	Energy Efficiency	• Photovoltaic panels • Wind or Hydro energy • Inverters • Occupancy sensor controls	0.00 0.00 0.00 2.00	0.50
3.	Solar Shading	• Windows overhang • Operable shading Devices(exterior) • Façade recesses • Internal Shading	3.00 0.00 3.00 2.00	2.00
4.	Passive Design	• Natural Ventilation (size, type and position of windows),ceiling height and natural lighting	3.00	1.38

		• Use of Courtyards/atriums/sky courts and use of wind walls • Rain water harvesting • Application of the loose-fit philosophy	0.50 0.00 2.00	
5.	Indoor Air Quality	• Use of ventilation control system • Operable windows • Plant(green) elements in the interior • Vertical landscaping	2.00 3.00 1.00 0.00	1.50
6.	Heating and Cooling	• Green roofs • Use of evaporative cooling • Solar heating • Low – energy appliances e.g. Inverter ACs	0.00 0.00 0.00 1.50	0.38
7.	Sustainable landscape	• Integration, preservation or creative inclusion of natural flora • Use of recycled water for watering plants • Retention or adaptive use of natural water bodies • Vertical landscape	1.00 1.00 0.00 0.00	0.50

Source: Fieldwork, 2022

The use of LED lamps in most spaces is an energy conservative technology employed in the building. No solar lighting or inverters are installed. The residents who were interviewed had no problems paying the exorbitant energy bills. They were not aware that their average monthly electricity bill was which are about four (4) times higher than the average household pays in a low or mid-rise building in the same locality. Residents who were interviewed admitted that they opened their apartment windows occasionally, most said they were afraid of heights while others decried the usually high wind pressure, especially from floor levels 20 and above.

The building's other features include greenery, water-bodies, swimming pools, tennis court, gym and clubhouse with underground parking. Its penthouses have roof gardens and curved balconies. Its glazed balustrade allows a 360-degree view of Lagos Island.

Eko Court Complex - Blocks A, B, and C

The popular Eko Court (coordinates 6.43649, 3.42334) complex situated at 175-178 Kofo Abayomi Street, Victoria Island, Lagos is a collection of three identical high-rise buildings referred to as blocks A, B and C. Each block contains forty apartments and is 24 storeys high. The three high-rise structures are not the only buildings within the complex (see Figure 10).

Figure 10: Blocks A, B, C – Eko Court complex, Victoria Island Lagos

Source: Fieldwork, 2022

An assessment of the application of Bioclimatic Architecture Principles in Design of Eko Court Towers A, B, C is shown in Table 4.

Table 4: Application of Bioclimatic Architecture Principles in Design of Eko Court Towers A, B, C

S/N	MAJOR INDICATORS	VARIABLES	WEIGHT SCORE	MEAN WEIGHT VALUE
1.	Building envelop and orientation	• Using materials that reduce heat gain and loss • East-West Orientation • Adaptive building form • Smart facades	2.00 2.50 1.50 0.00	1.50
2.	Energy Efficiency	• Photovoltaic panels • Wind or Hydro energy • Inverters • Occupancy sensor controls	0.00 0.00 1.50 0.50	0.50
3.	Solar Shading	• Windows overhang • Operable shading Devices(exterior) • Façade recesses • Internal Shading	3.00 0.00 3.00 2.00	2.00
4.	Passive Design	• Natural Ventilation (size, type and position of windows),ceiling height and natural lighting • Use of Courtyards/atriums/sky courts and use of wind walls • Rain water harvesting • Application of the loose-fit philosophy	3.00 0.00 0.00 0.00	0.75
5.	Indoor Air Quality	• Use of ventilation control system • Operable windows • Plant(green) elements in the interior • Vertical landscaping	0.50 3.00 0.50 0.00	1.00
6.	Heating and Cooling	• Green roofs • Use of evaporative cooling • Solar heating • Low – energy appliances e.g. Inverter ACs	0.00 0.00 0.00 1.50	0.38

7.	Sustainable landscape	• Integration, preservation or creative inclusion of natural flora • Use of recycled water for watering plants • Retention or adaptive use of natural water bodies • Vertical landscape	1.00 0.50 0.00 0.00	0.38

Source: Fieldwork, 2022

Constructed sometime around 1976, the three towers that make up the complex are arranged in a semi-circular pattern, making them easily noticeable to passers-by. The complex is owned and managed by the Lagos state development & property corporation LSDPC. With a building footprint measuring about 465sq.m, the floor plate remains the same as the building rises. As a purely state-owned property, and a not so modern building, the main source of power supply is the national grid which provides about 70% of the energy requirements of the building and 30% provided from diesel generator sets placed at the basement floors.

The mode of fenestration is single façade with single glazed operable windows. Decentralized air-conditioning systems are employed and each apartment has a dedicated electricity meter that measures and records the amount of energy supplied per month. Average electricity bill per apartment per month is N185,000 (USD 445.55/mo.). Residents are permitted to install stand-alone inverter systems in their apartments if they so wish, but there is no general provision for solar power or other sustainable energy technology.

RESULTS AND DISCUSSION

Analysis of the data gathered reveals that building envelope and orientation, solar shading and indoor air quality were the most provided while Energy efficiency and heating/cooling and sustainable landscape were the least provided in the three studied complexes. This is seen in Table 5 and Figure 10.

Table 5: Evaluation of Bioclimatic Principles in Design of High-rise Residential Buildings in Lagos, Nigeria

S/N	MAJOR INDICATORS	MEAN WEIGHT SCORES			
		Eko Atlantic towers	**#4 Bourdillon**	**Eko Court Tower**	**Mean**
1.	Building envelop and orientation	1.88	2.00	1.50	1.79
2.	Energy Efficiency	0.50	0.50	0.50	0.50
3.	Solar Shading	2.00	2.00	2.00	2.00
4.	Passive Design	1.13	1.38	0.75	1.09
5.	Indoor Air Quality	1.75	1.50	1.00	1.42
6.	Heating and Cooling	0.38	0.38	0.38	0.38
7.	Sustainable landscape	1.25	0.50	0.38	0.71
	TOTAL MEAN WEIGHT	**1.27**	**1.18**	**0.93**	**1.13**

Source: Fieldwork, 2022

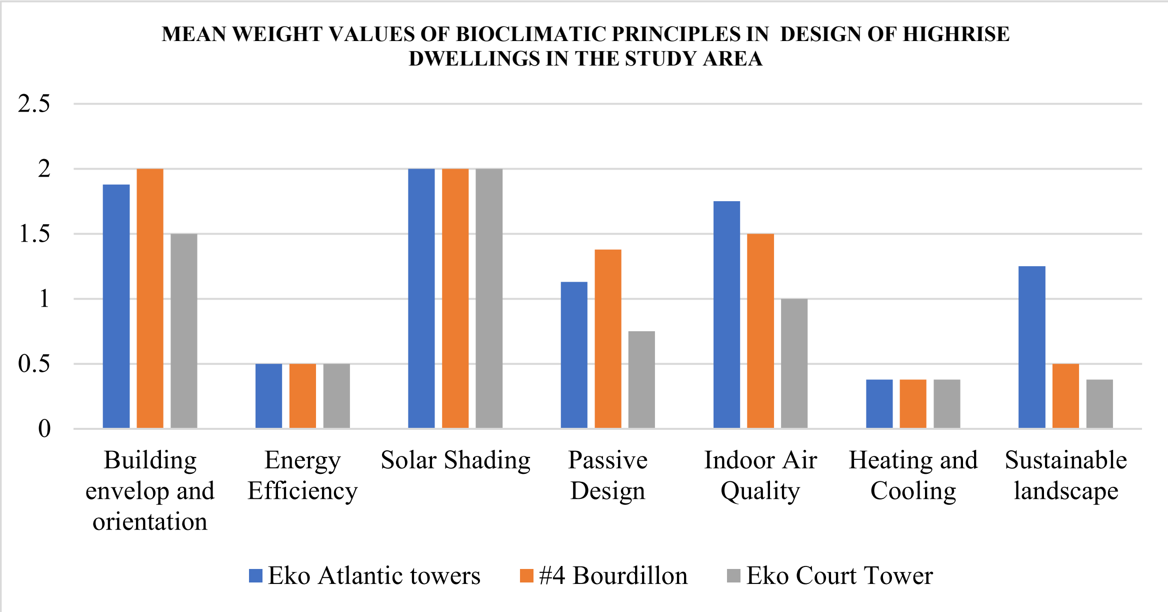

Figure 10: Evaluation of Bioclimatic Principles in Design of High-rise Residential Buildings in Lagos, Nigeria

Source: Fieldwork, 2022

The three towers scored uniform mean weightings for energy-efficiency (0.50-low), solar-shading (2.00-moderate provision) and heating/cooling (0.38 – low provision). As regarding sustainable landscape, The Eko Atlantic towers showed the most prospect for creative integration of natural flora of the site. This is partly due to its elaborate network of intentional green areas interconnected by roads and walkways. Furthermore, it was observed that the Eko Atlantic Towers (Black pearl and Champagne pearl), showed the most mean weighting of 1.27 (387%) compared to the #4 Bourdillon 1.18 (35%) and Eko-Court towers 0.93(27%) respectively. Eco court tower had the least provision for bioclimatic design principles. This is shown in Figure 11.

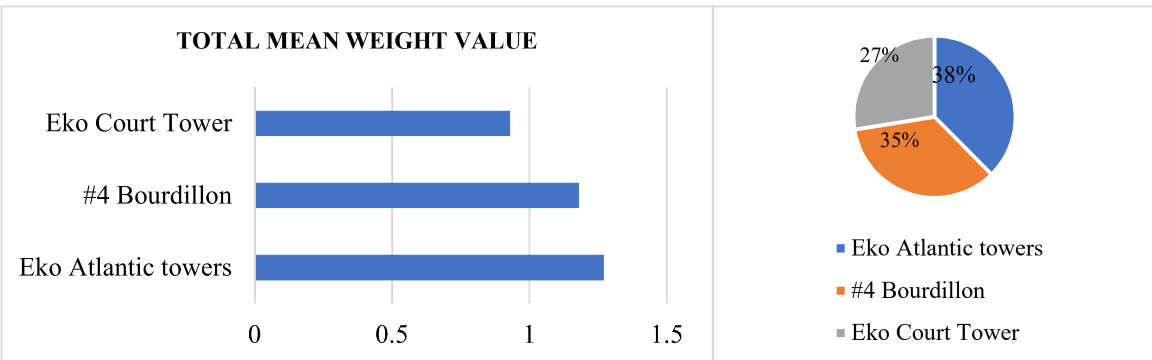

Figure 11: Total Mean Weight Value of Bioclimatic Principles in Design of High-rise Residential Buildings in Lagos, Nigeria

Source: Fieldwork, 2022

Table 6 and Figure 12 summarize the results of the field investigation regarding the bioclimatic principles applied in the studied high-rise residential buildings. The study revealed that the high-brow area of Victoria Island, Lagos hosts the most number of residential high-rise buildings in Lagos, here the average rent for a three (3) bedroom apartment is about N35,500,000/annum.(USD84,346.71).

Furthermore, the energy bills collected revealed a three (3) to four (4) times higher energy cost in high-rise buildings compared to the low and mid-rise neighbours in the same locality. The estate management revealed that the recent hike in the pump price of diesel as at the period of this study, affected the cost of backup power upwards.

Table 6: Energy consumption in selected high-rise dwellings in Lagos, Nigeria

	Bldg.	Type	Floors	Fenestrati on Mode	Energy Source	Avg. Energy Cost Per Flat/Mo. (N)	Avg. Energy Cost In Conventional Residences /Mo. (N)	Energy Conservative Technology	Residents' perception Of Energy Cost
1	**The Black Pearl Tower**	2bds. 3 bds.	30	Single skin, single glazed openable	Public 35% + diesel generator 65%	N490k	N135k	Motion sensitive lights, LED lights bulbs No solar No inverters	Acknowled ge high costs but do not mind
2	**The Champagne Pearl Tower**	2bds. 3 bds.	33	Single skin, single glazed openable	Public 35% + diesel generator 65%	N490k	N135k	Motion sensitive lights, LED lights bulbs No solar No inverters	Acknowled ge high costs but do not mind
3	**#4 Bourdillon drive**	3 bds. 4 bds. 5bd.duplex Pent house	25	Single skin, single glazed openable	Public 62% + diesel generator 38%	N644,651	N135k	Motion sensitive lights, LED lights bulbs No solar No inverters	Acknowled ge high costs but do not mind
4	**Eko Court Complex - Blocks A, B and C**	3 bds.	24	Single skin, single glazed openable	Public 70% + diesel generator 30%	N185,000	N135k	Personal Inverters allowed	Acknowled ge high costs but do not mind

Source: Fieldwork, 2022

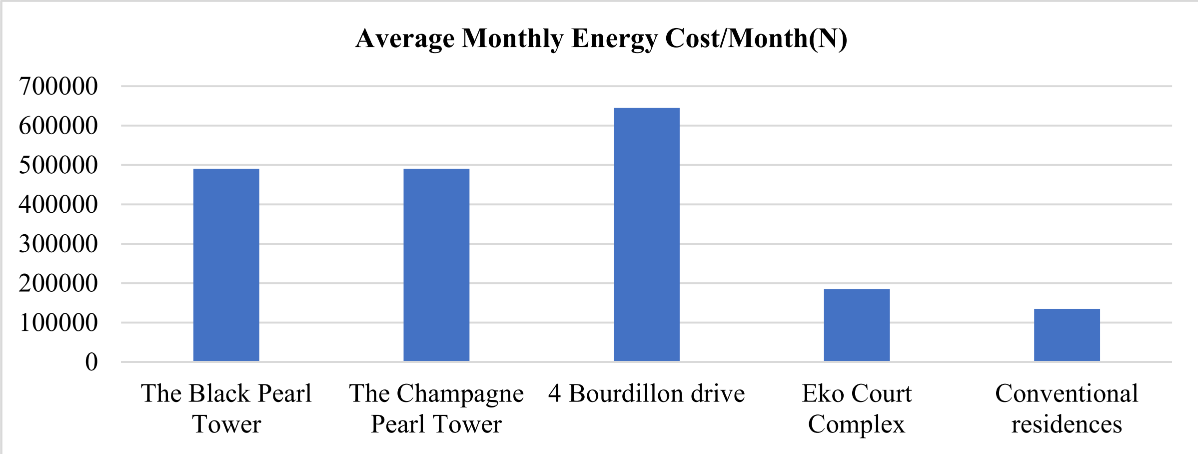

Figure 12: Energy consumption in selected high-rise dwellings in Lagos, Nigeria.

Source: Fieldwork, 2022

At the design level, the apartments were found to be well designed with ample ventilation and daylighting with projected horizontal hoods providing shades to corresponding floors. However, the study found that most residents preferred to maintain indoor weather absolutely dependent on air-conditioning even when they agreed that they were aware that they could open the windows to let in the fresh air. This continuous, uninterrupted use of the AC units culminates in heavy electricity bills in those buildings.

According to investopedia.com (2022), the per capita income of a nation is a measure of the amount of money earned per person in a nation or geographic region. Per capita income is also useful in assessing an area's affordability. It can be used in conjunction with data on real estate prices, for instance, to help determine if average homes are out of reach for the average family (Kenton, 2022). The per capital income of Nigeria as at the year 2020 is given as USD2,097.1 (The World Bank Group, 2022). This translates to about N870,757.86 per person. It is easy to see how difficult it is for the average Nigerian to afford to buy or rent high-rise properties, leave alone the exorbitant energy bills that come with them. Furthermore, the direct linkage between the economic purchasing power of the Nigerian people and the socio-cultural sentiments attached to owning or living in high-rise building in Nigeria cannot be over-emphasized. This means that less than 1% of the elite class can afford to own or live in high-rise buildings in Nigeria.

CONCLUSION AND RECOMMENDATIONS

In conclusion, the study identified the major problems associated with high-rise residential living in Nigeria to include; high tenancy costs, high-energy costs, high awareness but yet poor implementation of sustainable energy techniques and indolence on the part of occupants.

To address the issue of making tall buildings bioclimatic, global, regional, local and individual efforts have to be made at all levels of our human world. Changes must be made also at the political level by implementing and enforcing bioclimatic principles through legislation. This calls for a rethink as per, whether Nigeria is ready for high-rise living or, whether it is a borrowed luxury requiring a rethink and re-planning to match current economic, social and environmental realities.

Furthermore, future studies in this area should explore further the root cause of the high costs associated with building and operating high-rise apartments in Nigeria with a view to making them more accessible to the masses. Also municipal development control agencies should consider enforcing stricter regulations on the use of sustainable practices to drive down energy costs in high-rise residential buildings in Lagos state, Nigeria.

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