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Ameliorating Energy-Efficient Architecture for Buildings in Tropical Climates Using Passive Design Strategies: the Context of Nigeria

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ABSTRACT

Energy efficient architecture strategies are those that aim to improve the indoor environment and the natural environment of buildings by mitigating detrimental effects on the building and its surroundings through passive design strategies. Thus, this research aimed at identifying passive design measures through ardent literature review which can be incorporated to buildings in Nigeria to make them climate responsive. The study analyzed the climatic condition of Nigeria, energy crises, energy practices, energy use per sector, energy sources and the benefits of energy efficient building in Nigeria. It also stated out the roles which Architects and other professionals should play in order to achieve energy-efficient buildings in Nigeria. The findings from this research shows that passive design strategies like proper site planning, building orientation, building shape-cum-form, energy-efficient landscape design, the building envelope, renewable energy source (solar photovoltaic systems/ solar water heating systems) and the heating, ventilation, and air conditioning (HVAC) and lighting systems operating together as an interconnected system are all key actors in actualizing energy-efficient buildings in tropical climates while isolating them in the context of Nigeria.

Keywords: Energy-efficient building, passive design strategies, HVAC Systems, renewable energy, tropical climate

1.0 INTRODUCTION

Nigeria, the most populous black nation in the world with an ever-increasing population and her long-standing epileptic policies and policies implementation is continually falling short of efficient-energy demand in its building and construction industry, as there has been a global concern for efficient-energy use in all building typologies due to the threats posed by global warming on our ecosystem. This efficient-energy requirement in buildings across continents has not been adequately met in third-world countries, for example, Nigeria, due to her poorly managed insufficient energy infrastructure, and the self-aggrandized greed of her political elites. The predominant energy source in Nigeria is electricity generated from dams and burning of fossil fuels, and according to the Federal Ministry of Power, Works and Housing, the building sector accounts for the majority of electricity consumption in Nigeria and will inevitably increase significantly in absolute terms in the coming years driven by a rapidly increasing population, migration from low energy consuming rural dwellings to urban centres, and improvements in living standards (Federal Ministry of Power, Works and Housing). The burning of fossil fuels through the use of generating sets emits harmful gaseous substances like CO_2 into the atmosphere, resulting in toxic air pollution. On the other hand, an energy efficient building is that designed to minimize energy demand and provided with efficient equipment and materials appropriate for the location, use, and conditions, which is operated in such a manner that results in a low energy use when compared to other similar buildings (Meier& Thomas Olofsson, 2002). Furthermore, studies have shown that energy efficiency has proven to be a cost effective parameter for building economics without necessarily increasing energy consumption (Bala, 2014). Therefore, in a country like Nigeria with poor electricity supply and persistence power disruption due to inefficient management of energy resources, there is a great need for the introduction of passive design strategies in its building-cum-construction industry to create awareness of energy conservation in all types of buildings, because, the aforementioned peril, if not tackled, will rob us of whatever bond we had hitherto enjoyed with our ecosystem, and throw the survival of future generation into an awe of grave jeopardy; killing it before its arrival.

1.1 Necessity of the Research

For conscious observers, global warming is a "tide that floods all buildings," and studies have revealed an increasing paradigm shift toward sustainability (energy efficiency) in the design, development, and operation of buildings and facilities. This paradigm shift is becoming increasingly important for the advancement of high-quality building efficiency in terms of reducing buildings carbon footprint in our world. However, the norms of this paradigm shift towards energy efficiency is still a bandwagon which has not been adequately met in Nigeria. To this effect, it is necessary to take actions towards achieving efficient-energy design in Nigeria's building sector through the use of passive design strategies to the end of setting out quality precedents and ameliorating policy making in the design and construction of sustainable buildings in the hot-humid climate of Nigeria, so as to avert further ecological degradation. To this end, the future generation who loaned the earth to us will have a safe world to inhabit as the distance of years will teach them the value of what we have done.

1.2 Aim and Objectives

The aim of this research is to explore the criteria for energy efficiency, resulting in a series of feasible passive design solutions that can make a contribution in the building and construction industry, towards the knowledge of developing and designing energy-efficient buildings in Nigeria. The objectives include;

- To explore passive design strategies that caters for energy efficiency in hot-humid climate of Nigeria.
- The study will provide guidelines to assist architects and other professionals for designing and constructing energy-efficient buildings in Nigeria.
- To highlight the state of energy efficiency and conservation in Nigeria and ways of improving them.

2.0. LITERATURE REVIEW

Energy is one of the most important catalysts in wealth generation, economic growth, and social development in all countries. Buildings have a significant share in total energy consumed globally; therefore, they have a profound impact upon the environment. Energy is used in every stage of building life cycle (these stages are choice of locality, architectural design, structural systems and material selection, building construction, usage and maintenance, demolition, reuse-regainrecycle, and waste disposal), Yüksek and Karadayi, 2017. Buildings, as they are designed and used today, contribute to serious environmental problems because of excessive consumption of energy and other natural resources. The close connection between energy use in buildings and environmental damage arises because energy intensive solutions sought to construct a building & meet its demands for heating, cooling, ventilation & lighting cause severe depletion of invaluable environmental resources (Energy efficiency in architecture: An overview of design concepts and architectural interventions, 2005). Many studies and theories have emerged in recent years to contribute to a paradigm change in building design, construction and development from cradle-to-grave strategy to a cradle-to-cradle strategy, which is critical for the physical cooperation between the natural world and humankind's existence (Grierson, 2011). These studies have enabled researchers to contribute a vast amount of concepts filtered through the prism of sustainability criteria, leading to an architecture that is both pleasant and durable, well scaled, and beautiful without being ostentatious (Grierson, 2011). Nonetheless, as earlier stated, incorporating environmental architecture concepts into buildings is still a drab concept in Nigeria that must be discussed on a continuous basis through different purviews to avert an ecological calamity akin to standing in-between Scylla and Charybdis, and as time passes, energy-efficient building design in Nigeria must not fall under the rubric of things to be ignored, rather we must continue to proffer solutions through research spectrums, which I believe, will underpin many lessons and techniques for the betterment of our environment.

2.1 Climate of Nigeria

Nigeria is a country located in West Africa. It lies between 4°N and 14°N latitude and 4°E and 14°E longitude and is bordered in the South by the Atlantic Ocean and the North by the Sahara Desert (Figure 1). This gives the country a very wide range of climatic pattern experienced throughout the year (Akande et al, 2017). Nigeria is in a tropical climate were hot and dry season dominates the southeast while the warm season dominates the southwest and further inland. In places dominated by dry season, the average temperature is usually high (Okula, 2021).

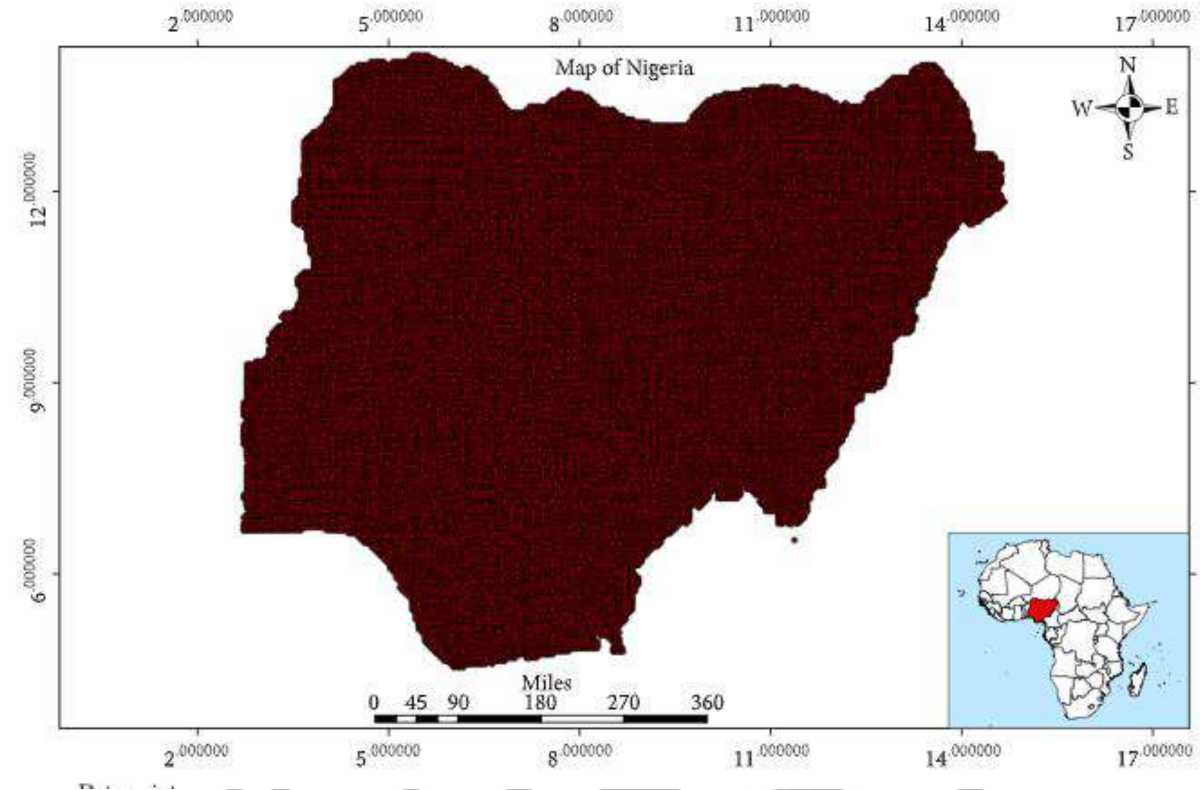


Fig 1; *Nigeria's geographical position*
Source; *Akande et al, 2017*

Its weather system is controlled by the Intertropical Discontinuity (ITD). The ITD is the area of lowest pressure over West Africa separating the moist Southwest Monsoon from the Atlantic Ocean and the dry northeast trade winds from the Sahara Desert, Akande et al 2017 added. According to the Koppen climate classification, as cited by Akande et al, 2017, Nigeria has four climatic zones: the warm desert climate in the northeast, the warm semiarid climate in the other parts of the north, the monsoon climate in the Niger-Delta, and the tropical savannah climate in the middle belt and parts of the southwest. The main ecological zones in Nigeria are the tropical rainforest in the south, savannah in the middle belt, and semi-arid zones in the north. Furthermore, Nigerian Energy Support Programme (NESP), 2015 stated that temperatures across the country are relatively high, with very narrow variation in seasonal and diurnal ranges, and wide regional differences. There are two main seasons: the rainy season (usually April to October); and the dry season (November till March). The dry season commences with Harmattan winds, a dry chilly spell that lasts till February and is associated with lower temperatures and dust brought by the winds blowing from the Arabian Peninsula across the Sahara. The second half of the dry season, namely February till March, is the hottest period of the year (temperatures range from 33 to 38 °C and are at their highest, as is aridity, in the north). Given this climatological cycle and the size of the country, there is a considerable variation in total annual rainfall across the country, both from south to north and, in some regions, from east to west. The maximum total precipitation is generally in the southeast, along the coastal area of Bonny and east of Calabar, where mean annual rainfall is more than 4,000 millimetres. To this effect, I contend that this climate scenario in Nigeria gives rise to a certain thermal behavior pattern in Nigerian buildings. Having knowledge of this behavioral pattern is crucial to control the amount of heat that goes into a building space. (Ahsan, 2009), stated that buildings will cause thermal discomfort if an effective strategy is not adopted to reduce the extra heat going into it.

2.1. Energy crisis in Nigeria

Throughout the world, electricity is the most widely used and desirable form of energy. It is a basic requirement for economic development and for an adequate standard of living. As a country's population grows and its economy expands its demand for electrical energy multiplies. If this demand is not met adequately a shortage in supply occurs. This shortage can assume crisis proportions (Akinbulire, 2007). For many years now, Nigeria has been facing an extreme electricity shortage. This deficiency is multi- faceted, with causes that are financial, structural, and socio-political, none of which are mutually exclusive (Julia et al, 2008). Electricity in Nigeria is controlled by the power sector, and NESP, 2015 mentioned that the power sector in Nigeria is seen by many analysts as the key constraint on economic development due to its negative development.

Furthermore, NESP, 2015 stated that the underlying reasons for the negative development regarding electricity supply in Nigeria are apparent. In spite of Nigeria's huge resource endowment in energy and enormous investment in the provision of energy infrastructure, the performance of the power sector has remained poor, in comparison with other developing economies (Oluseyi et al., 2007) Investment in the nationalized power sector had seriously diminished by the early 1990's, with maintenance budgets greatly reduced and no new capacity added. To this effect, On September 30, 2013, the federal government of Nigeria under the Goodluck Ebele Jonathan's administration carried out the long-standing reform by privatizing the power sector which was first promulgated in 2001. The underlying idea was to establish an efficient electricity market in Nigeria. However, electricity problems still persist in Nigeria, as the citizens are still facing perennial power outages and load shedding throughout the country, amid hot-humid conditions and the recent heat-wave surge across the country. This peril has exacerbated insubstantial livelihood amongst citizenry and the load-shedding problem is worsening as people demand for more energy usage in their homes and workplaces due to the extreme weather condition. On the other hand, over reliance on a single source (hydro) of electricity supply is also a major problem in the power sector as it hampers efficient energy production to cater for the growing energy demand among the populace.

2.2 Energy sources in Nigeria

Nigeria is Africa's largest oil producer and in 2012 was the world's fourth largest exporter of liquid natural gas (NESP, 2015). However, this production is currently exported, with only a fraction re-imported in refined form for use in Nigeria. In 2011, 159Mtoe of oil and gas were produced but only 20.5Mtoe consumed in Nigeria, accounting for 17.4% of Nigeria's raw energy consumption. Hydroelectric generation accounts for around 0.5Mtoe (0.4% of raw energy consumption). There are also reserves of coal although these have not yet been exploited on a large scale. The remainder and large majority of energy used in Nigeria (82% in 2011) is biofuel and waste, mostly in the form of firewood burnt for cooking and heating water. Over the last twenty years the amount of biofuel used has risen steadily while use of fossil fuels is relatively stable, presumably due to costs and poor infrastructure to deliver oil and gas to domestic users. This rate of firewood consumption far exceeds the replenishment rate, and is therefore unsustainable and leading to deforestation and desertification in many areas of Nigeria (Federal Ministry of Power, Works and Housing, 2016).

2.3 Energy use per sector in Nigeria

Of the electricity generated in Nigeria, it is estimated that households account for the largest share of consumption (about 78%). This is a significant contrast with countries such as South Africa and Brazil where the majority is used in industry, and suggests that lack of power is hampering industrial growth in Nigeria (Federal Ministry of Power, Works and Housing, 2016). They also added that an estimate of total energy consumption in Nigeria is challenging because a large percentage of the electricity consumed is generated on-site from private petrol/diesel generators. The World Bank estimates that the capacity of off-grid diesel and petrol generators totals 3GW and 1.3GW respectively. This is nearly equivalent to the total installed power plant capacity estimated at 6.2GW in 2011 (NESP, 2015). Due to fuel price rises and shortages, generating electricity with these small generators is not only inefficient in carbon emission terms, but also very expensive and unsustainable (Federal Ministry of Power, Works and Housing, 2016).

2.4 Energy Consumption in the Nigerian Building Sector

There is a shortage of reliable data on energy consumption in buildings, partly due to poor metering of mains electricity and also due to the fact that most buildings also generate electricity using petrol and diesel generators which complicates assessments (Federal Ministry of Power, Works and Housing, 2016). As cited by the Federal Ministry of Power, Works and Housing, 2016, in late 2014 the former Minister of Power, Professor Chinedu Nebo estimated that 55% of Nigerian electricity users are not metered (Nebo, 2014). This is recognized as a major barrier to energy efficiency, and efforts are underway to ensure appropriate meters are installed.

2.5 Energy Efficiency Practice in Nigeria

Efficient energy which is simply known as energy efficiency is using less energy to provide the same level of energy service. It is any action that reduces energy use per unit output without affecting the level of service provided. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature (Bala, 2014).

Energy efficiency means improvement in practices and products that reduce the energy necessary to provide services like lighting, cooling, heating, manufacturing, cooking, transport, entertainment etc. Energy efficiency products essentially help to do more work with less energy (La, 2002). In the past, the Federal Government of Nigeria made several policies in the energy sector that aimed to encourage uptake of renewable energy (RE) and energy efficiency (EE). However, these were limited in their scope and only mentioned in general issues without giving a detailed framework. It is hoped that the recent approval of the first ever RE and EE policy for Nigeria will provide better guidance to the industry. Within the building sector, this policy proposed developing energy efficiency building codes so that buildings are designed in line with bio-climatic design concepts and incorporate other energy saving measures (Federal Ministry of Power, Works and Housing, 2016).

(Oyedepo, 2012) asserted that presently, energy utilization in Nigeria is far from being efficient. He added that apart from the direct loss due to energy wasted, using energy inefficiently has three major implications in Nigeria. These are:

a) The investment in some energy supply infrastructure is far in excess of what the energy demand is;

b) The environmental problems associated with energy utilization are more aggravated due to large energy consumption;

c) Excessive energy consumption adds to the costs of goods produced especially in energy intensive industries like cement, steel works and refineries.

If we use energy efficiently, it will help to reduce the building of more power stations, thus the money for building power stations will then be spent on other sectors of the economy. More also, more people will have access to energy; if we save energy in one part of the country, the energy saved can be made available in another part. In Nigeria, where the utility companies do not have enough energy to meet the needs of everybody at the same time, energy supply is alternated. With good energy management at the residential, public and private sector, there will be no need to alternate electricity supply (Oyedepo, 2012). Furthermore, energy utilization in Nigeria has been inefficient due to the earlier mentioned poor policy implementation. Oyedepo, 2012, noted that policies are only written on paper but never implemented so as to promote practice of energy efficiency and energy conservation principle in the country. On the other hand, Oyedepo, 2012, was of the opinion that Energy efficiency does not mean that we should not use energy, but we should use energy in a manner that will minimize the amount of energy needed to provide services. This is possible if we improve in practices and products that we use. He also listed out some of the inefficient utilization of energy practiced in Nigeria. They are;

A. Use of Inefficient Traditional Three Stone Fuel Wood Stoves:

For most Nigerians, cooking is the most important energy need. Fuel wood was found to be the predominant energy source in the household sector with about 70-80% of households depending on it as their cooking fuel in both the remote villages and the towns with the use of inefficient earth stove (traditional three stone stoves) with efficiencies of between 5 to 12%. The consequences of this to the natural environment are that unchecked felling of trees to provide the fuel wood requirements will exacerbate desert encroachment, soil erosion and loss of soil fertility problems.

B. Use of Vehicles with Low Fuel Efficiency:

In Nigeria, nearly all vehicles are imported from overseas, often used cars and trucks. Fuel efficiency is low because the vehicle fleet is old and poorly maintained, because of traffic congestion in most urban centres, and because of bad driving habits. Energy savings of 30 percent could be achieved in the road subsector by shifting from an energy-intensive transport mode to a less energy-intensive public transport system and by adopting traffic management schemes.

C. Dominant Use of Incandescent Light Bulbs:

The use of incandescent bulbs for lighting is energy intensive. Only about 5% of total energy used by an incandescent bulb is converted to light energy, the remaining 95% is converted to heat energy. A major factor working against the shift from incandescent bulbs to energy saving bulbs is the cost. Energy saving bulbs are far more expensive than incandescent bulbs. The cost of energy saving bulb in the Nigerian market ranges between N800 to N1000. However, some substandard energy saving bulbs could be purchase for about N200. On the other hand, the prices of incandescent bulbs range from N30 to N100. Energy consumed in Nigeria can be drastically reduced if Nigerians replace their incandescent bulbs with energy efficiency bulbs.

D. Indiscriminate Use of Electricity among Urban Dwellers in Nigeria:

In many major cities in Nigeria, indiscriminate use of electricity for different purposes is common. These include putting on light to advertise goods in the day time, switching on outdoor lighting during the day, building of industries in residential areas, proliferation of private water boreholes, setting appliances on standby mode, simultaneous use of multiple appliances in public buildings, leaving appliance on when not in use, multiple use of inefficient heating equipment for cooking and heating water in the residential and commercial buildings etc. All these practices encourage the wastage of electricity and bring about inefficient utilization of energy.

E. Purchase of Second-hand Appliances:

The Nigerian market is flooded with all kinds of second-hand appliances. Over 90% of Nigerian use one second-hand product or the other. They are cheaper compared to the new ones. Many Nigerians are on the opinion that second-hand products are more durable than the new ones. This assertion could be based on the fact that there are a lot of substandard goods in the market and the second-hand goods tend to last longer than them. Many of the second-hand products come from European and North American countries and they may have been manufactured long time ago. The efficiency of these products is quite doubtful and the possibility exists that they may have been rejected by the former users to purchase more recent and efficient appliances. The second hand market needs to be further.

F. Gas Flaring:

Gas flaring also has significant negative impacts on the environment, not least due to its climate change impacts. Associated gas has been flared since the start of oil production in the Niger Delta. Nigeria flares about 2.5 billion cubic feet (over 70 million m3) of gas per day. In other words, 40 percent of its annual gas production accounts for 12.5 percent of all globally flared gas). This amounts to about 70 million tonnes of carbon dioxide. Apart from causing a direct loss in energy sector, gas flares have detrimental effects on the environment. It releases toxic substances, including benzene and particulates, which damage the human immune system and increase the acidity of rain. Health risks include child respiratory illness, asthma and cancer. Households that rely on traditional livelihoods such as fishing and crop production have suffered due to negative impacts on fish and vegetation.

The above listed inefficient energy practices in Nigeria has been detrimental to the development of the quality energy usage in Nigerian sectors. To this effect, promotion of energy efficiency in

Nigeria should be popular amongst the citizens in order to create conscious awareness of the disadvantages of inefficient energy practices to their environment.

2.6 ARCHITECT'S ROLE IN ENHANCING ENERGY EFFICINCY IN NIGERIA

Sustainable design and construction has raised a unique challenge in the field of architecture. To achieve societal resilience, architects must integrate the concept of sustainable construction practices into their actions as tenants and practitioners. (Sant Chansomsak and Brenda Vale, 2009). Additionally, they argued that Although architects' professional duty is to conserve, improve, and create the required degree of physical environment in each community's specific circumstances, in an ideal and sustainable world, their role as citizens tasks them to become productive members of their own community when it comes to sustainability. The concept of sustainability encourages architects to think about and respond in terms of the long-term consequences of their decisions on the earth's scarce resources. There is a growing awareness that industrial construction practices have negative environmental consequences that damages the environment (Obiefuna, 2013). John, 2004 as cited by Obiefuna, 2013 stated that the productivity and sustainability of natural resource and forest utilization, as well as the standard of living and the impact of energy generation and use, are all factors that architects must consider. Architects must, alas, compete with current tech, cost factors, consumer demands, and governmental regulations when it comes to construction architecture, he said.

In Nigeria, building designs are currently created by a linear and conventional construction process. An architect is employed with no input from other consultants and has a design and scheme plan. At the detailed construction stage, structural, mechanical, and electrical engineers are employed to provide their expertise in conjunction with the design provided, but they have no influence on how the design is shaped for operating performance. Since the construction of energy efficient buildings is outside the skills of just architects, the integrated architecture process becomes an important platform for the fruitful synthesis of knowledge from various fields. (Building Energy Efficiency Guideline for Nigeria Federal Ministry of Power, Works and Housing). While an architect's professional practice is fraught with problems, involving not just logistical and functional issues but also disagreements with contracting parties and clients, (Wojciech Bonenberg and Oleg Kapli ´ nski, 2018), I believe that the architect, as the person with the power and authority to bring controlled thinking into practice, must continue to promote the core values and concepts of sustainable development, which will improve energy efficiency in Nigeria without compromise.

3.0 THEORETICAL FRAMEWORK

3.1 Energy Efficiency in Tropical Climate

Different temperature regions have an effect on the concepts of sustainable development when they are applied in various contexts. Many researchers have based their energy efficiency studies on specific temperature zones around the globe. Many studies seem to be concentrating their efforts on achieving energy efficiency in tropical climates. It is important to verify these concepts for the purposes of this study. In the "Handbook-Sustainable Building Design for Tropical Climates," Niccolò Aste et al., 2020 provides an easy-to-use platform with general guidance and specific knowledge on building physics, as well as all of the realistic resources required to construct a low-energy building in a tropical environment. According to the handbook, the following 30 strategies are to be considered in the design of sustainable building in the tropical climate:

1. **Location analysis**: Examine the geographical setting, including the topography of the place. It is essential to collect data on temperature, relative humidity, wind speed and direction, sun path, and radiation.

2. **Building footprint:** The building's footprint can ideally not exceed 60% of the plot's surface area.

3. **Building orientation:** To limit direct solar radiation penetration and mitigate heat gain, the building's long axis should be aligned East–West.

4. **Building shape:** It should be constructed in compliance with the local climate. In hot, humid climates, narrow plans are used to maximize natural light, cross-ventilation, and minimize heat gain. In humid, arid climates, lightweight styles and courtyards are used to retain cold air in the building and minimize heat gain. Multi-story buildings should be chosen to maximize density and optimize capacity.

5. **Allocation of spaces within the building:** Toilets, stairwells, lifts, and lobbies should be located on East and West-facing walls to act as heat buffer zones while also allowing for natural light.

6. **Opening:** Window sizes should be determined by current climatic conditions, with a preference for north and south wall placement; the window to wall ratio (WWR) should not exceed 40%. Glazing walls can be removed if special coated glass is used.

7. **Daylighting:** The building should be built with windows on the north and south sides, shallow floors for optimum sunshine, and light shelves in the darker spaces, according to the climate zone. At least a tenth of the floor space can be taken up by glass. The room's depth should not be more than 2.5 times its height. There's enough space.

8. **Solar protection:** Using sun shielding devices including overhangs, vertical and horizontal shading elements, balconies, curtains, and vegetation to minimize heat gain.

9. **Natural ventilation:** Cross-ventilation should be provided through the holes. Roof vents and openings, thermal chimneys, and clerestory windows are all examples of things that can be used. To build ventilated roofs, use insulation materials under the roof cover.

10. **Cooling:** To integrate passive cooling systems, model water bodies and features for evaporative cooling (just in hot and arid regions). Buildings that use air conditioning systems should be well sealed to mitigate heat gains and reduce energy consumption.

11. **Heating:** In the highlands, boost passive heat gain. Create passive solar heating techniques to ensure maximum sun penetration during the winter months.

12. **Building envelope materials:** Consider the carbon emissions when using building materials. Prioritize building materials with a low energy quality that are locally available. Items that are recyclable and reusable, as well as items that cause the least amount of waste, are valued. Prioritize envelops with a low U-value or low heat transmittance (walls and roofs).

13. **External finishes**: To reflect unnecessary solar radiation, light-colored materials are used on exterior facades and roofs, as well as green and living walls, vertical gardens with vegetation that grows on the facades.

14. **Renewable energy:** Integrate solar energy (thermal and electrical) technologies, such as photovoltaic and solar water heaters; wind energy, biogas, and other available clean energy systems, into the building architecture.

15. **Water conservation and efficiency:** Make plans to capture rainwater. Grey water is a resource that can be reused. Using water-saving appliances and fixtures.

16. **Drainage:** Reduce flood water runoff and allow rainwater runoff to replenish the water table by using appropriate irrigation techniques.

17. **Sanitation:** In the absence of a public drainage facility, design on-site wastewater treatment plants that produce biogas, compost, and recycle water for agriculture.

18. **Solid waste management:** Make allowances for waste separation for on-site sorting facilities. Introduce new services that encourage people to recycle, reuse, and remove waste.

19. **Landscaping:** Design soft landscaping (greening site) with low-water native plants and hard landscaping with permeable paving materials to enable rainwater to percolate. Keep paved areas around the house to a minimum to reduce heat island effects.

20. **Energy-efficient appliances and energy demand management:** Plan soft landscaping (sustainable green site) with low-water native plants and hard landscaping with permeable flooring materials to enable rainwater to percolate. Limit paved areas around the house to a minimum to reduce heat island effects.

21. **Well-balanced public spaces:** nearly half of usable land will be taken up by avenues, roads, green squares, gardens, and parks (30 percent for streets, 15 percent open space).

22. **Mixed land use:** You will prevent zoning by combining industrial, administrative, and residential activities. This removes the need for flying and ensures the use of public facilities.

23. **Mixed social structure:** Promote social equality and diversity. Discourage gated communities in favor of cultivating cosmopolitan values and a desire to collaborate. Subsidized housing will take up anywhere from 20% to 50% of total residential area.

24. **Adequate density and compact design:** Elevated neighborhoods with sufficient density to reduce costs and quality of life.

25. **Connectivity:** Establish street configurations and systems to connect the metro's different places and make products and services more available.

26. **Urban form matters:** Mixed-use, street life, and walkability are encouraged by compact blocks and houses.

27. **Walkability:** To encourage public mobility, prioritize travel distance, mixed use, and mass transit.

28. **Active mobility:** The street plan should include sidewalk and cyclist lanes. Riding a bike expands public transportation's scope.

29. **Promote the "shift":** Promote people to switch from high-energy modes like automobiles to low-energy modes like walking, riding, and using public transportation. Increasing the attractiveness and health benefits of commuting and walking.

30. P**romote vehicle efficiency:** To promote green mobility, allow people to move from fossil-fuel-powered automobiles to hybrid and electric vehicles.

In conclusion, all of the aforementioned initiatives sought to improve and initiate the quality of both technological and natural imperatives in order to confront climate change in tropical climates, which, Nigeria is among.

3.2 Energy Efficiency in Buildings

A well-designed energy efficient building maintains the best environment for human habitation while minimizing the cost of energy (Ashan, 2009). Energy efficiency in buildings is described as the degree to which a building's energy consumption per square metre of floor area meets current energy usage criteria for that particular building form under prescribed temperature patterns (sustainable energy regulation and policymaking manual for Africa, 2005). On the other hand, the Federal Ministry of Power, Works and Housing in Nigeria defined efficient buildings in their journal as those structures that use less energy while maintaining or even improving occupant comfort. They went on to state that energy-efficient buildings are not only good for the atmosphere, but also profitable and long-lasting. Meier & Olofsson, 2002 as cited by the Federal Ministry of Power, Works and Housing defined energy efficient building as a structure designed to use as little power as possible, equipped with energy-efficient equipment and materials appropriate for the location, use, and environments, and operated in a manner that uses less energy than comparable structures.

These concepts all follow the same philosophy of minimizing energy consumption throughout a building's life cycle.

3.3 Benefits of Energy Efficient Buildings

As shown in the figure 3.1 below, the advantages of energy-efficient building siting and architecture are economic (saving money), social (reducing fuel poverty), and environmental (reducing resource exploitation and emissions). Any new invention should, preferably, have a clear energy plan that outlines how these benefits can be realized (Hui, 2005).

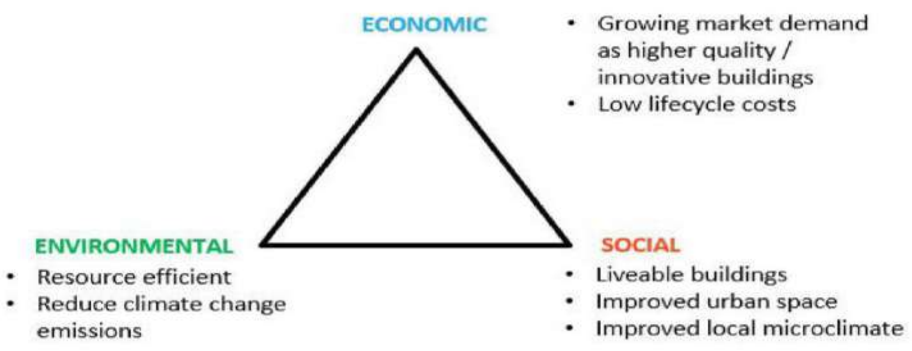


Fig.3.1; Benefits of Energy Efficient Building
Source; (Building Energy Efficiency Guideline for Nigeria Federal Ministry of Power, Works and Housing).

Energy saving systems are designed to reduce energy demand while maintaining or improving the quality of services provided in buildings. The following are some of the anticipated benefits of building energy efficient facilities

i. Using less electricity for room heating and/or cooling, as well as water heating

ii. Light, office machines, and household equipment consume less energy.

iii. Lower maintenance requirements

iv. increased ease of use

v. Enhanced property value.

End-users in developing countries with insufficient utilities and daily power rationing have a strong appetite for backup/ stand-by power generation dependent on diesel or renewable energy. The initial investment as well as the recurring costs of these stand-by systems will be reduced by reducing the volume of power and resources consumed in buildings (sustainable energy regulation and policymaking manual for Africa).

3.4 Energy Efficiency Measures for Buildings in Nigeria

"Creating an energy efficient building starts with the right design approach, considering the specific microclimate conditions of the site, orientation and shaping the building form, a conscious selection of building materials and envelope systems aiming to minimise building heat gains. Following this, any active systems should be selected on the basis of high efficiency (e.g. highly efficient lighting systems) or to enable a reduction of cooling loads appropriate to the climate" (Federal Ministry of Power, Works and Housing, 2016).

Yüksek and Karadayi, 2017 claimed that since the methods of providing energy efficiency can differ depending on the intent, process, place, and importance of a building, it is difficult to offer recommendations for strategies that can guarantee that all buildings are energy efficient. As a result, by allowing necessary data, a deliberate method must be developed in order to arrive at the ideal option at each stage of construction. Finally, the outcome must have the quality of being rather successful, i.e., requiring less resources over a lengthy span of time to complete the same task. There are many initiatives designed to lower building energy consumption. The analysis of building life allows for energy consumption to be taken into account at any stage of development. (Yüksek and Karadayi, 2017) iterated that in this respect, building life cycles must be understood.

They went on to say that the building life cycle is split into three major phases: pre-construction, construction, and post-construction. There are several processes in these stages. The pre-construction phase includes site selection, site planning, building form, building plan, and appropriate space organization, as well as building envelope design, energy-efficient building materials selection, energy-efficient land development, obtaining raw materials for building materials, manufacturing, and transporting them, and the design and use of the facility. They clarified that the methods used to improve building energy efficiency are determined by the lifecycle processes.

It is evident from the above sections that energy efficiency in buildings is beneficial for many reasons. Having justified the needs for energy efficiency and how to obtain it, it is now important to focus on the basic measures that can bring about energy efficiency in Nigerian buildings. An extensive literature review consisting of different journals, books, researches and related websites was undertaken to establish the basic passive strategies for designing energy efficient buildings. These strategies, as described below was drawn from the literature review and isolated to the Nigerian context:

i. Site selection and analysis

Proper site selection and analysis is a core requirement on the road to attaining energy efficiency. This analysis involves understanding the site's micro-climatic condition so as to know the proper orientation a building would assume on site and the best way to shade the building from prevailing wind and solar radiation. For example, wind breaks are not desirable in tropical climates as they impede desirable breezes. Instead, it is desirable to have air movement (Ahsan, 2009). Since Nigeria is near the Equator, there is little change throughout the sun's direction during the year, making optimizing orientation and shading relatively simple (Federal Ministry of Power, Works and Housing).

ii. Site planning

Optimal site planning is as a result of understanding the site analysis properly. This involves understanding where to and where not position the building footprint, planting of new Trees and retention of existing once, optimal landscaping (soft and hard), building setbacks on site and distance from other existing buildings and other infrastructures. (Yüksek and Karadayi, 2017) mentioned that in the design of buildings, distance between buildings is an important designing parameter that affects utilization of solar energy, wind direction, and speed concerning artificial environment. In the design process, building should be handled as a whole with its environment.

UNEP (2006) warns that improper planning of the site can result in 'heat island effect'. Such effects according to UNEP (2006) can be alleviated by reducing the total paved area on the site and shading the paved surfaces.

iii. Building shape and form

Strategies related to the building form deal mainly with their major components, volume, configuration of rooms and outdoor areas (Federal Ministry of Power, Works and Housing). Gut and Ackerknecht (1993) as cited by Ahsan, 2009 suggested that forms with broad surfaces rather than compact buildings as large surfaces favor cooling and heat emission at night-time. As a result, Slits can be used to create open, outward-facing building forms. However, the Federal Ministry of Power, Works and Housing were of the opinion that Reducing building outer skin area in relation to the volume proportionally reduces heat gains. Compact forms such as cubes show lower heat gains than elongated or articulated forms for the same volume, cooling demand will be lower for the lower surface-volume ratio (S/V). This phenomenon is illustrated in fig 3.2. Givoni, 1998 is of the opinion that the shape of a building is primarily determined by whether it is designed to be air-conditioned or to depend on natural ventilation. Gut and Ackerknecht ,1993 hinted that Givoni, 1998 posits a streamlined shape for people who are passionate about using air conditioners, as well as open designs for naturally ventilated homes, since the compactness of the building shell decreases the surface area of the building shell, reducing heat absorption from the envelope. *The paper, Energy efficiency in architecture: An overview of design concepts and architectural interventions, 2005* stated that the amount of room inside a building that needs to be heated or cooled, as well as its contact with the region of the envelope enclosing the volume, affect a building's thermal efficiency.

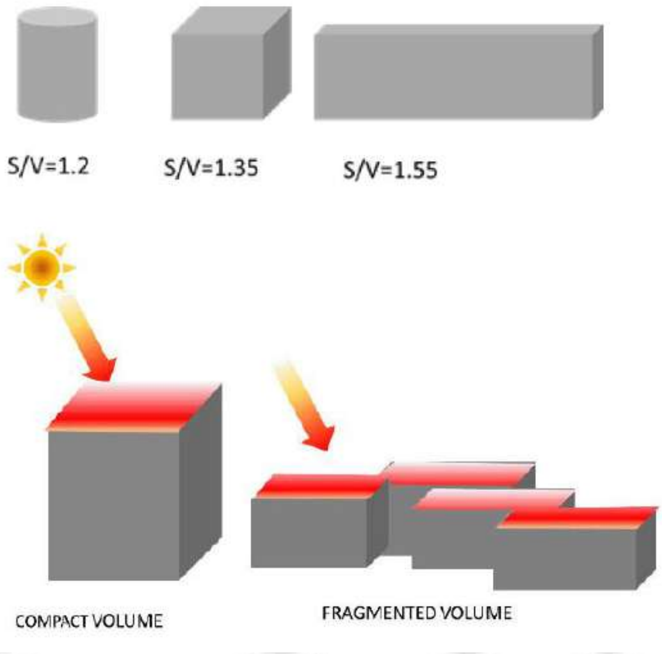


Fig.3.2; *Surface-to-volume ratio for warm humid zone*
Source; (Building Energy Efficiency Guideline for Nigeria Federal Ministry of Power, Works and Housing).

Research has shown that in sunny, dry regions and cold climates, buildings are compact in shape with a low S/V ratio to reduce heat gain and loss. Furthermore, the shape of the building determines the airflow pattern that surrounds it, which has a direct effect on ventilation. Artificial lighting requirements are often dictated by the depth of a structure; the greater the depth, the more artificial lighting is needed. Yüksek and Karadayi, 2017 opined that the shape, volume surface rate, and frontal movements all have an impact on a building's energy efficiency, and they concluded that the geometrical shape of a building has a direct association with its energy efficiency.

iv. Building orientation

Properly oriented buildings take advantage of solar radiation and prevailing wind (Ahsan, 2009). According to **Gut and Ackerknecht (1993), as cited by (Ahsan, 2009)** the longer axis of the building should lie along east-west direction for minimum solar heat gain by the building envelope. Orientation and planning for reducing solar entry into buildings is dependent on the location (that is, the latitude) of the site. The main objective in deciding upon a given orientation in hot climatic regions is to minimize the impact of the sun on the building (Hernandez, 2011). As cited by Bala, 2014, the Department of Veterans Affairs, 2007 asserted that in hot humid climates, orientation should aim to exclude the sun all year round and maximize exposure to cooling breeze. Building orientation related to the sun and prevailing winds will have a significant impact on the required heating and cooling systems and thus the overall energy efficiency of the project. Fig 3.3 below illustrates a proper building orientation where the longer sides of the north and south poles and the shorter sides faces the east and west poles respectively;

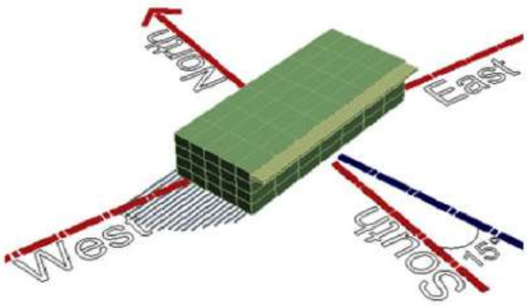
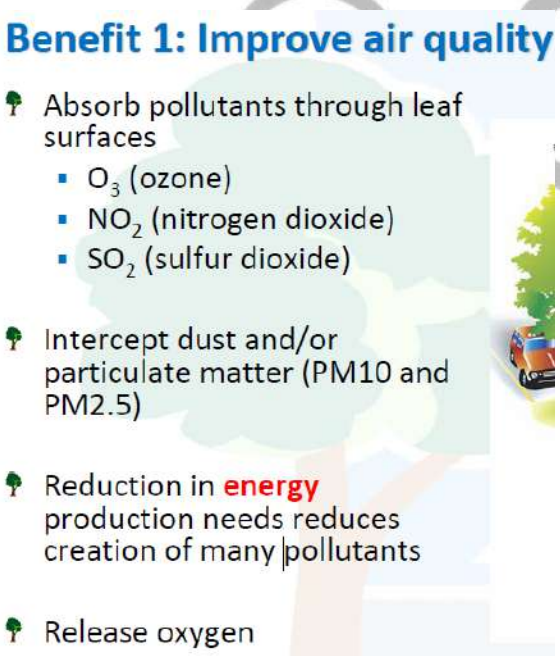


Fig 3.3; proper building orientation
Source; Okula, 2021

This type of orientation in fig 3.3 above is known as the east-west orientation. However, the passive design feature on orienting the longer axis of the building towards east- west direction, as contended by Wong and Li, 2007 is not always possible, especially due to actual orientation of the site, that is, when the site itself is longer on the west and east sides. Such cases are outside the influence of the developer and the architect. In such cases, the west facade needs more attention because it heats up in the afternoon and in residential buildings, important rooms such as bedrooms are generally used later during the day when residents return from office. The east side is less problematic as it warm only in the morning when only few households occupy the major rooms. The west façade can be treated by locating auxiliary spaces, kitchen and staircase to minimize solar heat gain and openings should be avoided on the west and if they cannot be avoided, they should be adequately shaded by using verandahs. It should also be noted that the orientation requirement for wind flow can conflict with the requirement for solar protection (Ahsan, 2009).

v. Energy-efficient landscape design

Efficient landscape design s earlier mentioned is very beneficial to a building and its environment. it is essential to save 30% on energy costs for heating and cooling during the summer and winter seasons by using an accurate and mindful energy-saving landscape design (Yüksek and Karadayi, 2017). These benefits are shown in the fig3.4 – 3.7 below;



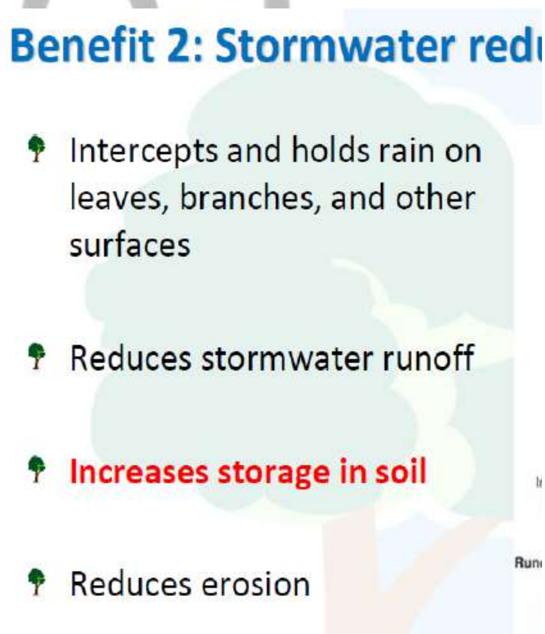


Fig 3.4; benefit 1
Source; energy efficiency through landscape design

Fig 3.5; benefit 2
Source; energy efficiency through landscape design

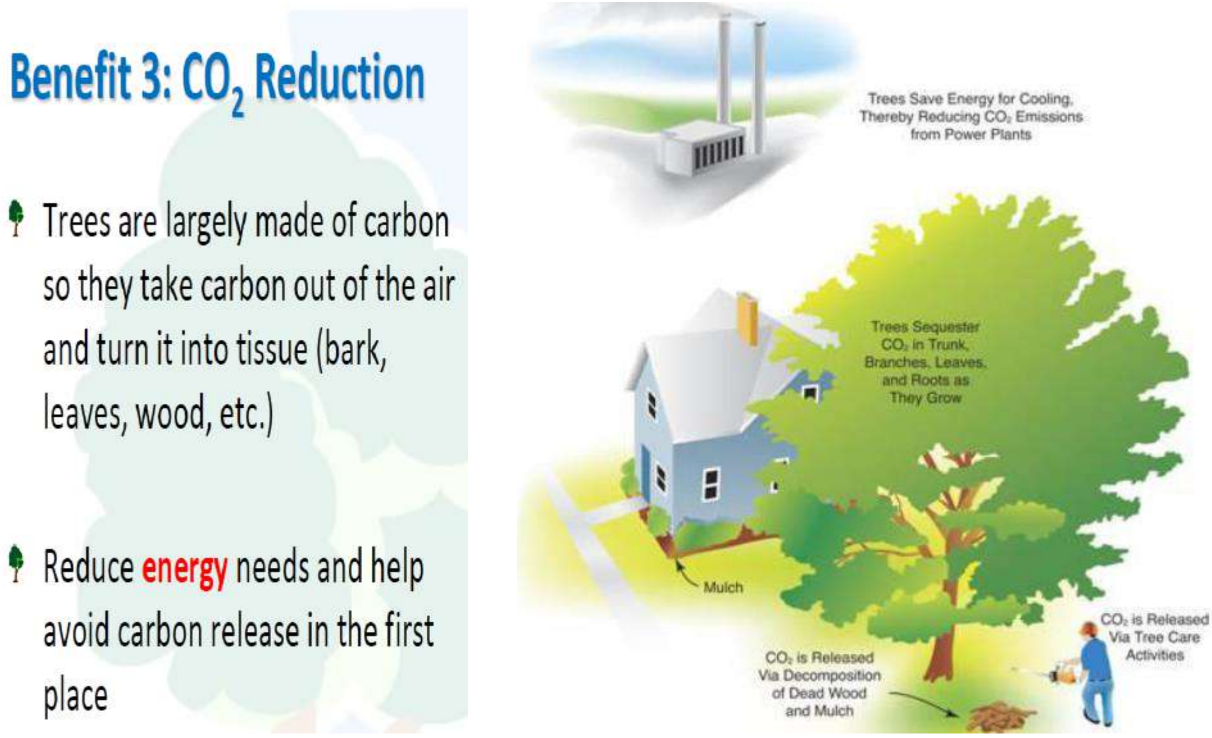


Fig 3.6; benefit 3
Source; energy efficiency through landscape design

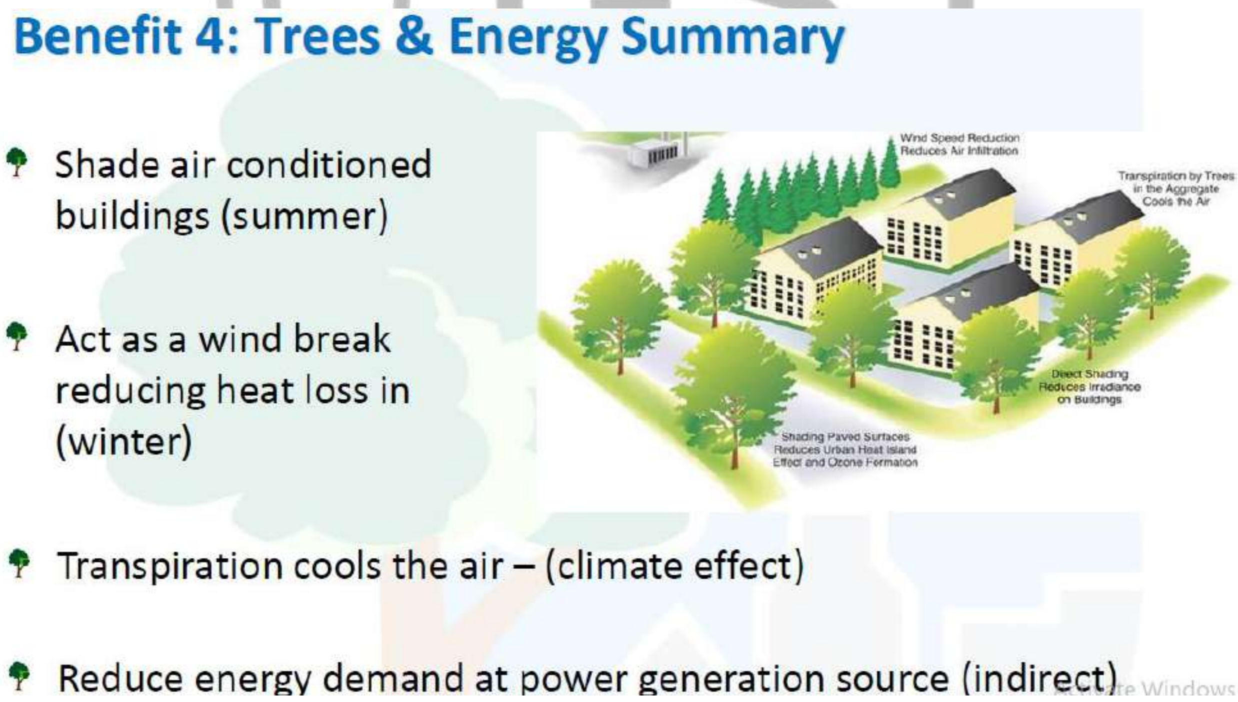


Fig 3.7; benefit 4
Source; energy efficiency through landscape design

Landscaping is an integral part of changing a building's microclimate. Landscaping effectively blocks direct sunlight from hitting and heating up building surfaces. It keeps heat from the earth or other surfaces from entering a building by reflecting light. Numerous airflow patterns created by landscaping can be used to advantageously redirect or divert the wind by generating a pressure differential. Furthermore, the shade offered by trees, as well as the cooling effect of grass and shrubs, lowers surface temperatures near the house. Roof gardens that are well-designed can help reduce a home's heat load. According to a survey, the air temperature under a tree next to the wall is 2 to 2.5 degrees Celsius colder than in open fields, limiting heat gain by conduction. (Energy efficiency in architecture: An overview of design concepts and architectural interventions, 2005).

vi. Building envelope

The building envelope is a shield that prevents heat from leaking from the interior to the outside, and it is critical for the thermal comfort of people (Govini, B., 1998). Many of the construction materials that distinguish the indoors from the outside are used in the building envelope. Exterior walls, foundations, roof, windows, and doors are all part of the building envelope. A variety of subsystems, such as heating, cooling, and ventilating machines, plumbing, and electrical systems, have an effect on the building envelope's efficiency. The relationship between subsystems and building envelope components, as well as some occupant habits, can have an effect on the performance of the building envelope (Home owner protection office, branch of BC housing)

Also, the building envelope and its elements decide the amount of heat gain and loss, as well as the amount of wind that enters the structure. The following are the major determinants of a building envelope's efficiency:

(a) Materials and construction techniques,

(b) Roof,

(c) Walls,

(d) windows and shading, and

(e) Finishes (Energy efficiency in architecture: An overview of design concepts and architectural interventions, 2005).

A significant feature of green building design is the development of an acceptable building envelope. Building consumers would have efficient and secure interior environments that do not need a lot of energy if the building envelope is well-designed (Gibberd, 2009). As seen in fig 3.8, These elements when efficiently done will aid the building withstand the pressure mounted on its envelope by environmental factors such as solar radiation, rainfall, prevailing wind, etc.

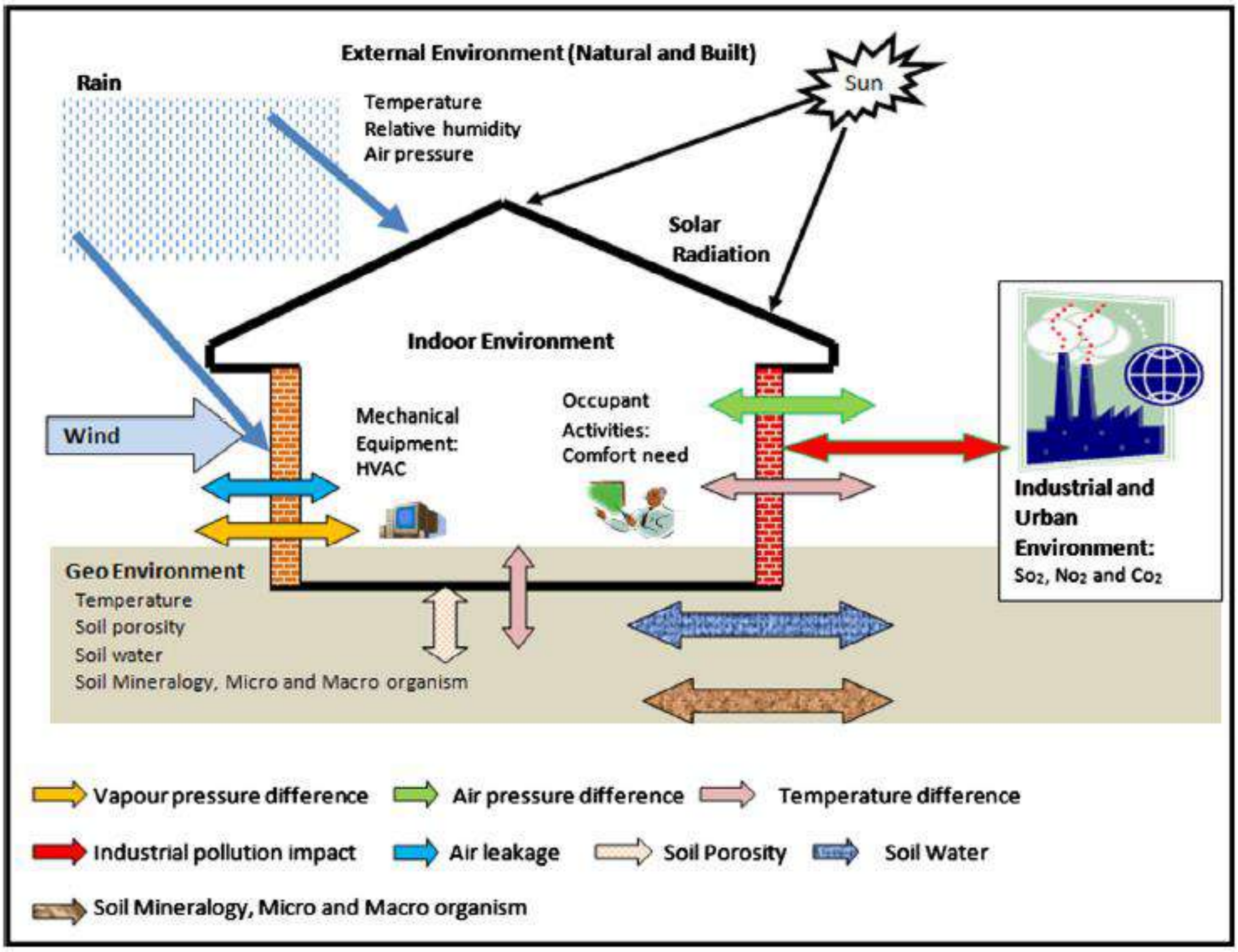


Fig 3.8; Environmental loads on building envelope.
Source; Iwaro and Mwasha, 2014

The earlier mentioned determinants of a building envelope's efficiency will be discussed further;

a. Materials and construction techniques

For the purpose of this study, energy used in manufacturing the building materials and transporting the building materials from the production plant to the site will not be taken into consideration. Neither will it attend to the energy used in on-site construction activities and the energy used in the demolition of the building and the recycling of their parts, rather the study will focus only on the energy used by a building during the operation stage. In this regard, Niccolò Aste et al., 2020 stated that it is important to consider carbon emissions when using building materials. They Prioritized building materials with a low energy quality that are locally available. Items that are recyclable and reusable, as well as items that cause the least amount of waste, are valued. Prioritize envelops with a low U-value or low heat transmittance (walls and roofs). Furthermore, Akbari, 1992 was of the opinion that dark surfaces absorb solar radiation and become hot which raises the air temperature surrounding them and slowly dissipates heat into a building. Using light colours and reflective materials can, according to some estimates, reduce the heat gain of a building by up to 30% during the hottest hours of the day, he inferred. As cited by Ahsan, 2009, Gut and Ackerknecht (1993) recommend using the following building materials in tropical climates:

1.Burnt clay: Burnt clay bricks can be used in tropical climates because they have good thermal resistance and good regulating property against humidity.

2. Timber: Timber has good thermal resistance and is a good regulator of humidity.

3. Matting of bamboo, grass and leaves: these are good because they are not airtight and allow proper ventilation.

Studies has also recommended concrete because concrete is an embodied material with the ability to buffer large path of free heat gains and can save the cost of energy consumption to a minimum degree and improve thermal comfort.

b. Roof

The Solar Reflectance Index (SRI) of a material describes the ability of that material to reflect solar radiation and emit heat. The SRI for a black surface is close to 0 while for a white surface is close to 100. For roof surfaces, a SRI higher than 78 is recommended by most green building certification schemes such as LEED® in order to minimise heat gains through the roof and reduce the contribution to the heat island effect in urban areas (Federal Ministry of Power, Works and Housing, 2016). Fig 3.9 below shows examples of SRI for typical roofing materials:

Roofing material	Solar Reflectance	Infrared Emittance	Temperature rise	SRI
Galvanized steel	0.61	0.04	31°C	46
Tiles-clay red	0.33	0.9	34°C	41
Metal with high reflective white paint	0.67	0.85	16°C	82
Metal with white polymer coating	0.85	0.91	5°C	88

Fig 3.8; Solar Reflectance Index (SRI) of common roofing materials
Source; Federal Ministry of Power, Works and Housing, 2016

Studies has shown that providing roofing materials with light color will help reflect off solar radiation. It's also important to use pitched roof for easy runoff of rainwater. Furthermore, in hot climates, insulating the roof is generally the first priority since the roof is exposed to very high solar gains (Federal Ministry of Power, Works and Housing).

c. Walls

Studies has shown that the major aim in designing buildings for tropical climatic zones is to mitigate the impact of excessive heat gain by conduction, convection and radiation through apertures and decrease in internal surface temperature of the building. In this regard, (Gut and

Ackerknecht, 1993) stated that buildings in tropical climates should be designed with deep consideration of protected openings and walls. The protection of walls will do much to reduce the total heat that enters the building and therefore drastically reduce the amount of heat to be later emitted into the building (Bala, 2014). The walls can be protected by designing the roof so that it extends far beyond the line of walls and has broad overhanging eaves (Ahsan, 2009). Walls could also be protected through insulation; this will be discussed subsequently in this research.

d. Fenestration and Shading

Generally, studies have shown that fenestration influences the amount of natural lighting and ventilation in a building. Living in hot climate can quickly become uncomfortable for its inhabitants with the extreme heat that is built up by midday. That is why it is important for the building structure to have effective ventilation and an internal temperature below the outdoor level. Natural ventilation keeps the air moving within the indoor environment and, therefore, keeps the inhabitants cooler even without the use of energy (Akande, 2010). Daylight (natural lighting) is necessary for human comfort and reduces the need for artificial lighting. Daylight incidence must be balanced against the need to minimise solar heat gains and avoid glare from direct sunlight. The amount of solar heat gains which a window will transmit can vary depending on the coating. Modern coatings allow the heat gains (infra-red) to be reduced while still allowing much of the daylight to pass through the window enabling a good level of daylight to enter whilst avoiding much of the heat gain (Federal Ministry of Power, Works and Housing, 2016). For natural ventilation, the Federal Ministry of Power, Works and Housing, 2016, stated that Various rules of thumb exist to help with the design of naturally ventilated spaces. Single sided openings are the simplest form of ventilation, but are only viable for room depths around 6m or 2.5 times the ceiling height.

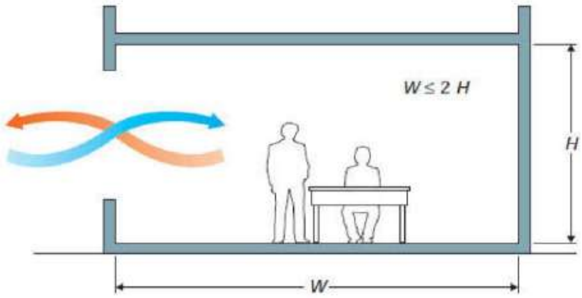


Fig 3.9; Single sided ventilation, single opening
Source; Federal Ministry of Power, Works and Housing, 2016

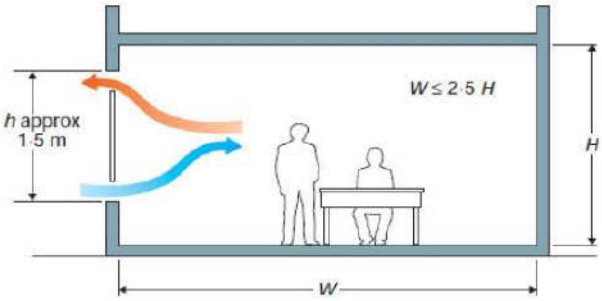


Fig 3.10; Single sided ventilation, double opening
Source; Federal Ministry of Power, Works and Housing, 2016

Cross ventilation is more effective since the wind pressure will help force air through the building. In this case, room depths of around 12m or more are possible (5 times the ceiling height) More complex natural ventilation schemes are possible involving atria, light wells etc. Atria must be designed with caution in Nigeria, since any roof lights will result in high solar gains into the building, they added.

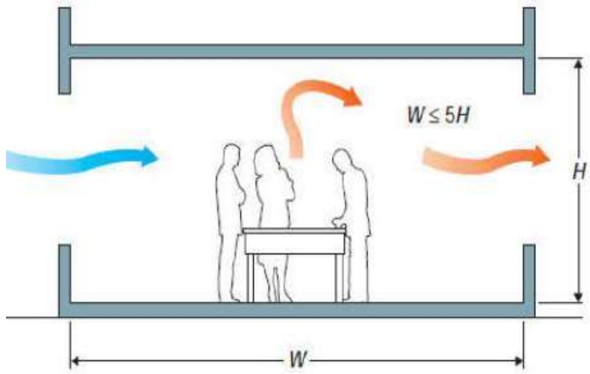


Fig 3.11; Cross ventilation
Source; Federal Ministry of Power, Works and Housing, 2016

Studies has also shown that it is import to have energy efficient windows in buildings in the tropics as this will aid in the overall building performance in terms of mitigating solar heat gain coefficient (SHGC). The Solar Heat Gain Coefficient (SHGC) is the fraction of incident solar radiation that actually enters a building through the entire window assembly as heat gain. The g-value is the equivalent for the glass itself (ignoring the frame). The visual transmittance (VT) is how much daylight passes through the window. A VT of at least 60% is recommended to receive sufficient daylight. Tinted glazing with a strong colour can give an unpleasant internal environment. The table below shows several glazing configurations. The optimal combination should be selected on a case by case basis based on factors such as the size of windows, the level of exposure of the window and daylight requirement (Federal Ministry of Power, Works and Housing, 2016). Fig. 3.12 below shows the anatomy of an energy efficient window;

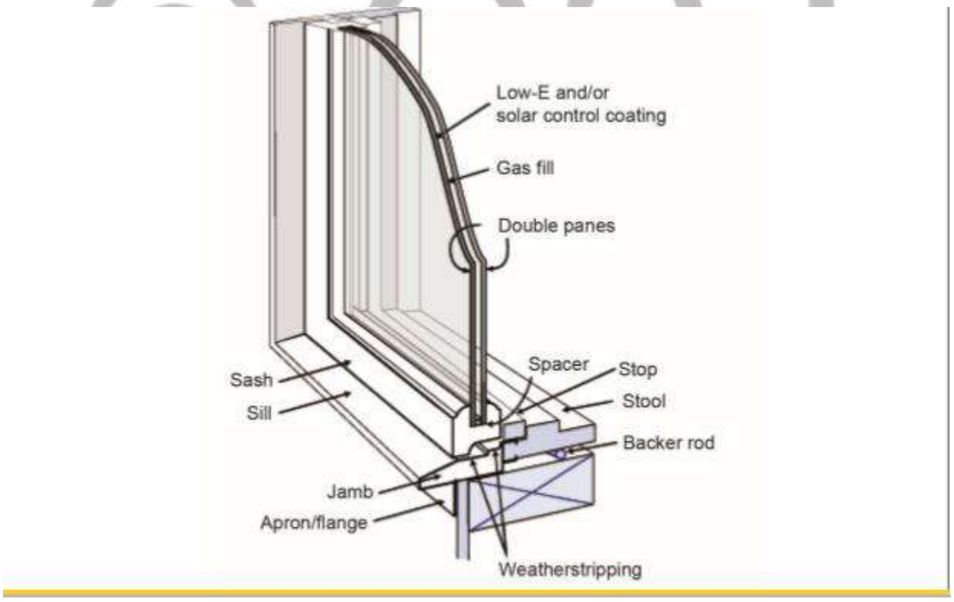


Fig 3.12; Anatomy of an energy efficient window
Source; U.S. Department of Energy

Shading of a building refers not only to shading of its windows, but to the walls themselves (Bala, 2014). The shading of walls will do much to reduce the total heat that enters the building and therefore drastically reduce the amount of heat to be later emitted into the building. Canopies, louvres, awnings, fixed overhangs and external sun shading devices are examples of shading elements that can be used to great effect in building. It is important to note that wall shadings are only necessary under extreme conditions (Hernandez, 2011). Shading of windows can be achieved in two ways which are external and internal shading (Bala, 2014). Exterior shading reduces the direct solar radiation entering the building through the windows. North and south facing elements can be easily shaded with overhangs and horizontal shading, given the high solar altitude in Nigeria. East and west façades are problematic and require a combination of horizontal and vertical shading, since the sun is very low and reaches the façades almost perpendicularly (Federal Ministry of Power, Works and Housing, 2016).

e. Finishes

The external finish of a surface determines the amount of heat absorbed or reflected by it. For example, a smooth and light colour surface reflects more light and heat in comparison to a dark colour surface. Lighter colour surfaces have higher emissivity and should be ideally used for warm climate (Energy efficiency in architecture: An overview of design concepts and architectural interventions, 2005). Futhermore, the journal stated that buildings can be designed to meet occupant's need for thermal and visual comfort at reduced levels energy & resources consumption. Energy resource efficiency in new constructions can be effected by adopting an integrated approach to building design. The primary steps in this approach would be to:

i. *Incorporate solar passive techniques in a building design to minimise load on conventional systems (heating, cooling, ventilation and lighting)* Passive systems provide thermal and visual comfort by using natural energy sources and sinks e.g. solar radiation, outside air, sky, wet surfaces, vegetation, internal gains etc. Energy flows in these systems are by natural means such as by radiation, conduction, convection with minimal or no use of mechanical means. The solar passive systems thus, vary from one climate to the other e.g. in a cold climate an architects' aim would be design a building in such a way that solar gains are maximised, but in a hot climate his primary aim would be to reduce solar gains, maximise natural ventilation and so on.

ii. *Design energy-efficient lighting and HVAC systems (heating, ventilation and air-conditioning)* Once the passive solar architectural concepts are applied to a design, the load on conventional systems (HVAC and lighting) is reduced. Further, energy conservation is possible by judicious design of the artificial lighting and HVAC system using energy efficient equipments, controls and operation strategies. The Federal Ministry of Power, Works and Housing, 2016, asserted that lighting is one of the systems where large improvements can be achieved by simply changing lamps from incandescent bulbs to compact fluorescent or LED to the end result of significant energy savings, especially in the residential sector, where lighting is one of the major energy uses. The addition of daylight and occupancy controls provide an extra level of saving which are recommended in office buildings.

The figures below show different lamp types and their efficiency chart.

Fig 3.11; Lamp Types

Source; Federal Ministry of Power, Works and Housing, 2016

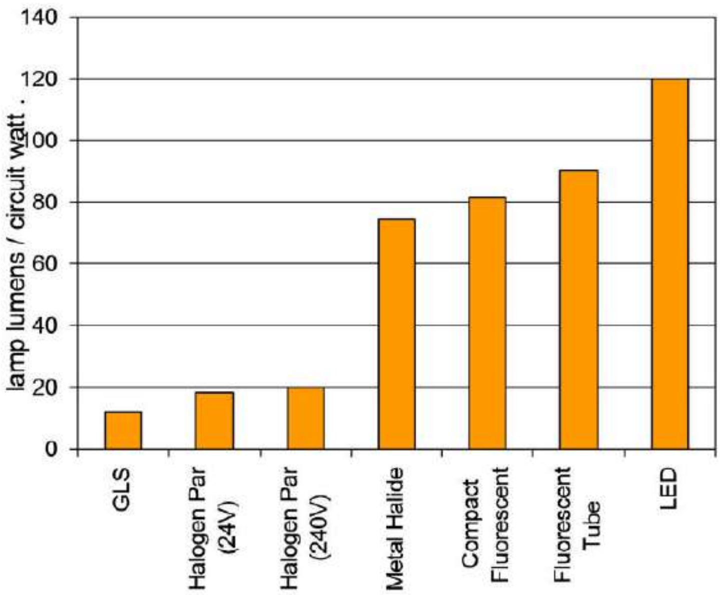


Fig 3.13; Lamp Types efficiency chart

Source; Federal Ministry of Power, Works and Housing, 2016

iii. *Use renewable energy systems (solar photovoltaic systems/ solar water heating systems) to meet a part of building load* The pressure on the earth's nonrenewable resources can be alleviated by judicious use of earth's renewable resources i.e. solar energy. Use solar energy for meeting electrical needs for a building can further reduce consumption of conventional forms of energy.

The Federal Ministry of Power, Works and Housing, 2016, stated that the main renewable energy source in Nigeria is solar energy. Solar resources are highest in the north of Nigeria, and lower in the southern coastal region. Nevertheless, it is sufficient for solar energy viability. Other potentially viable renewable energy resources in Nigeria include wind and bioenergy. Different renewable technologies feature different characteristics of production, costs, scale, maturity, bankability, etc. and because of these reasons, a feasibility assessment should be performed for each potential site to ensure it is both technically and financially suitable to install renewables.

Furthermore, the figure below shows passive design strategies applicability suitable for Nigeria.

Strategy	Hot & dry	Hot & humid
Compact geometry	√	X
Exterior Shading	√	√
Daylighting	√	√
Window low SHGC	√	√
Cross/stack ventilation (if naturally ventilated)	√	√
Building permeability (if naturally ventilated)	X	√
Roof Insulation	√	√
Wall insulation (exterior)	√	X
High thermal mass	√	X
Low thermal mass	X	√
Evaporative cooling	√	X

Fig 3.14; Passive Design Strategies Applicability Suitable for Nigeria

Source; Federal Ministry of Power, Works and Housing, 2016

4.0 Conclusion

The aim of this study was to explore the idea of sustainable design strategies to the end of ameliorating Energy-Efficient Architecture for Buildings in Tropical Climates Using Passive Design Strategies: The Context of Nigeria. To this effect, an in-depth analysis of sustainable design strategies and energy efficiency considerations was conducted, and their use in tropical zones, as well as the degree to which these techniques were used in hot-humid climate of Nigeria. It was asserted that the use of low-energy materials for the building envelope and its elements, complete use of daylighting in all areas to reduce the need for supplemental artificial lighting during the day, use of openable windows to enhance ventilation, and in turn, prevent air conditioning in areas where natural ventilation has been adequately met. The location's climatic condition, energy crises, energy practices, energy use per sector and energy source were described and discussed in the literature review.

In inference, the quest to achieve thermal comfort within a building is the primary reason why a lot of energy is consumed during the building's operational stage. This is true because most electrical and mechanical devices within the building are usually used for adjusting interior conditions to suite the users. Deductions made from various literature shows that the application of sustainable design strategies can reduce energy consumption in a building, this will maximize occupant health and comfort and minimize energy use by relying less on mechanical and electrical systems. Furthermore, it is intended to achieve higher standard of energy efficiency without jeopardizing thermal comfort.

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