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Modern Vernacular Architecture: An Ecological approach towards energy efficiency;toreduce climate change impact in Nigeria.

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Abstract: *In the quest for beauty in diversity; majority of Architects shifted away from the antecedent methods of design and construction. Perhaps this action has proven to be more rebellious by the founding Architects of modernism than the later. Due to recent rises in energy costs and global warming, the trend has sensibly swung the other way. Vernacular architecture, the most adaptive form of addressing the impact of climatic change round the globe, is apparently neglected in modern architecture. Architects are embracing regional adaptation and cultural building traditions, given that these structures have proven to be more energy efficient and environmentally friendly. The human lungs and eyes are designed for something natural; the eyes are designed for natural light, and the lungs are designed for natural air, our skin is also designed for something also natural. This implies that the totality of human comfort desires are culturally connected to one's natural surrounding which is reflected in a harmonious architecture, a typology which can be identified with a specific region. This proven approach can be seen in a material, color scheme, spatial language, architectural styles, or form as expressed through the urban framework. The way human settlements are structured in modernity, has been vastly unsystematic.Current architectural trends exists mainly on beauty and functionality, unfocused on the connectivity of a community as a whole. Traditional building materials are resources that are found readily in large quantities across Nigeria and the extensive use of this materials isn't just enough as there are naturally occurring environmental factors as well as the use of fixtures, fittings, lifestyles, equipment's etc. to be considered in building design and construction, towards achieving almost a net-zero energy efficient building. The availability of these materials may largely be dependent on geographical location of the area as well as the chemical and physical components of such materials. In this time of rapid technological advancement and urbanization, there is still much to be learned from the traditional knowledge of vernacular construction. This paper is aimed at identifying ecological systems in vernacular architecture and the application of technological advancements to improve its usability, sustainability, and constructability to achieve an energy efficient modern design. A structure can ideally achieve net zero energy use, and be a wholly self-sufficient building.*

Keywords:*Energy efficient homes, Endo-Vernacology, Exo-Vernacology,Modern vernacular architecture, Traditional buildings in Nigeria, Vernacular Architecture.*

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I. Introduction

The study of the continuous development of human activities and their ecological impact reveal that pollution is a result of three factors: population (demographic growth), consumption economy (extravagant ways of life) and polluting technology. The relation between these factors is important because it can help us direct the population to new sustainable ways of life. Pollution is the negative aspect of energy consumption and buildings are the most important energy consumers, using about fifty percent of the global generated energy. (Moleavin, n.d.)The human history is marked by energy transformation. Every era is marked by its own energy generation techniques. In our society, we are now required to generate, renewable energy through its natural sources and its evolution patterns. The chat below (figure 1.0) clearly shows the percentage of buildings, transportation and Industries, global energy consumption rate with buildings taking up to 50%. This is a warning to mankind on the immediate need to revolving our thinking in building design and construction towards an energy efficient design; and the most reliable and sustainable way of achieving this concept, is by adopting ecological principles while also taking advantage in technological advancements in solving housing problems. It should be noted that ecological principles and vernacular architecture are not only applicable to residential homes or low rise buildings but can be widely used in all forms of building design and construction ranging from commercial, institutional, religious, and industrial buildings just to name a few in achieving maximum energy efficiency.

More also, not all energy efficient and locally sourced materials meet up all sustainable requirements but all sustainable materials must meet with energy efficiency requirements. I.e. using thatch as a building material is very energy efficient as it blends with the natural environment in achieving a passive cooling and saves cost generally but it isn't sustainable because it deteriorates within a short period of time. With the emergence of modern vernacular Architecture, this paper carefully highlights the use of renewable energy techniques and user lifestyle, new innovations in building components, materials, equipment's, fixtures, and appliances in reducing the cost of energy consumption in buildings. Most importantly, this research clearly states the various environmental factors that should be adopted by Architects in Nigeria in designing an energy efficient and sustainable buildings for now and the future.

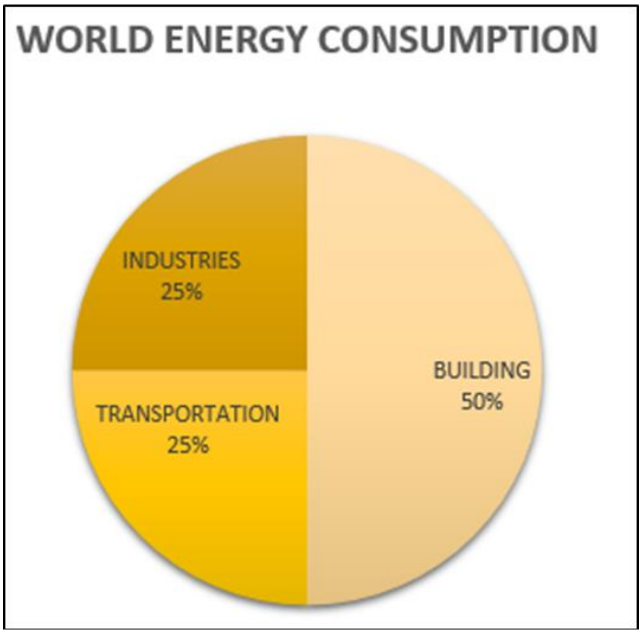

Figure 1.0 showing world energy consumption by sectors. Adapted from (Moleavin, n.d.)

This chart shows how we consume the energy we produce. Transport – 25%, Industry – 25%, Building – 50%. The human history is the history of energy transformation. Every era is marked by its own energy generation techniques. In our society, we are now forced to generate, as soon as possible, "an exodus to nature", to its sources of energy and its evolution patterns. The orientation of the built environment and of the human way of life towards creating a symbiotic relation with nature, is not only a matter of pollution, but one also related to the human psychology. We are, and always will be, a part of the natural system and the universe. Denying this truth during our lives can create psychic disharmonies for individuals or different groups of peoples. Through its intelligence, humanity must try not to forget but to elevate, spiritually and materially, its indissoluble connection with the Universe. Today, the goal of energy efficient design; is to create comfortable living environments in a sustainable way.

Some sustainable design principles that can be adopted in vernacular Architecture are:
- Planning and orientation of buildings
- Design and spatial flexibility
- Climate responsiveness
- Material usage and Indigenous construction techniques,
- Density and sense of place.

1.2. Statement of problem

According to the National Climatic Data Center, before the Industrial Revolution (about the year 1800), levels of carbon dioxide were about 280 parts per million by volume (ppmv); current levels are greater than 380 ppmv and increasing at a rate of 1.9 ppm per year since 2000. The burning of fossil fuels (coal, natural gas, and oil), solid waste, trees and wood products, and certain chemical reactions (e.g., manufacture of cement) are responsible for the increase in greenhouse gases. Furthermore, because plants absorb CO_2 (thus remove it from the atmosphere) as part of their biological carbon cycle, deforestation has also lead to increased CO_2 levels in the atmosphere. Adverse impacts of global warming are extensive. A few of the impacts include rising sea levels due to increasing rates of glacial melting, more acidic oceans due to increasing carbon dioxide levels, and more frequent and severe weather events - like hurricanes.

Known low-tech methods of creating housing which is perfectly adapted to its locale are brilliant, for the reason that these are the principles which are more often ignored by prevailing architects. The use of traditional building materials in design and construction has been a common topic for researchers, designers and engineers across the country, but less emphases has been given to how ecological features could be harnessed in maximizing the energy efficiency of these traditional buildings. In other words, designing and constructing with locally sourced materials isn't just enough. Creating sustainable buildings starts with proper site selection, including consideration of the reuse or rehabilitation of existing buildings. The location, orientation, and landscaping of a building affect local ecosystems, transportation methods, and energy use.

1.3. Aims/objectives

The main objectives of this research are as follows:

1. To identify the benefits of energy efficiency in traditional buildings to obtain sustainability.
2. To identify indigenous building materials suitable for energy efficient design and construction
3. To explore the methods to apply efficient energy usage in green building to accomplish Sustainability.
4. To bring to notice the two broad yet harmonious categories in modern vernacular architecture and how these could be adopted in maximizing energy efficiency.
5. To make broad suggestions for the promotion of energy efficient housing practices in Nigeria for The long term benefit of the society at large and protection of the environment.

II. Literature Review

'Designing spaces and places in the built environment with energy in mind, takes much more than a technical understanding of science, tools and technology. The physics of materials and enclosure, no matter what the architectural form, define the need for supplemental building systems, including mechanical or passive heating, cooling, air circulation, lighting, and human conveyance. For much of the last century and in large part since architecture and engineering became separate professions, energy has typically been addressed at the building systems level, taking a back seat to many other drivers of the design and construction process.' (American Institute Of Architects, 2012)

"Energy is a design topic, not a technology topic, but there are few of us who have always believed this." (Donald Watson, FAIA)

2.1 Nigerian geography, demography and climate overview:

Nigeria can be located on the west coast of Africa, lies on latitude 4^o north of the equator and latitude 3^o and 14^o on the east of the Greenwich meridian. Nigeria measures about 1,200 km from east to west and about 1,050 km from north to south. The country's topography ranges from lowlands along the coast and in the lower Niger Valley to high plateaus in the north and mountains along the eastern border. The country is bifurcated by two main rivers, the Niger and the Benue. The ecology varies from tropical forest in the south through savannah to the sub-Sahel zone in the far north.

Nigeria is known to be the most populous African country with an estimated population of over 200.96 million people (UN. 2019) and a land mass of 923,768km^2.

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 millimeters.

According to Köppen-Geiger classification, Nigeria has five climatic zones ranging from tropical rainforest climate in the south to dry desert climate in the north. The Federal Republic of Nigeria is divided into six geopolitical zones and 36 federal states. Figure 2.1 show the federal states and the Federal Capital Territory, Abuja.(GOPA-International Energy Consultants GmbH, 2015)

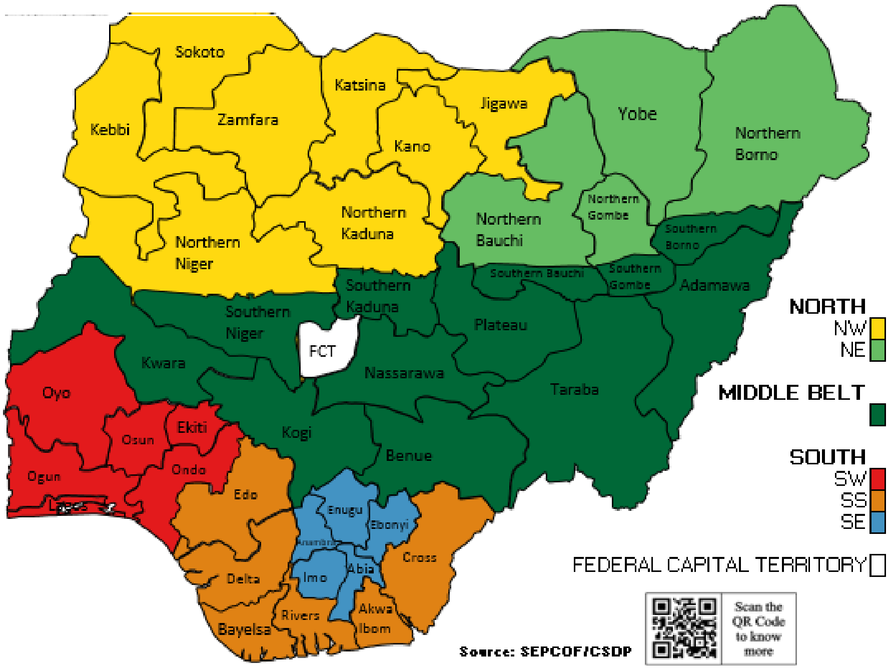

Figure2.1. Map of Nigeria showing the 6 geo-political zones and the federal capital territory.

Nigeria is also part of the West African Power Pool (WAPP), a specialized institution of ECOWAS. The target of WAPP is to ensure regional power system integration and realization of a regional electricity market. It covers public and private generation, transmission and distribution companies. It represents 55% of West Africa's GDP, whereby for instance the GDP of Lagos is larger than that of Ghana. This makes Nigeria the largest economy in Africa, and the 26^{th} largest economy in the world. (GOPA-International Energy Consultants GmbH, 2015)

2.2 Current housing needs:

Starting from 1992 various government housing policies has been promulgated to provide specifically for the low and medium incomeclass but the policy suffered a set-back owing to several factors; Prominent amongst the factors is the high cost of building materials as it constitutes over 80% of building cost. Also, the reviews of various past government programs reveals that none of the housing policy have been able to achieve 20% of success.

Demand for affordable housing in Nigeria is large and growing in the face of a sizable deficit and there is a dearth of existing interventions to support closing this gap. The housing deficit has been estimated at up to 17 million, and is growing at about 20 percent a year. Estimates of output in the formal housing sector range from no more than 100,000 per year to an optimistic 200,000 per year, which covers only a fraction of the at least 700,000 units required per year to keep up with growing population and urban migration. Furthermore, most new housing production caters to upper income households, leaving an acute housing shortage for middle and lower income households. The greatest need for affordable housing is lower income households in urban areas. Almost 50% of the Nigerian population lives in cities and about 80% of this urban population lives in substandard conditions. (World Bank Group, 2018).

If proper energy efficiency methods are adopted alongside with ecological sustainable materials and indigenous construction techniques and man-power, the average cost of erecting and maintaining housing units in Nigeria will decrease by almost 55.5% from the current estimated 80% cost. (UKAID, 2019).

'The problem of our built environment escalated when Architecture and Engineering where separated as two distinct professions' (Moses Agbete, 2020).

2.3 Global warming:

Global warming refers to the modern-day rise in global temperature near the earth's surface. The increase in temperature is due to increasing concentrations of greenhouse gases (carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases) in the atmosphere. The sun's energy falls on the earth as ultraviolet, visible (light), and infrared (heat) electromagnetic energy. The earth absorbs some of the sun's energy as thermal energy. The earth reflects another part of the sun's energy (infrared heat) back into the atmosphere where it either passes through the atmosphere or is reflected back to the earth's surface. Nitrogen and oxygen, which are the dominant gases in the atmosphere, allow infrared heat to pass through the atmosphere, while the greenhouse gases absorb infrared heat and redirect it back to the earth. The more greenhouse gases, the more heat is redirected back to earth; hence the increase in global temperatures near the earth's surface.

2.4. Bright future for renewables:

Renewables capture two-thirds of global investment in power plants to 2040 as they become, for many countries, the least-cost source of new generation.

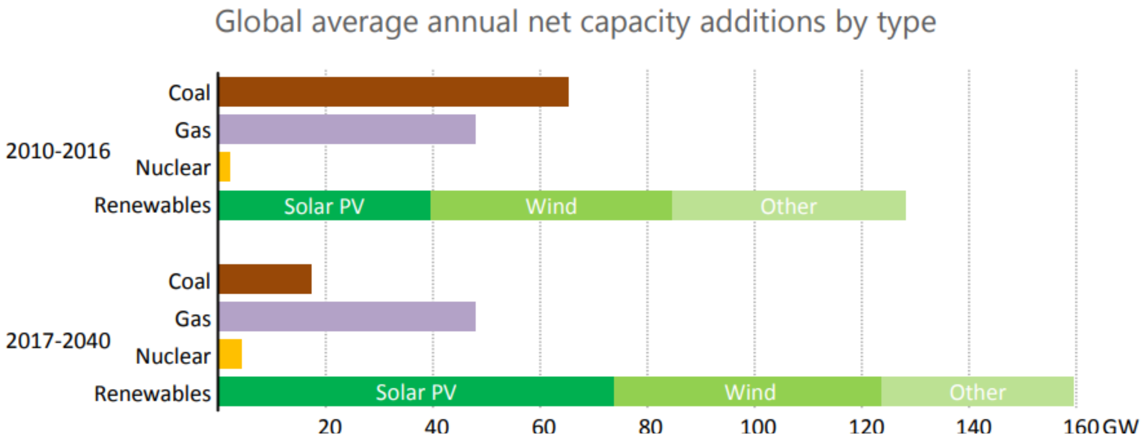

Figure 2.2showingWorld energy outlook 2017. (International Energy Agency (iea), 2017)

Rapid deployment of solar photovoltaics (PV), led by China and India, helps solar become the largest source of low-carbon capacity by 2040, by which time the share of all renewables in total power generation reaches 40%. In the European Union, renewables account for 80% of new capacity and wind power becomes the leading source of electricity soon after 2030, due to strong growth both onshore and offshore. Policies continue to support renewable electricity worldwide, increasingly through competitive auctions rather than feed-in tariffs, and the transformation of the power sector is amplified by millions of households, communities and businesses investing directly in distributed solar PV. Growth in renewables is not confined to the power sector. The direct use of renewables to provide heat and mobility worldwide also doubles, albeit from a low base. In Brazil, the share of direct and indirect renewable use in final energy consumption rises from 39% today to 45% in 2040, compared with a global progression from 9% to 16% over the same period. (International Energy Agency (iea), 2017).

The energy efficiency market is a start-up market. As part of the process, the government has started to draft mechanisms to encourage investments in energy efficiency through policies, strategies and support provisions. It is now well understood that energy efficiency is a source of energy. (GOPA, 2015).

2.5 National renewable energy and energy efficiency policy (NREEEP).

This was approved by Federal executive council (FEC) for the electricity sector on the 20th of April, 2015 through the Ministry of Power, Federal republic of Nigeria. This policy document recognizes the multi-dimensional nature of energy and therefore addresses diverse issues such as renewable energy supply and utilization; renewable energy pricing and financing; legislation, regulation and standards; energy efficiency and conservation; renewable energy project implementation issues; research and development; capacity building and training; gender and environmental issues; planning and policy implementation. The overall thrust of this policy is the optimal utilization of the nation's energy resources for sustainable development. Nigeria is blessed with abundant primary energy resources. These include non-renewable energy sources such as natural gas, crude oil, coal and tar sands; and renewable energy sources such as hydro, biomass, solar and wind. However, the economy has mainly depended on the consumption of oil and gas for commercial energy. The use of hydro-power plants, which entered the Nigerian energy scene in the 1960's, now accounts for the second largest energy resource for electricity generation in Nigeria, contributing approximately 26% of the total installed grid-connected generated energy.(Ministry of Power, 2015).The chart (figure 2.3) below indicates residential building construction consumes up to 80% of the country's energy.

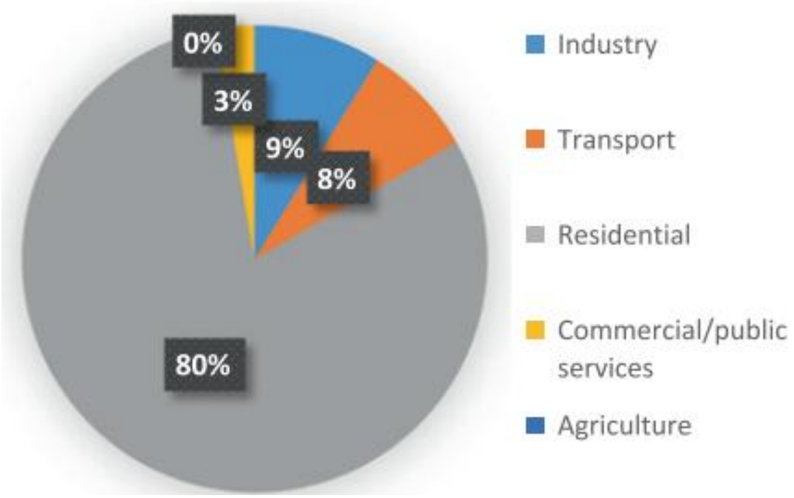

Figure 2.3 Total primary energy consumption in Nigeria by sector. Source 9IEA (2015b)

2.5.1 Policy focus:

Based on the resource situation and the technological base of the country, this policy will focus on hydropower, biomass, solar, wind, geothermal, wave and tidal energy power plants and cogeneration plants for energy production, as well as the improvement of energy efficiency as an additional source of energy. This policy refers to the ongoing harmonization process of renewable energy and energy efficiency policies in the ECOWAS region. It will be implemented through a national renewable energy action plan (NREAP) and a national energy efficiency action plan (NEEAP) which will guide the development of future renewable energy and energy efficiency related sectorial policies, as well as the national action plans to achieve renewable energy and energy efficiency targets. This approach will take input from all stakeholders in a coordinated process to be managed by the Federal Ministry of Power. This will avoid policy conflicts and improve efficiency in the allocation of public and private sector funds, for implementation of renewable energy and energy efficiency programs by Ministries, Departments and Agencies of government.(Ministry of Power, 2015)

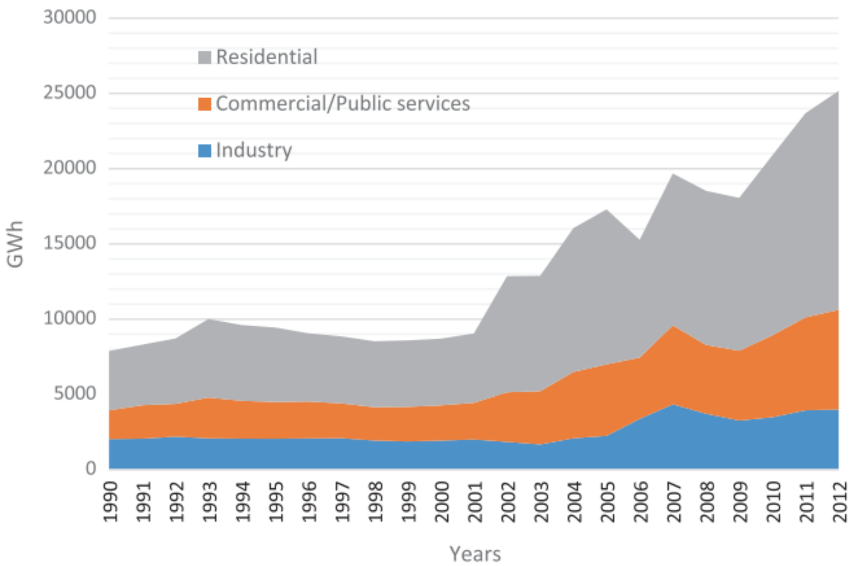

Figure 2.4. Nigerian Electricity consumption by sector. Source IEA (2015c).

III. Energy efficiency in building design

Energy efficiency in building design involves constructing or upgrading buildings that are able to get the most work out of the energy that is supplied to them by taking steps to reduce energy loss such as decreasing the loss of heatthrough the building envelope. To reduce operating energy use, high-efficiency windows and insulation in walls, ceilings, and floors increase the efficiency of the building envelope, (the barrier between conditioned and unconditioned space). Another strategy, passive solar building design, is often implemented in low-energy homes. Designers orient windows and walls and place awnings, porches, and trees to shade windows and roofs during the summer while maximizing solar gain in the winter. In addition, effective window placement (day lighting) can provide more natural light and lessen the need for electric lighting during the day. Solar water heating further reduces energy costs. Energy efficient homes, whether they are renovated to be more efficient or built with energy efficiency in mind, pose a significant number of benefits. Energy efficient homes are less expensive to operate, more comfortable to live in, and more environmentally friendly. An energy efficient building reduces maintenance and utility costs, but, in many cases, improves durability, lessens noise, increases comfort and creates a healthy and safe indoor environment. A further goal of energy efficient construction is to limit damage to the ecosystem and reduce the use of natural resources like energy, land, water, and raw materials. Reducing energy consumption is crucial because it means fewer emissions of greenhouse gases; a known cause of global warming. Energy efficient measures can be integrated into new construction or retrofitted into an existing building. Fortunately, there are many methods, materials, and resources to help designers, architects, contractors and building owners move towards creating an energy efficient and high-performance building.

Resource Efficiency can be accomplished by utilizing materials that meet the following criteria:

- **Recycled Content**: Products with identifiable recycled content, including post-industrial content with a preference for post-consumer content.
- **Natural, plentiful or renewable:** Materials harvested from sustainably managed sources and preferably have an independent certification (e.g., certified wood) and are certified by an independent third party.
- **Resource efficient manufacturing process:** Products manufactured with resource-efficient processes including reducing energy consumption, minimizing waste (recycled, recyclable and or source reduced product packaging), and reducing greenhouse gases.
- **Locally available:** Building materials, components, and systems found locally or regionally saving energy and resources in transportation to the project site. Salvaged, refurbished, or remanufactured: Includes saving a material from disposal and renovating, repairing, restoring, or generally improving the appearance, performance, quality, functionality, or value of a product.
- **Reusable or recyclable:** Select materials that can be easily dismantled and reused or recycled at the end of their useful life.
- **Recycled or recyclable product packaging:** Products enclosed in recycled content or recyclable packaging.
- **Durable:** Materials that are longer lasting or are comparable to conventional products with long life expectancies.

3.0.1 Benefits of energy efficiency:

According to Department of Energy and Climate Change (2012), stated the benefits of energy efficiency consist of help in economic development. Investment in energy efficiency technology can decrease the cost of innovation, reduce the gas emission, and create a sustainable energy system. Economic studies demonstrate that enhanced energy efficiency can increase the productivity and trim down the inflation problems. Energy efficiency also helps to build a sustainable energy system, throughout decreasing energy consumption (Department of Energy and Climate Change, 2012), and reducing carbon emission has guided to concentrate on energy efficiency of buildings (Organ, Proverbs, & Squires, 2013). The constructed environment details for 30-40% of global energy consumption and connected greenhouse gas (GHG) emissions, presenting the most potential of any field for energy savings and prevention of GHG emissions and at great benefit-cost ratios (Dunphy, Morrissey et all, 2013).

3.0.2 Design of an energy efficient building:

Implementing ‘a whole-buildingsystemsapproach’ to new construction is the most efficient way to achieve an energy efficient building. ‘The whole-building system approach’ treats the building as one energy system with separate, but dependent parts. Each part affects the performance of the entire system (the whole-building).

1. The design should make efficient use of water and electricity and other natural resources and energy sources.
2. To minimize waste and materials, choose the smallest possible building for the intended application.
3. The design should strive to meet the EnergyStar requirements for sustainability, the Leadership in Energy and Environmental Design (LEED) standards, and the International Green Construction Code (IgCC).
4. The design of an energy efficient building should easily allow for future retrofits without impacting the performance of the building.
5. The design should take into consideration building orientation. The way a structure is situated on a site and the placement of windows, rooflines and other features is critical for efficiency.

6. The design of an energy efficient building should be sustainable. A sustainable design aims to lessen depletion of critical resources like land, water, energy, and raw materials. Sustainable design of facilities and infrastructure also averts the destruction of the ecosystem.
7. Utilizing an energy modeling software is an effective way to estimate a building's energy use. The model's output can help architects, contractors, and building owners modify a building performance and cost before construction starts.

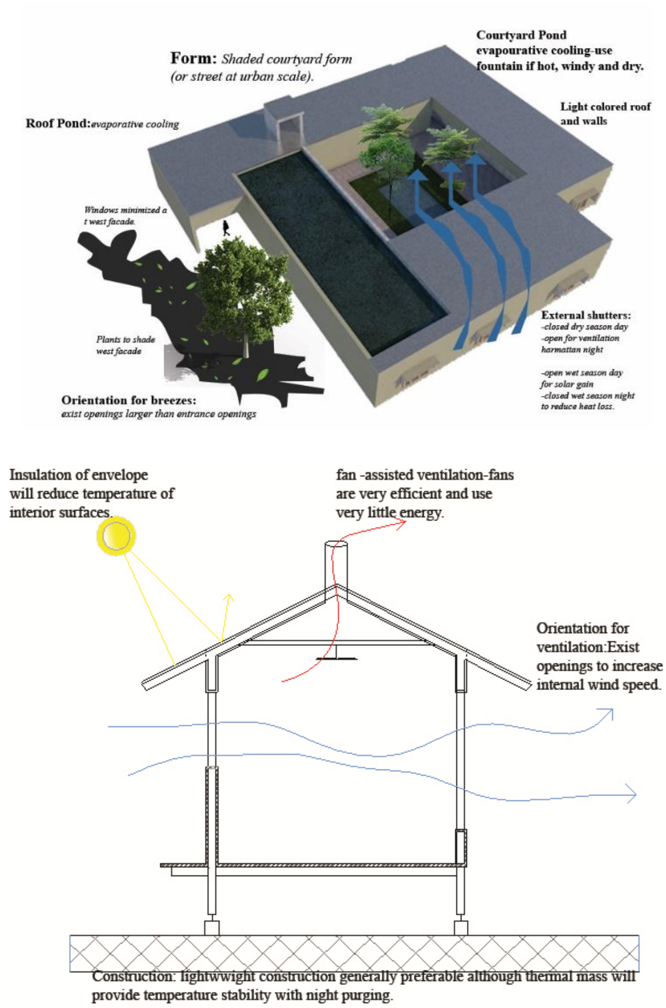

Figure 3.1. Showing energy efficient strategies for hot-dry and hot-humid climate 'rule of thumb 82-85'
Adapted from (Heywood, 2013)

IV. The ecological approach

In achieving an energy efficient home in Nigeria, architects must understand that building design all begins with site selection and never ends; rather it should evolve into a lifestyle of its users. Without much ado, ecology in this context has been broken down into two distinct but harmonious categories to better understand how modernism has changed the way traditional buildings are designed and constructed. These two broad categories are:

- Endo-Vernacology
- Exo-Vernacology

This concept is in full conformity with addressing the sustainable design issues: economic, environmental and social sustainability. It should be noted that this two broad categories of energy efficiency in modern vernacular architecture does not only apply to building design and construction practices In Nigeria, but can be globally adopted as a guild in various regions in achieving maximum energy savings, and of cos an environmentally friendly and sustainable home.

4.1 Endo-Vernacology:

The word 'Endo' is a Greek word meaning 'within, or internal' (Google, 2019). The word 'Vernacology' is coined from two words namely: 'Vernacular' and 'Ecology'

'Vernacular', from the architectural perspective, means 'architecture concerned with domestic and functional rather than public or monumental buildings'. (Google, 2019) While the word 'Ecology' means the study of the relationships between plants, animals, people, and their environment, and the balances between these relationships. (Collins, 2019).

From the individual meanings, 'Endo-Vernacology', could be defined as the study of relationship between plants, animals, people and their environment, and balances between these relationships as it relates to the buildings and technology within an ecosystem.

4.1.2 Endo-vernacular strategies:

The climatic conditions in various geo-political zones in Nigeria affects the architectural environment and should shape the concept of housing. The following are endo-vernacular strategies that could be adopted by architects and designers in achieving an energy efficient home in Nigeria.

i. Passive solar design

Passive solar design refers to the use of the sun's energy for the heating and cooling of living spaces. The building itself or some element of ittakes advantage of natural energy characteristics in its materials to absorb and radiate the heat created by exposure to the sun. Passive systemsare simple, have few moving parts and no mechanical systems, require minimal maintenance and can decrease, or even eliminate, heating andcooling costs (BCKL, 2009).Passive solar design uses that to capture the sun's energy:The following are a few Solar passive features as listed below:

- Shape and form of buildings.
- Orientation of the facades.
- Design of Building plan and section.
- Thermal insulation and thermal storage of roof.
- Thermal Insulation and thermal storage of the exterior walls.

Homes in any climate can take advantage of solar energy by incorporating passive solar design features and decreasingCarbon dioxide emissions. Even in cold winters, passive solar design can help cut heating costs and increase comfort (BCKL, 2009). In Nigeria, the winter period is a dry season and passive solar design can help increase indoor comfort during excessive heat periods.

Solar buildings are designed to keep environment comfortable in all seasons without much expenditure on electricity; 30 to40% savings with additional 5 to 10% cost towards passive features.

Major Components are: Orientation, double glazed windows, window overhangs, thermal storage walls roof, roof painting,Ventilation, evaporation, day lighting, construction material etc. Designs depend on direction & intensity of Sun & wind, ambient temp., humidity etc.

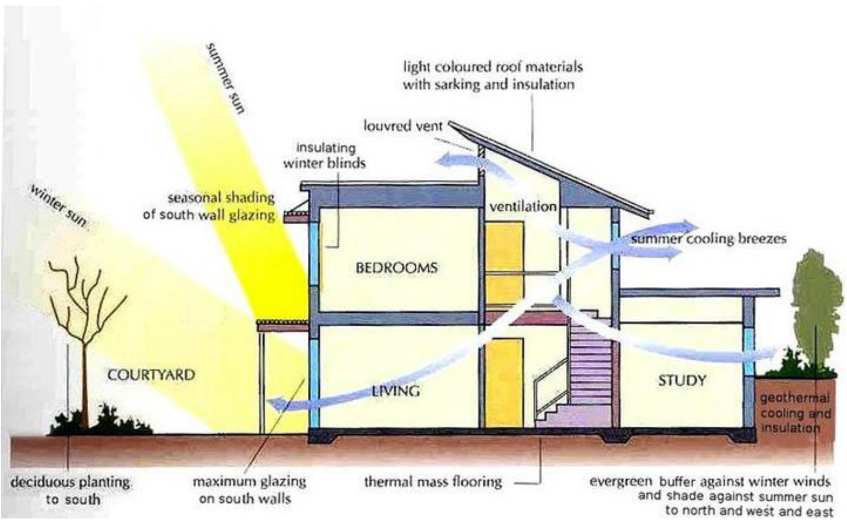

Figure 4.0 to illustrate passive solar strategies in hot-humid climate (Winter, 2015)

ii. Green roofs:

Decreasing stress of the people around the roof by providing a more aesthetically pleasing landscape, and helping to lower urban airtemperatures and mitigate the heat island effect (Vandermeulen, 2011). There are two types of green roof:

1. Intensive roofs, which are thicker, with a minimum depth of 12.8 cm, and can support a wider variety of plants but are heavier and require more maintenance.
2. Extensive roofs, which are shallow, ranging in depth from 2 cm to 12.7 cm, lighter than intensive green roofs, and require minimal maintenance (Volder, 2014).

The term green roof may also be used to indicate roofs that use some form of green technology, such as a cool roof, a roof with solar thermal collectors or photovoltaic panels. Green roofs are also referred to as eco-roofs, vegetated roofs, living roofs, green roofs and VCPH (Wilmers, 1990). (Horizontal Vegetated Complex Partitions).

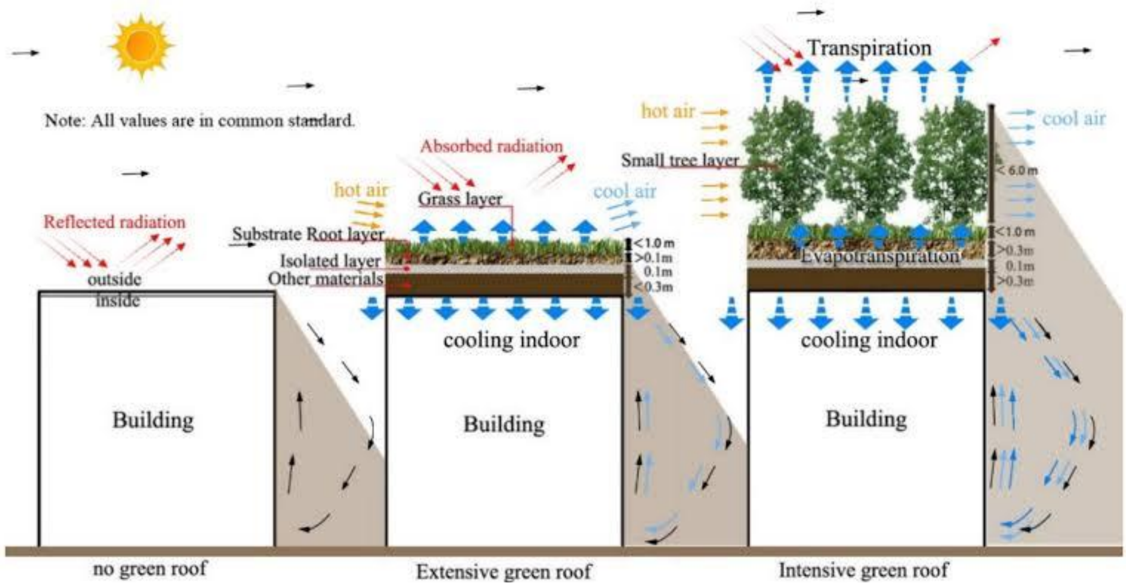

Figure 4.1a schematic structure of an extensive green roof and intensive green roof, and the cooling mechanism in the daytime.(Zhang, He, Zhu, & Dewancker, 2019)

iii. Living Green walls:

Also known as vertical greenery is actually introducing plants onto the building façade. Many studies have investigated the effects of indoor plants on people and the outcomes relevant to the effectiveness and well-being of office workers. Those outcomes included improvements in psychophysiological stress responses, task performance, emotional states, and room assessments.

Some of the benefits of living green walls are

1. Improved air quality
2. Balanced natural humidity
3. Habitat restoration
4. Overall reduction in energy cost
5. Thermal Insulation
6. Aesthetics and value.

Along with the serene aesthetics that accompany a green wall, there are other upsides for those who get one installed. If you're a foodie, here are some items vertical gardens can possibly grow:

- Herbs (basil, oregano, mint, santolina)
- Teas (bee balm, sweet lavender, chocolate mint)
- Berries (strawberry and blueberries)
- Vegetables (cabbage, spinach, cherry tomatoes)

Living green wall could be some worth expensive to in cooperate in building designs but on the long run, saves a cost and energy with low maintenance.

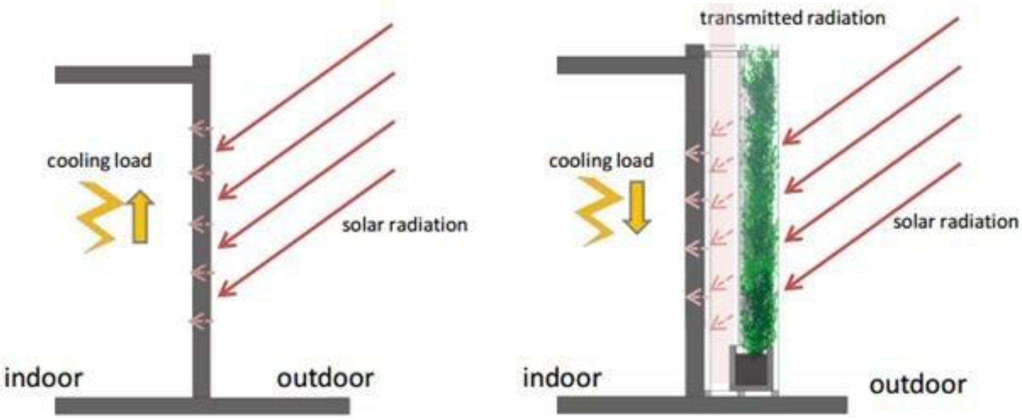

Figure 4.2. Difference between a conventional wall façade and a green façade. (Hadba, Silva, & Mendonca, 2017)

iv. Water systems:

Water - often called the source of life - can be captured, stored, filtered, and reused. It provides a valuable resource to be celebrated in the process of green building design. According to Art Ludwig in Creating an Oasis out of Greywater, only about 6% of the water we use is for drinking. There is no need to use potable water for irrigation or sewage. (BCKL, 2009). The protection and conservation of water throughout the life of a building may be accomplished by designing for dual plumbing that recycles water in toilet flushing or by using water for washing of the cars. Waste-water may be minimized by utilizing water conserving fixtures such as ultra-low flush toilets and low-flow shower heads. Bidets help eliminate the use of toilet paper, reducing sewer traffic and increasing possibilities of re-using water on-site. Point of use water treatment and heating improves both water quality and energy efficiency while reducing the amount of water in circulation. The use of non-sewage and greywater for on-site use such as site-irrigation will minimize demands on the local aquifer (Stephen & Harrell, 2008).

V. Use of indigenous materials:

The use of locally sourced materials such as Bamboo and reclaimed hard wood for flooring and columns. Stones, ceramic tiles etc. can also help to reduce energy cost of buildings.

4.3. Exo-vernacology:

The word 'EXO' is a Greek word which means 'external; from outside' (Google, 2019). Therefore, from the meaning of the word 'Vernacology as defined 4.1 above, Exo-Vernacology could be defined as the adoption of innovations and technological advancements and the study of its relationship/application between plants, animals, people and their environment, and balances between these relationships as it relates to the buildings within an ecosystem.

4.3.1. Exo-Vernacular strategies:

Throughout the 6 major geo-political zones as shown in fig 2.1; on the average, there is predominantly rainfall across the country throughout the year. Also Temperatures throughout Nigeria are generally high; diurnal variations are more pronounced than seasonal ones. Highest temperatures occur during the dry season; rains moderate afternoon highs during the wet season. Average highs and lows for Lagos are 31° C and 23° C in January and 28° C and 23° C in June. Although average temperatures vary little from coastal to inland areas, especially in the northeast have greater extremes. There, temperatures reach as high as 44° C before the onset of the rains or drop as low as 6° C during an intrusion of cool air from the north from December to February. (U.S. Library of Congress, n.d.) These are indications that buildings in Nigeria could save a lot of energy consumption and drastically reduce the amount of greenhouse gases released into the atmosphere by employing technologies which are not already part of the environment but have been designed to work harmoniously with plants, animals, people and their environment as well as balance the relationships as it relates to the buildings and technology within an ecosystem.

4.4. Renewable Energy Sources and Technology for Energy Efficient Buildings

According to the Energy Information Agency, worldwide energy consumption is expected to increase 1.4% per year through 2035, implying that buildings will consume 296 quadrillion Btu by the year 2035 (EIA 2010).

The following list below are innovations In building science and technology that could be adopted to maximize energy efficiency in our modern day vernacular Architecture, though many but a few to mention as the world is now know to be in the age of rapidly increasing knowledge.

i. Solar photovoltaic (PV) Technologies when properly constructed, can generate a cost-effective form of renewable energy. Solar photovoltaic(PV) Technology can power all the energy needs of a building including lighting, heating and cooling systems, appliances and hot water. Nigeria has a potential for electricity production from Solar PV technology in the range of 207,000 GWh per year if theoretically only 1% of the land area (e.g. 920 km² = 920*106 m²) were covered with state-of-the-art poly-crystalline PV modules, with an electricity yield of 1,500 Wh/Wp per year. This figure is tenfold the total electricity production of Nigeria in 2011. (GOPA-International Energy Consultants GmbH, 2015)

ii. Wind Turbine Technologies can also be used in Nigeria to generate substantial amount of energy either connected to the electric grid through your power provider or stand-alone (off-grid). A small wind electric system can lower electric bill by 50 to 90 percent. A variety of applications can use a small wind system, including water pumps. The map below shows the wind speed map of Nigerian states. Sokoto, Kano, Katsina, Plateau, and jigawa has the highest amount of wind speed >7.00 m/s.

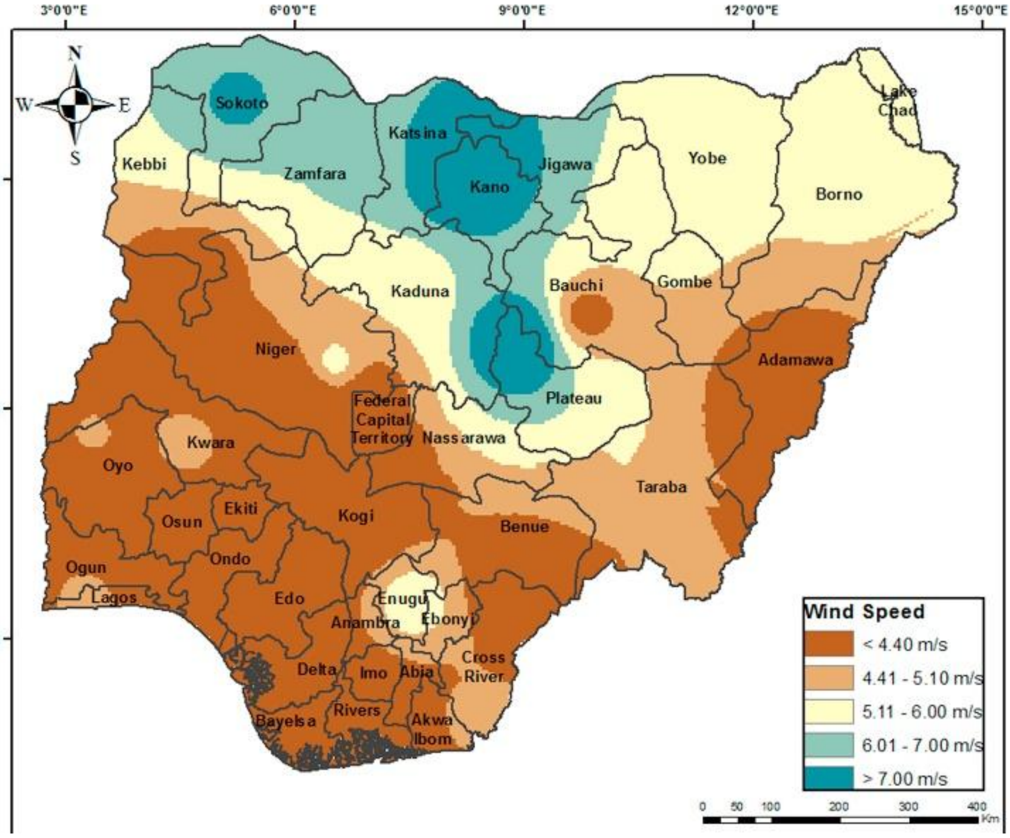

Figure 4.3 showing wind speed map of Nigeria. (Ayodele, Ogunjuyigbe, & Jimoh, 2018)

According to the U.S. Energy information administration, monthly energy review, March, 2019, preliminary data, the total United States electricity generation in 2018 was 275 billion kilowatt-hours and the share total of wind power generated was 6.6% of total U.S utility-scale electricity generation; which is 18,150,000,000 billion kilowatt-hours.

Figure 4.4 below further illustrates the wind farm suitability in Nigeria by states. If the major cities such as Sokoto, Kano, Katsina, Plateau, and jigawa which are most suitable for wind farms due to high amount of the prevailing wind from Sahara desert, can be connected via a grid system of wind turbines, this can generate more energy from environment to service Part of the northern states and reduce the impact of climatic change in Nigeria.

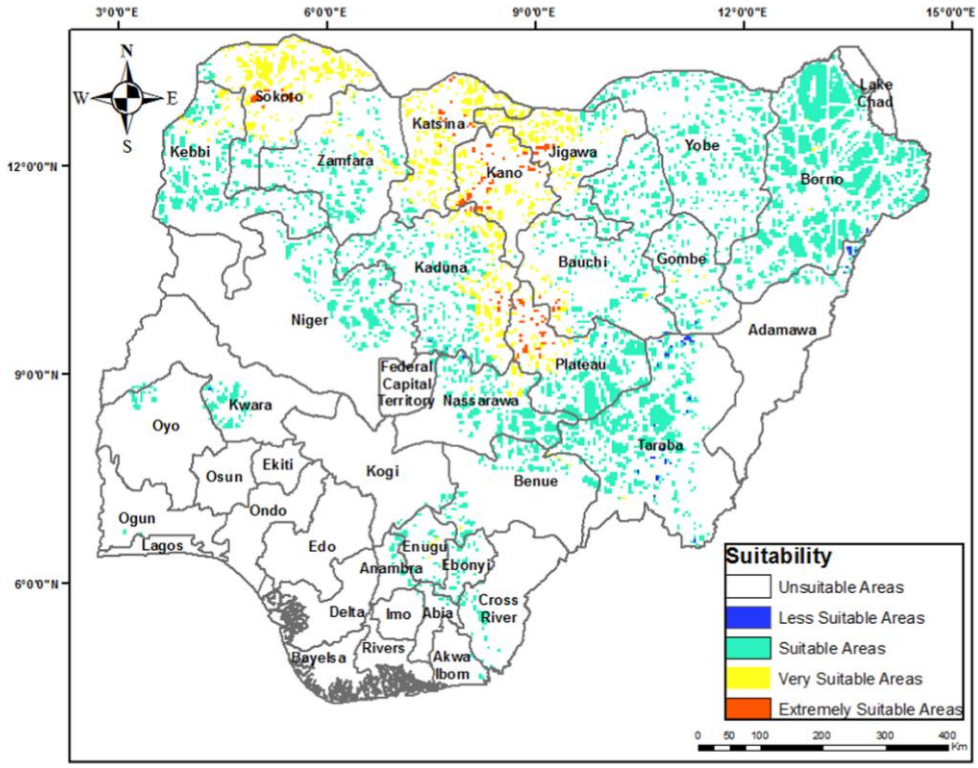

Figure 4.4. Showing wind farm suitability map for Nigeria. (Ayodele, Ogunjuyigbe, & Jimoh, 2018)

iii. BioPower Technologies which refers to electricity generation through the use of Biomass. As at 2010, there was 35 GW (47,000,000 hp) of globally installed bioenergy capacity for electricity generation, of which 7 GW (9,400,000 hp was in the United States.) (National renewable energy laboratory, U.S. 2010).There are six major biomass systems that can be used to generate electricity for single residential, small towns or commercial use namely: direct-fired, cofiring, gasification, anaerobic digestion, pyrolysis, and small modular. High amount of waste is being generated everyday by households, factories, mining operations, livestock farming, and wood processing; all this can be harnessed through the BioPower technology by combining different small, modular systems which has the potential to generate electricity capacity of 5 megawatts or less as distributed energy resources to improve the operation of electricity delivery in Nigeria.
iv. Micro—hydropower Technologies has an efficiency of up to 53% and can generate electricity of up to 100 kilowatts which can power homes, ranches, farms, machineries or a village. A micro-hydropower is a simple and consistent form of renewable energy. A hydropower system requires a turbine, water wheel, and pump to transform the energy of flowing water into rotational energy, and then into electricity. Houses close to a flowing water and villages with streams and rivers can take advantage of this in generating clean energy. For even larger hydropower station such as the kainji dams in Niger state across river Niger, which can serve as an eco-tourist center for economic development.

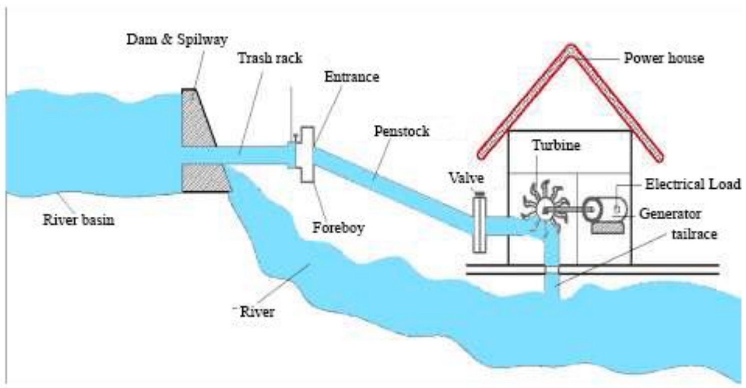

Figure 4.5. Showing a schematic diagram of a Micro-Hydro power house. (Hoxha et-all, 2017)

4.5. Application of Interdisciplinary elements:

1. Computer Aided design and simulations;
2. BIM;
3. Energy modelling tools
4. Notions of biochemistry and bionics, biophilia, bioclimatology and biomimicry;
5. New techniques that can help us to achieve our goals.

Ideally, buildings should not utilize, for the needs of its inhabitants, more energy that can it collect from its environment. In the end, buildings and cities will have to reach an ecological energy equilibrium with the environment, during the entire life-cycle.

V. Recommendations

1. The building site and its climate should be carefully evaluated to determine the optimum design suitable.
2. It is highly recommended that energy star® rated appliances, lighting, heating, and cooling, showers, water taps etc. used in buildings are also necessary for low energy consumption and high conservation.
3. The best windows are awning and casement styles because these styles often close tighter than sliding types therefore should be used more often.
4. Foundation walls and slabs should be as well insulated as the living space walls.
5. Energy efficiency in building design doesn't just end after construction, but rather it should evolve as a lifestyle to the users. Therefore architects, designers and engineers should educate the clients and should also provide a building manual as every building, is a unique product of its own.
6. The development of building energy efficiency code and green building rating systems for Nigeria will be a break through towards mitigation of climatic change impact.
7. A post occupancy evaluation (POE) should be carried out on the building as at when required to evaluate how the building and the users compliment with the environment and information gotten could be used for further considerations.
8. A national frame-work/assessment method for energy efficient building design such as BREEAM), Building for Environmental and Economic Sustainability (BEES), Leadership in Energy and Environmental Design (LEED) etc. should be made available by the appropriate bodies for the building professionals to adopt in their various design.

VI. Conclusion

The benefits of vernacular architecture have been realized throughout the large part of history, diminished during the modern era, and are now making a return among green architecture and natural builders. In order to progress in the future of architecture and sustainable buildings, we must first gain knowledge of the past and employ these strategies as a well-balanced, methodical whole to achieve optimum energy efficiency. (Edwards 2011). New construction gives architects, contractors and building owners the opportunity to design and build an energy efficient building, and even a net-zero energy project. A net-zero energy building consumes less than or equal to the amount of energy that it produces on site through renewable resources. The steps for constructing a modern energy efficient structure begin with choosing a site and implementing a detailed, holistic design plan. If anything is to be taken from vernacular architecture, it provides a vital connection between humans and her natural environment. It re-establishes us in our particular part of the world and forces us to think in terms of pure survival (Edwards, 2011).

The design of an ecological building must be defined as a holistic approach to the utilization of energies and materials according to the principles of sustainability, during the entire life-cycle of the building, from the source of the raw materials to recycle.

Ecological buildings are the only way to apply into the built environment, the principles of sustainability. To this end, we need a new theory of the built environment, developed through practice, to discover new materials and building and recycling techniques, the final goal being a new kind of symbiosis with the natural environment from which mankind separated no more than two centuries ago.

'The building itself is not how it looks or feels, but the extent of how it functions to meet the client's needs and the architect's original intentions.' (Moses Agbete, 2020).

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