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Energy Efficiency and Conservation Problems in Nigeria: Measures for Alleviation.

OKULA, Harrison Esuoghene MSc. Architecture.

Department of Architecture, Rivers State University, Port Harcourt, Nigeria.

Email: harrisonworld25@gmail.com

ABSTRACT

Energy is one criteria for measuring the growth and success of a nation. Efficient and clean energy contributes to economic growth and offers comfortable living condition for humans. Nigeria is blessed with abundant sources of clean and renewable energy. Unfortunately, Nigeria has not utilized such efficient, reliable and clean energy in generating the required electricity to the taste of its citizens as there has been crisis and inconsistency in power supply for some decades. In the quest to improve the energy state of the country, the Nigeria government has tried its best by setting up some energy policies and plans, but due to poor administration, there has been little or no positive results. In buildings, more than half of the energy generated is utilized in residential and commercial buildings. In spite of the fact that the country is dominated by the hot-dry and warm humid climate, Nigeria has not been able to generate the required quantity of energy needed for the regulation of indoor air temperature, industrial and domestic activities. The country has been overly dependent on the use of fossil fuel for generating energy that has spawned negative effects on the environment- the emission of harmful gases such as the chlorofluorocarbon (CHFs) which has contributed to global warming. This paper unveils the energy crisis in Nigeria and analyses recent surveys that reveals the state of power supply and the rate of energy utilization in some residential buildings. This paper also discusses some alleviation measures for the energy problem in Nigeria by emphasizing on the use of Solar Photovoltaic (PV) - a renewable energy source and a potential for clean and efficient energy. Most importantly, for the design and construction of buildings, it further discusses effective energy efficient design and construction measures that architects and engineers should adopt.

Keywords: Energy Efficiency; Energy Conservation; Renewable Energy; Hot-dry & Warm Humid zone; Sustainable Development, Design, Construction.

1.0 Introduction

As world population continues to grow, there has been a strong demand for efficient source of energy for residential, commercial, industrial and agricultural purposes. Man's consumption of energy for a variety of reasons has caused environmental issues.

Several natural gas-rich countries in the world, which include Nigeria, are facing energy and economic turmoil as a result of falling price of crude oil and destabilization in several parts of its territories. Energy efficiency and conservation are main driving force to urban development in many countries without a doubt. Nigeria is in a terrible energy state, with 60-70 per cent of its population of some 200 million living without steady supply of electricity.

We need electricity for residential, manufacturing, commercial and agricultural uses. Nigeria, though, has struggled to provide electricity for these purposes and the present lack of electricity has been distressing. (Akorede, Ibrahim, Amadu, Otuoze, & Olufeagba, 2017) This has led to the establishment of the systems required to create and sustain the electricity market. Nigeria primarily generates electricity from the burning of fossil fuels, yet it has not satisfied the need of many. Majority of Nigerians has resorted to the use of generating sets to power their appliances. As electricity is extracted from these generating sets, fossil fuels are burnt, hence, the release of dangerous gaseous substances into the environment resulting in air pollution.

During the industrial revolution, there was an enormous use of electricity, including major productivity gains and lifestyle changes. The main source of energy before the industrial revolution was fire wood and fuel usually for cooking. It was until 1769 when steam was invented and internal combustion energy invented in 1875 that energy was used for the production of electricity.

According to the Ministry of Natural Resources and Energy, Swaziland (Eswatini), Energy efficiency (EE) is an innovation or technological innovation program that needs less energy to perform the same task. On the other hand, Energy conservation (EC) is any action that avoids loss of energy or uses less energy.

Energy efficiency mechanisms are simpler, safer and easier to be introduced than any other energy alternative. It also has the advantage of fostering economic growth and may build employment and contributions in personal income. .Adequate renewable energy at national and regional level contributes to steady economic growth, export promotion and expanded competition in the global economy.

In his study of energy efficiency and sustainability, Scott; (2014) found that Energy efficiency and conservation does not mean that less energy is used or that energy audits are the only way to be more efficient. Energy efficiency means more productive use of energy. Energy audits although overwhelming, they are beneficial if properly utilized.

Nigeria's population is continuously on the increase, hence, there is a growing demand for energy that must satisfy the population. This has raised panic regarding the country's state of energy. What is the underlying issue of energy generation in Nigeria? Apart from fossil fuel energy source, what other energy-efficient technology is available? What can be done to conserve energy in our day-to-day activities?

The aim of this paper is to construe information that will facilitate the adoption of energy efficient and conservation measures in the hot and warm-humid zones of Nigeria.

2.0 Methodology

For any research to be carried out, it is important to undergo a methodology that will achieve the aim of the research. The influence of the methodology on the potential outcome of any research effort can never be over-emphasized. It is crucial to choose the correct methodology when conducting a study, to ensure that the research purpose and goals are met and that the results can be confirmed.

The research method used in this study is purely documents analysis. The source of data exploits the review of some works done on this subject taken from both published books, articles, journals, newspaper and magazines.

3.0 Discussion

Energy is crucial to the growth of any economy, to national development and ultimately, to sustainability. Our Planet is blessed with abundant resources that are sources of energy to man. There are numerous sources of energy: (1) fossil energy in the form coal, oil and natural gas and (2) renewable energy sources include the wind, solar energy and geothermal energy supplied as heat from the earths. These primary energy sources is further transformed to electricity-a secondary source of energy which flows across power lines and other transmission systems to buildings for both domestic and commercial use. (US department of Energy, 2020)

Nigeria is in a tropical climate. 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. Energy is predominantly used in domestic homes for cooling and heating and also needed in manufacturing industries. But the energy needed is meagre or sometimes unavailable. This has been the major reason why other sources of energy are needed, hence there is an urgent call for efficiency and conservation.

Before we explore the measures to be taken, let us take a brief look at the energy crisis that has engulfed the country.

2.1. Brief Overview of the Energy situation in Nigeria

Nigeria is a country with a thriving economy, a country with abundance of natural resources, such as crude oil and natural gas. Nigeria is

known as the largest producer of oil in Africa. Unfortunately, supply of electricity to residential homes and industrial sectors has been awful over the years. Currently, only 40 per cent of Nigeria's population has access to electricity, with 60 per cent having experienced power difficulties. (Aliyu, Ramli, & Saleh, 2013) The maximum average power supply to the average citizen is calculated to be 4hours. More often, there is no power supply in some days.

For more than a decade, Nigeria's power reforms have concentrated on privatizing the energy sector and promoting private investment, but the government has continued to monitor the transmission assets while making limited development towards a favorable environment for foreign investors. (Ogundeye & Eric, 2017) In spite of all efforts to solve the electricity problem, the daily supply of electricity still remains meager.

Another problem that the power sector has been facing is low water level and difficulty in accessing the gas by generating companies. According to the Transmission Company of Nigeria (TCN), the power generation in Nigeria has dropped from 3959MW as at January 2017 to 2662MW.

2.2. Energy Efficiency Bodies and Polices in Nigeria

The estimated population of Nigeria is 170million of which 65% are between the ages of 18-45years. 60% of the population lack electricity while only 40% of the population has access to electricity. The government has seek alternative sources of electricity through the exploration and exploitation of renewable energy as known as clean energy. To explicitly show the government's devotion in improving the country's renewable energy reputation and increasing its availability, there have been policies and plans enacted in the past.

The Renewable Energy Plan (REMP), was the first to be drawn up in 2005 and adjusted in 2012, but this was not approved by the Federal Executive Council (FEC). The Nigerian renewable Energy and Energy Efficiency policy (NREEEP) was the next policy established, proposed by the Federal Ministry of Power and approved by the government in 2015. The Ministry of Power, Energy commission of Nigeria (ECN) and some other Ministries, Departments and Agencies (MDAs) are responsible for implementing this policy. They are under the supervision of the National Energy Efficiency Action Plan. (NEEAP).

The Energy commission of Nigeria (ECN), is another body that was established by Act in 1979 and further amended by Act No 32 of 1988. In subsequent time, it was strengthened for the strategic planning in the field of energy with a statutory authorization in all its divisions. It has both external and internal support as well as international relations that are necessary to support its specialized functions. As the greatest government organ, the ECN is empowered to

implement overall energy sector planning and policy enforcement, and encourage energy resource diversification, by developing and making optimal use of all the energy sources.

2.3. Energy efficiency of a Building

The Sustainable Energy Regulation and Policy making for Africa states that, "energy efficiency of a building is the extent to which the energy consumption per square meter of a floor area of the building measures up the established energy consumption benchmarks for that particular type of building under defined climatic conditions."

According to the Federal Ministry of Power, Works and Housing, "the design of energy efficient buildings is beyond the skill and expertise of only the architects and, therefore, the integrated design process becomes an essential tool for the executive incorporation of expertise across different disciplines." The various disciplines in the building industry includes the structural engineer, the mechanical engineer and the electrical engineer who are supported at the detailed design stage. They are required to provide their expertise in conjunction with the design but have no part in amending or shaping the design either to perfect or optimize construction operation. The architect plays the crucial role in the creation of a structure.

2.4 The Use of Solar Photovoltaic cells

Solar energy is a renewable source of energy gotten from the sun as light and heat are harnessed using a range of technologies such as photovoltaic, solar thermal energy, solar architecture and artificial photosynthesis that are ever-evolving. These renewable source of energy is cheaper when compared to fossil fuel.

The first two Photovoltaic system in Nigeria was powered by The Nigeria Telecommunications (NITEC) in 1991. By 1997, more than 50 repeaters stations in Nigeria networks were powered by solar photovoltaic system. Since then, the application of photovoltaic solar system has continued to grow even in residential and commercial buildings. This has heavily contributed to the improvement of power supply in many households, businesses and industries.

Before technological revolution the harnessing solar energy for man's use has been a mystery to scientists for centuries. Availability and technology is the sole driver for the use of solar energy. (Nasir, 2001). Nigeria is located between the equators and has an abundant supply sunshine almost throughout the year. The energy can be harnessed to booster the supply of electricity. According to a study on solar cells, the current efficiency is recorded to 43.6% and in the future, solar will be regarded as the most important source of energy due as its efficiency progresses. (Adeel , Rashid, & Mehmood, 2016)

Abdullahi et al. (2017) conducted a random survey on 150 residential buildings in Akure, Ondo state, Nigeria. The occupants of the buildings were then administered a structured questionnaire. The table below shows the data of the survey

Distribution of Apartment		
Apartments	Frequency	Percentage
2-bedroom flat	35	23.3%
3-bedroom flat	43	28.7%
4-bedroom flat	40	26.7%
5-bedroom flat	32	21.3%

Tab 4.

The table shows the types of apartments that were administered questionnaires. The correspondent were asked whether they use alternative source of power supply. Out of the150 apartments, 113 agreed that they used alternative power supply while 37 apartments said they do not use. Out of the 113 apartments that use alternate source of power, 102 apartment were observed to use diesel powered generator while 11 use solar inverters. Building owners were further asked whether they can adopt solar photovoltaic installation as an alternative to the national grid. 94 residential owners were willing to adopt solar PV installation as an alternative to the national grid, 56 residential owners were not willing to adopt solar PV installation. The 56 who were unwilling to adopt solar PV as an alternative source of power, 36 said that could not afford solar PV while 15 correspondents said they lack awareness on solar PV while 2 correspondents responded with others barriers such as lack of technical-know-how, environmental problems and among others.

From the data analyzed, it is crystal clear that few residential buildings in Nigeria uses solar PV as an alternative to the power supply from the national grid. It also revealed that the cost of installing a solar PV and lack of awareness are some disadvantage of adopting renewable energy for many people.

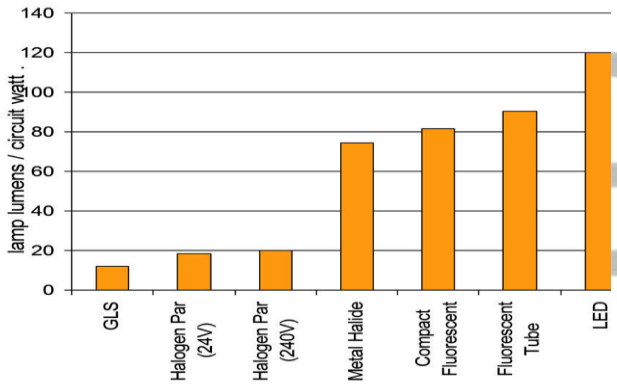
3.0 Design Measures for Energy efficiency and conservation

To increase reliability, reduce cost by optimizing component technologies and improve the comfort level of building occupants, a well-designed building or system and control strategy is very important. There is minimal cost in designing and building low energy buildings. (US Department of Energy, 2015). Providing a comfortable and healthy interior environment is one of the core function of building energy systems and this accounts for about one-third of the total energy use. Some energy efficiency and conservation measures to introduce into a building during design and construction are as follow;

A. Windows and Lighting Devices

A well-positioned window in a space can improve the ambiance of that space and also reduce demand for artificial light. In an energy-efficient building, outdoor light is the dominant source of light. Light and heat energy from the sun is a very important for a building in terms of warming and lighting. A windows that is designed and positioned in a way that transmit maximum light into a building during the day, the energy that could have been required to light up the building is conserved. This is one aspect of applying energy efficiency in a design.

While the choice of lighting device can conserve energy, there are many lighting technologies available today, the dominant technology is Light Emitting diode (LED).There are two major Classes of LEDs. Crystalline semiconductor device LED that share similar features as the silicon-based computer chips, and organic (OLEDs), which use organic materials that have the characteristics of semiconductors. The compact lamp (CFL) also called compact fluorescent light and energy-saving light is energy efficient and considered the best replacement of lower incandescent lamps at homes, offices, commercial and industrial outfits.



***Source**: Federal Ministry of Power, Works and Housing*

Furthermore, a Lighting control system helps in minimizing energy consumption in lighting devices. These system uses a network-based computing device in the control of lighting. This could also optimize energy in lighting devices.

Many features and technologies make windows more energy efficient and improve the durability, aesthetics and functionality. The following features of a window determines its efficiency during design and installation;

i. Frames: Frames should be thermal resistant. Frames that resistant to heat are energy efficient frames, especially its U-factor (i.e. the rate at which window components resist heat flow). A lower U-factor indicates high resistant to heat flow. Vinyl, wood, fiberglass are some materials that provides greater thermal resistance compared than metals. This is why an architect is required to provide detailed description on the type of window to be installed.

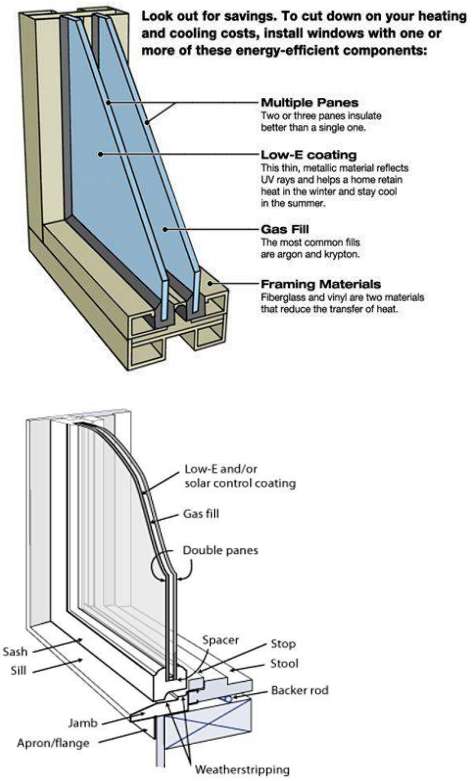
ii. Glass: Choice of glass material is also a determining factor to the energy efficiency of a window. Insulated glass windows provides lower U-factor than non-insulated ones. This is done by using sealed glass panes properly spaced to provide air space. The use of low-emissivity (low-e) coatings on glass controls heat transfer through windows, there saving energy as much as 30-50%. A low-e coating material on glass can also lower the U-factor of the window. Low-e coating are usually design to allow for high solar gain, moderate solar gain, or low solar gain, the choice of

a coating material depends on the climate of that region.

iii. Gas fills and Spacers: gas fill materials also minimize heat transfer from the exterior material to the interior material of a window.

iv. Window operating type: The choice of a window in terms of opening direction or movement pattern will also determine the energy efficiency of that window.

The diagram below illustrates the features of an energy efficient window.



Credit: David Bounsall,

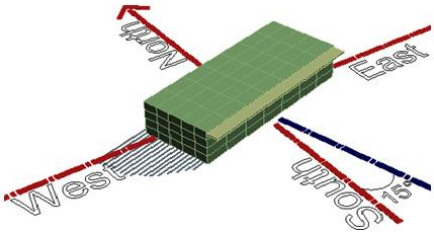
B. Building Orientation and Form

Building orientation is the relationship between the position of the building elevations and its geographical direction. In design, a proper oriented building is important to the quantity of solar gain and also affects the cooling indoor spaces. It is also a determining factor of ventilation. During winter seasons for cold climates, a building oriented in such climates will determine the amount of solar heat gained for warming up livable spaces while for hot, warm and humid climates, orientation will determine the amount of cool breezes flowing across the building. The sun is lower at certain times of the year. Optimizing solar radiation and introducing good shading devices are relatively straightforward for countries that are close to the equator, where there is little variation in the sun path in some periods of the year.

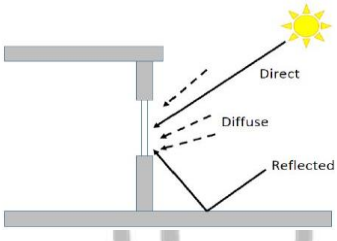
In the design of habitable spaces, spaces that requires little light should be positioned away from the sun's path, rather, spaces of activities that requires abundance of naturel light should be located as to receive direct natural light from the sun. Shading devices in windows protects from direct solar radiation during the day and improves the quality of light entering a space. Research has found out that it is preferable for a building to adopt the East-West orientation, such that the building's longitudinal direction axis is along the east-west while the short sides is North-South so that the north side takes less amount of heat

during hot periods depending on the sun's level and azimuth. (Rania & Neveen, 2017).

The picture below illustrates the east-west orientation pattern.

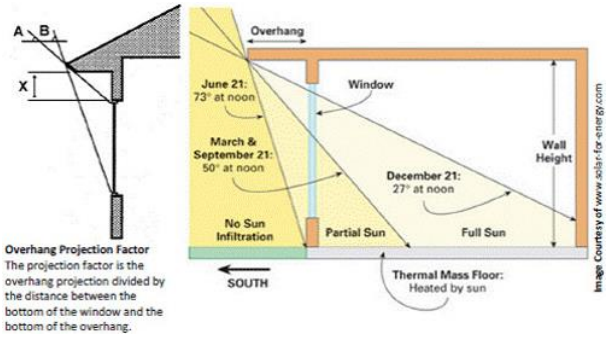


Building orientation: Reducing conductive heat flow (Pour, 2015)



Solar radiation entering a building through the window.
***Source**:(www.qualibuild.ie/solar_gain/)*

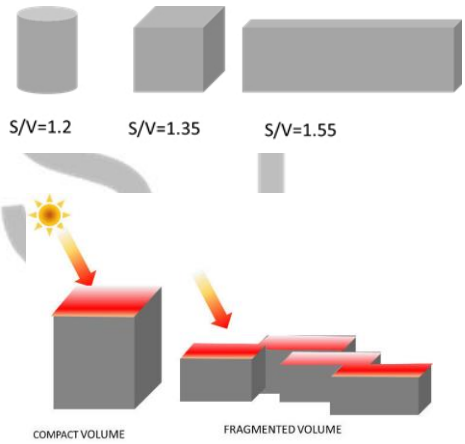
The diagram below shows how the use of a simple shading device or overhang can address this problem.



Source: SBIC and the Beyond Green Guidelines for High-Performance Homes

The understanding of the position of the sun in the sky during the cold and hot seasons will help in the design of shading devices.

Building forms that are compact such as cubes reduces heat gain than elongated forms. The cost of cooling will be lower in lower surface volume (SV) than higher surface volume. The diagram below illustrates this.



Surface volume ratio for warm humid zone

***Source**:* Building Energy Efficiency Guideline for Nigeria (Federal Ministry of Power, Works and Housing

Achieving cross ventilation should be a priority in designing spaces in the hot and warm humid zones. To this end, Givoni; (1994), opines that cross ventilation should be the ultimate priority

in case conflict arise between solar heat for warmth and wind for cooling.

C. Building Materials

Materials used as finishes such as wall, floor, ceiling and roof finishes also determine the energy efficiency conservation level of buildings. The choice of roof material determines the degree of protection from moisture and solar heat gain. In hot and warm humid climate where solar heat is intense, such climates requires materials that can reflect maximum heat. The use of such materials minimizes the energy required in cooling the space, thereby, cutting down the cost of cooling. It would be ideal to specify roofing materials that are light, reflective and well insulated. Shake shingles, slate roofing, metal roofing, asphalt shingles and tile roof are such roofing materials that are energy efficient. The image below illustrates the types of energy efficient roof.

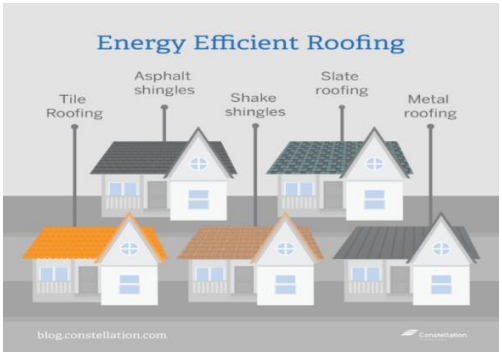


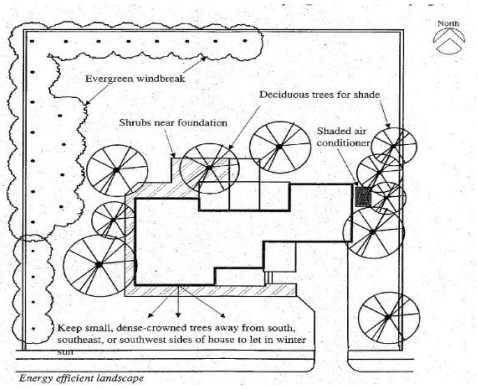
Image Credit: constellation energy resources (2017) (www.constellation.com)

Consideration should also be given to wall elements and finishes. In the tropics where concrete is the dominant building material, the thermal stability of concrete should be taken into consideration. Thermal stability of concrete saves energy and produces better indoor environment for building users and occupants. Concrete has 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.

The choice of ceiling finish also affects the energy efficiency of a building. Ceiling also regulates and protects buildings from high temperatures during the hottest part of the day. Ceiling with bright surfaces can reflect away heat coming from some roof materials thereby, contributing to energy efficiency.

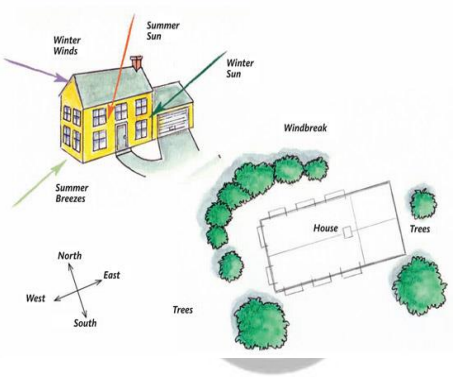
D. Trees and Vegetation

A well designed landscape is able to reduce the cost of heating and cooling by 40%. (Johnson; 2018). Vegetation such as trees, shrubs, groundcover and vines are effective in controlling the microclimate by provide a cool atmosphere by shading a particular area of a building, thereby, shading off heat as well as acting as insulation against heat. Vegetation also help to create different air flow pattern by causing minor pressure differences in a place. The diagrams below illustrate how tree planting can serve as shading off solar rays as well as windbreakers



Shading east and west world in a hot and warm humid climate

Credit: Michael Kuhns



Planting trees to act as windbreakers

Credit: Michael Kuhns

Trees serves as wind breakers in climates were winter cold is significantly worse. In such climates, the cost of warming up a space is cost intensive. Planting trees perpendicular to the direction of the wind can significantly reduce the energy needed for heating. This too is energy efficient. The image below demonstrates a building with trees serving as windbreakers.

Image of an energy efficient building with wind breakers

***Source**: (www.landscapeforlife.org/plants)*

Shading houses and paved lands using deciduous trees is energy conservative as the trees are effective in acting as barriers to cold winds in the summer. A well-designed landscape can go a long way in promoting energy efficiency and conservation not only by reducing cost of cooling but also reducing the cost of heating in cold climates.

4.0 Conclusion/Recommendations

Over reliance on fossil fuels not only brings more harm than good to the environment but also discourages sustainable development and impedes economic growth of a nation. Nigeria is a developing nation blessed with abundance natural resources, more especially renewable source of energy to an abundance electricity to all citizens. But sad to say, over-reliance on fossil fuels has begun to cripple economic growth and sustainable development not only in Nigeria but also in many countries in the world. As energy from fossil fuel cannot provide sufficient clean energy for the ever-increasing population, there

has been a huge call for an alternative source of clean energy that will be satisfactory to all.

This paper has enumerated the sources of renewable energy; energy from the sun through solar photovoltaic (PV) has been proven as the best source of renewable energy. Although, adopting this source is cost intensive. To resolve this issue, the government has a huge role to play. Provision of efficient source of energy by making solar PV installation devices in abundance and at subsidized rate can go a long way in addressing this issue. However, living in the current state of energy crisis does not mean there isn't other alternative to being energy efficient or conservative. This research has emphasized some energy efficiency and conservation measures in all building type. Energy efficient window design and lighting devices, building orientation and form, adopting the use of energy efficient building materials and a well-designed landscape for regulating the microclimate. These measures not only make the habitable environment comfortable but also promote sustainable development. They are easy to adopt if properly planned for.

Since the government has not effectively handled the issue of energy efficiency, it is high time the building industry enforced energy efficient and conservation rules in the design and construction of buildings.

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