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MITIGATING CLIMATE CHANGE THROUGH GREEN ARCHITECTURE.

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Abstract

Climate change is real and felt globally. Climatic factors such as intense solar radiation, high humidity and condensation, dust and sandstorms and flood affects the comfort of man and safety of built environment. Most of the climatic changes are due to human activities in the environment, particularly the built environment. These suggest that human activities and physical constituents of built environment interact with other climate drivers. These prompt the need for response,and response to climate change falls into two phases- mitigating and adaptation. Therefore, this paper discusses how climate change can be mitigated through green architecture in Nigeria. In this light, the paper will be a conceptual paper.The library research method was used in this study to gather secondary data from textbooks, articles and journals to develop a conceptual framework on how green architectural practices can be used to mitigate climate change in order to sustain built environment in Nigeria. This paper adopts the U.S. Green Building Council (USGBC) (2015) principles of green building and sustainable site design. It highlights climatic changes and their effects in Nigeria. It further discusses the concept and principles of green architecture. The study concludes that Nigerian built environment is vulnerable to the impact of climate change. Therefore, there is need for architects, builders, engineers and clients to promote and adopt green architectural practices in order to mitigate the effect of climate change for sustainable environment.

Introduction:-

Climate change has become a global threat. Climatic factors such as intense solar radiation, high humidity and condensation, dust and sandstorms and flood affects the comfort of man and safety of built environment. In Nigeria, cities for instance anticipate climatic changes such as periods of extreme cold, increase frequency of air and water pollution, increase in rainfall, increased thermal discomfort in buildings, water shortages and draught, rising and changes in timing, frequency and severity of urban flooding, building collapses and increase in cost of building construction and operation.

Studies have revealed that increase in research, technological advancement and economic growth, building construction has greatly increased and has been said to account for nearly half of all the greenhouse gas emissions and energy consumed owing largely to the energy used in the production and transportation of materials to building construction sites, and energy used to operate these buildings. The picture is not different about Nigeria who is now faced with the challenge of evolving performance standards, systems, codes and other regulatory means to mitigate and adapt to the built environment and climatic changes.

Researches have established that most of the climatic changes are due to human activities in the environment, particularly the built environment. These suggest that human activities and physical constituents of built environment interact with other climate drivers. The interaction between human activities and the built environment which prompt climatic changes raises the need for response. And response to climate change falls into two phases-mitigating and adaptation.

Consequently,the adoption of an environmentally responsible approach to building design and construction has become inevitable. Therefore, the aim of this paper is to discuss and promote green architectural practices as a means of mitigating climate change in Nigeria. Embracing sustainable architectures in Nigeria is aimed at reducing energy, operation and maintenance cost, reduced building related illness, increase the productivity and comfort of building occupants; reduce waste and pollution and increase building and component durability and flexibility.

Methodology:-

The paper is a conceptual paper. The library research method was used in this study to gather secondary data from textbooks, articles and journals to develop a conceptual framework on how green architectural practices can be used to mitigate climate change in order to sustain the built environment in Nigeria.This paperadopts the U.S. Green Building Council (USGBC) (2015) principles of green building and sustainable site design. The discussion was based on these five principles.

Climate Change and Its Effectsin Nigeria:-

According to Federal Government of Nigeria (2009), the location and size of, and the characteristic relief in Nigeria give rise to a variety of micro climates ranging from tropical rainforest climate along the coasts to the Sahel climate in the northern parts of the country. Nigeria has a population of about 140 million impacting on the physical environment through their various activities within an area of about 923,000 square kilometres. This, coupled with variability in elements of climate such as rainfall and temperature among others, exposes several physical and socio-economic sectors in the country to the impacts of climate change. For instance, climate change will lead to a shift in the boundaries of major ecological zones, alter animal and plant composition, aggravate soil erosion and flooding in areas of higher rainfall, heighten drought and desertification in the marginal arid zones of the country and salt water intrusion along the coastal belt.

Climate change will also impact the agricultural sector. Agriculture remains a major source of food, industrial raw material and a means of earning foreign exchange. It employs close to 70 per cent of the Nigerian population.

With respect to energy, it is a two-way vulnerability for Nigeria. First, Nigeria is vulnerable to the adverse impacts of climate change. In this regard, the most important significant impact of climate change on energy will include higher electricity demand for heating, cooling and pumping water; reduced availability of hydroelectricity and fuel wood; and extensive damage on petrochemical industrial installations presently concentrated in the coastal belt. Inadequate supply of power could force closures of many industries thereby rendering several Nigerians jobless. This, in turn, will aggravate the country's existing macroeconomic problem of unemployment. Products from such industries become unavailable and where available through importation, the prices are beyond what an average Nigerian can afford.

According to Komolafe (1988), Climatic change do not affect people's comfort alone; they can also impair the safety of buildings and lead to building damage and premature fatigue of building materials. In the tropics, for example, factors such as intense solar radiation, high humidity and condensation, dust and sandstorms and the salt content of the air affect building material**.** Walling materials for instance, the comfort implication of heat storage capacity, where they are needed, are secondary to those of privacy, stability, protection and security against house walling and thin mud walls, adobe or wattle and daub are commonly used in various climatic zones. The picture is not better with respect to roofing materials in common use. For example, galvanized iron sheet absorbs 65% of solar radiation which increases to 80% when it gets old roofing sheets absorb as high as 61% of heat, which increases to 83% when old and dirty (Komolafe, 1988).Generally, the problem is not what is thermally desirable and efficient, but what is readily available and economically affordable to the people.

Concept of Green Architecture:-

The term "sustainable architecture", is used to describe the movement associated with environmentally conscious architectural design (Boston Society of Architects, 1991 cited in Pragrad, n.d.). The term sustainable architecture is interchangeably used with sustainable design or green design, is a philosophy of designing buildings to comply with the principles of social, economic and ecological sustainability. Sustainable architecture uses a conscious approach to energy and ecological conservation in the design of the built environment.The main goals of sustainable design are to reduce depletion of resources including energy, water, and raw materials; minimize negative environmental impacts caused by buildings and facilities throughout their life; and create better building environments.

According to Nwafor, (2006) green architecture sustainable design is the systematic consideration of a project's life cycle impact on environmental and energy resources. Integrated Waste Management Board (2005) cited in Kadiri, (2006) defined green building (also known as sustainable building) as "a structure that is designed, built, renovated, operated or used in an ecological and resource-efficient manner.

According Giaccardo, (2004) defines green design as design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants in five broad areas: sustainable site planning, safeguarding water and water efficiency, energy efficiency and renewable energy, conservation of materials and resources and indoor environmental quality.

The key features of green architecture is the need to minimize material and resource consumption and some strategies for achieving this and consequently sustainable construction through efficient use of renewable energy resources and materials; selection of materials and products that minimize life cycle environmental impacts for example, the use of local, natural and renewable/recycled materials; employing construction techniques that enhance energy savings, water and waste minimization; use design that works in harmony with climate, prevailing air movement path and other natural features to achieve comfort (Nwafor, 2006).

The call and desire for sustainable construction is in realization of the construction industry's capacity to make a significant contribution to environmental sustainability because of the enormous demands it exerts on global resources. The construction industry accounts for one-sixth of global fresh water consumption, one-quarter of global wood consumption and two-fifths of global material and energy flows, and almost one-quarter of ozone depleting gases come from air-conditioning units in buildings. Apart from global resource consumption, the industry also generates waste on a scale that dwarfs most other industrial sectors. Given the conflicting scenario of the rapid depletion in global natural resources simultaneous to the acceleration in global population, it is imperative that the attendant demands on global natural resources are balanced with the 'carrying capacity' of the physical environment (Kadiri, 2006).

Green Design and Environmental Sustainability:-

Green architecture is about environmental interactions. It involves energy efficiency, water efficiency, waste reduction, building operation, construction, maintenance, occupant health and productivity, stormwater management, climate and environmental integration (Immaculata& Henry, 2011). According to Engel– Yan, Kennedy, Saiz and Pressnand (2005 cited in Immaculata& Henry, 2011), energy efficient buildings may both reduce stormwater runoff and provide evaporative cooling.

According to Gottfried (1996), 50% of the energy used in a building is devoted to producing an artificial indoor climate through heating, cooling, ventilation and lighting. A typical building energy's bill constitutes approximately 25 percent of building's total operating costs in the United States. However, estimates indicate that climate sensitive design with the use of appropriate and available technologies could cut heating and cooling energy consumption by 60 percent. Federer in (Engel – Yan, Kennedy, Saiz&Pressnand, 2005 cited in Immaculata& Henry, 2011) describes the effect of trees in modifying the urban microclimate, which affects both comfort and building space conditioning energy use.

In a study conducted by Simpson & McPherson (2001) in the United States, it is recommended that urban trees be located in several regions to maximize energy saving. This is because the east and west orientation provides shades when sun angles are lower and conclude that larger trees should be used to maximize benefits. They did find that except for southerly orientated trees, energy savings are generally inversely proportional to tree building distances. And factors such as climate conditions, electricity emissions factors, building construction and tree growth rates, must be considered in energy savings and carbon dioxide emission reduction calculation. Energy saving through natural ventilation and lighting could further be enhanced through wide windows and external doors and good material choice in window design like glazed windows of different brands (Fulleton 1978, Hachler, Holderen 2008; &Lippiatt& Norris 1996).

Poor stormwater management could lead to flooding in urban areas. This could adversely affect the sustainability of the urban environment. High levels of stormwater runoff in urban areas cause many environmental and economic problems including water pollution, flooding and erosion. Different measures are taken by planners to enhance environmental sustainability through stormwater management. The principle of stormwater source control is to manage rainwater at its source, instead of discharging it into conventional, combined or separated sewer systems. The urban forest helps to mitigate the negative impact of stormwater through double fold process. The first is that trees intercept and store rainfall on leaves and branch surfaces which helps in alternating runoff volume and delays the onset of peak-flows. Secondly, root growth and decomposition enhances the capacity and rate of soil to absorb or infiltrate rainfall and minimize overland flow.

Other methods of stormwater management include; provision of infiltration basins, retention ponds, infiltration tranches, porous paving with reservoir structure e.t.c (Immaculata& Henry, 2011; Engel-Yan, Kennedy, Saiz&Pressnand, 2005, & Martin, Ruperd&Legret, 2007).

Another important factor in green architecture is materials used. Materials flow and cycle is a technique for tracing material use and location over time. For example, steel is routinely recovered from demolished buildings and other products such as automobiles, melted and re-used in close recycle loop. Some materials are disposed into landfills. These materials can equally be recovered and reused (Hedrickson et-al undated cited in Immaculata& Henry, 2011).

Application of green buildings and concepts can yield savings during the construction process. Measures that are readily easy to implement can result in savings to the contractor or developer. Some of these include; lower energy by monitoring usage, and installing energy efficient lamps, lower water costs by monitoring consumption and using storm water, lower material costs with more careful purchase and re-use of resources and materials among others.(Gottfried,1996).

Designing and manufacturing green products require appropriate knowledge, tools, production methods and incentives. These design tools will help identify design changes that have lower costs while improving material use and recyclability (Hendrickson 2008 & Roberts 2007).

Principles of Green Architecture:-

To advance the understanding of green architecture, this study examines five fundamental principles of green building and sustainable site design:sustainable site design, water quality and conservation, energy and environment, indoor environmental quality and materials and resources identified by The U.S. Green Building Council (USGBC) (2015).

Sustainable site design:-

Minimize urban sprawl and needless destruction of valuable land, habitat and green space, which results from inefficient low-density development. Encourage higher density urban development, urban re-development and urban renewal, and brownfield development as a means to preserve valuable green space.

Preserve key environmental assets through careful examination of each site. Engage in a design and construction process that minimizes site disturbance and which values, preserves and actually restores or regenerates valuable habitat, green space and associated eco-systems that are vital to sustaining life.

Water Quality and Conservation:-

Preserve the existing natural water cycle and design site and building improvements such that they closely emulate the site's natural "pre-development" hydrological systems. Emphasis should be placed on retention of storm water and on-site infiltration and ground water recharge using methods that closely emulate natural systems. Minimize the unnecessary and inefficient use of potable water on the site while maximizing the recycling and reuse of water, including harvested rainwater, storm water, and gray water.

Energy and Environment:-

Minimize adverse impacts on the environment (air, water, land, natural resources) through optimized building siting, optimized building design, material selection, and aggressive use of energy conservation measures.

Resulting building performance should exceed minimum International Energy Code (IEC) compliance level by 30 to 40% or more. Maximize the use of renewable energy and other low impact energy sources.

Indoor Environmental Quality:-

Provide a healthy, comfortable and productive indoor environment for building occupants and visitors. Provide a building design, which affords the best possible conditions in terms of indoor air quality, ventilation, thermal comfort, access to natural ventilation and daylighting, and effective control of the acoustical environment.

Materials and Resources:-

Minimize the use of non-renewable construction materials and other resources such as energy and water through efficient engineering, design, planning and construction and effective recycling of construction debris.

Maximize the use of recycled content materials, modern resource efficient engineered materials, and resource efficient composite type structural systems wherever possible. Maximize the use of re-usable, renewable, sustainably managed, bio-based materials. Remember that human creativity and our abundant labor force is perhaps our most valuable renewable resource. The best solution is not necessarily the one that requires the least amount of physical work.

Mitigating Climate Change through Green Architectural Practices in Nigeria:-

Base on the above principles of green building and sustainable site design, climate change can be mitigated in Nigeria if Nigeria architect and building engineers adopt andpromote the following green design strategies and technologies:

Sustainable site design:-

- Make more efficient use of space in existing occupied buildings, renovate and re-use existing vacant buildings, sites, and associated infrastructure and consider re-development of brownfield sites. Design buildings and renovations to maximize future flexibility and reuse thereby expanding useful life.
- When new development is unavoidable, steer clear of sites that play a key role in the local or regional ecosystem. Identify and protect valuable greenfield and wetland sites from development.
- Recognize that allowing higher density development in urban areas helps to preserve green space and reduce urban sprawl. Invest time and energy in seeking variances and regulatory reform where needed.
- Evaluate each site in terms of the location and orientation of buildings and improvements in order to optimize the use of passive solar energy, natural daylighting, and natural breezes and ventilation.
- Make best use of existing mass transit systems and make buildings and sites pedestrian and bike friendly, including provisions for safe storage of bicycles. Develop programs and incentives that promote car-pooling including preferred parking for commuters who carpool. Consider making provisions for re-fueling or recharging alternative fuel vehicles.
- Help reduce the urban heat island effect by reducing the building and site development footprint, maximizing the use of pervious surfaces, and using light green colored roofs, paving, and walkways. Provide natural shading of buildings and paved areas with trees and other landscape features.
- Reduce impervious areas by carefully evaluating parking and roadway design. Pursue variances or waivers where local ordinances may unintentionally result in the over-design of roadways or parking.
- Optimize the use of on-site storm water treatment and ground water recharge. Minimize the boundaries of the construction area, avoid needless compaction of existing topsoil, and provide effective sedimentation and silt control during all phases of site development and construction.
- Use landscape design to preserve and restore the region’s natural habitat and heritage while emphasizing the use of indigenous, hardy, drought resistant trees, shrubs, plants and turf.
- Help reduce night-time light pollution by avoiding over-illumination of the site and use low cut-off exterior lighting fixtures which direct light downward, not upward and outward.
- Water quality and conservation.
- Recognize that the least costly, least time consuming and most environmentally preferable design for site and storm water management is often the one in which the design of buildings and site improvements respect the existing natural flows and features of the land, instead of designing the building and site improvements with total disregard for the site, which results in needless, extensive, disruptive, costly and time consuming excavation and earthmoving.
- Conduct a thorough site assessment and strategically locate buildings and site improvements so as to preserve key natural hydrological features. Special effort should be made to preserve areas of the site that serve as natural storm water retention and ground water infiltration and recharge systems. Preserve existing forest and

mature vegetation that play a vital role in the natural water cycle by absorbing and disbursing up to 30% of a site's rainwater through evapo-transpiration.

- Minimize the building's footprint, site improvements and construction area, and minimize excavation, soil disturbance and compaction of existing topsoil as this soil in its natural uncompacted state serves a vital role in absorbing and storing up to 80% of natural rainfall until it can be absorbed by vegetation or enter the site's natural sub-surface ground water system.
- Design and locate buildings and site improvements to optimize use of low-impact storm water technologies such as bio-retention, rain gardens, open grassy swales, pervious bituminous paving, pervious concrete paving and walkways, constructed wetlands, living/vegetated roofs, and other technologies that support on-site retention and ground water recharge or evapo-transpiration. Storm water that leaves the site should be filtered and processed naturally or mechanically to remove trash and debris, oil, grit and suspended solids. Use "hold and release" technologies such as dry retention ponds only as a last resort as these technologies do not preserve the natural water cycle, have little or no benefit in terms of ground water recharge and result in needless additional site disturbance.
- Establish a water budget for the building and implement a design that minimizes the use of potable water by using low-flow plumbing fixtures and toilets and waterless urinals. Harvest, process and recycle rainwater, site storm water, and building gray water and identify appropriate uses within the building and site. Use on-site treatment systems that enable use of rain water for hand washing, graywater for toilet flushing, rain and storm water for site irrigation, cooling tower make-up and other uses.
- Conserve water and preserve site and ground water quality by using only indigenous, drought resistant and hardy trees, shrubs, plants and turf that require no irrigation, fertilizers, pesticides or herbicides.
- Energy and environment.
- Optimize passive solar orientation, building massing and use of external shading devices such that the design of the building minimizes undesirable solar gains during the summer months while maximizing desirable solar gains during winter months.
- Optimize building orientation, massing, shape, design, and interior colors and finishes in order to maximize the use of controlled natural day lighting which significantly reduces artificial lighting energy use thereby reducing the buildings internal cooling load and energy use. Consider the use of light shelf technology.
- Use high performance low-eglazing, which can result in significant year round energy savings. Consider insulated double glazing, triple glazing or double pane glazing with a suspended low-e film. Selective coatings offer optimal light transmittance while providing minimal solar gain and minimal heat transmission. Window frames, sashes and curtain wall systems should also be designed for optimum energy performance including the use of multiple thermal breaks to help reduce energy use.
- Optimize the value of exterior insulation and the overall thermal performance of the exterior envelope assembly. Consider advanced/high performance envelope building systems such as structural insulated panel systems (SIPS) and insulated concrete form systems (ICF's) that can be applied to light commercial and institutional buildings. SIPS and ICF's and other thermally "decoupled" envelope systems will offer the highest energy performance.
- Use energy efficient T-8 and T-5 bulbs, high efficiency electronic ballasts, and lighting controls. Consider using indirect ambient lighting with workstation based direct task lighting to improve light quality, reduce glare and improve overall energy performance in general office areas. Incorporate sensors and controls and design circuits so that lighting along perimeter zones and offices can be switched off independently from other interior lights when daylighting is sufficient in perimeter areas.
- Use state-of-the art, high efficiency, heating, ventilation and air conditioning (HVAC) and plumbing equipment, chillers, boilers, and water heaters, etc. Use variable speed drives on fan and pump motors. Use heat recovery ventilators and geothermal heat pump technology for up to 40% energy savings.
- Avoid the use of HCFC and Halon based refrigeration, cooling and fire suppression systems. Optimize the use of natural ventilation and where practical use evaporative cooling, waste heat and/or solar regenerated desiccant dehumidification or absorption cooling. Identify and use sources of waste energy.
- Use Energy Star certified energy efficient appliances, office equipment, lighting and HVAC systems.
- Consider on-site small-scale wind, solar, and/or fuel cell based energy generation and co-generation. Purchase environmentally preferable "green" power from certified renewable and sustainable sources.
- Indoor environmental quality.
- Use building materials, adhesives, sealants, finishes and furnishings which do not contain, harbor, generate or release any particulate or gaseous contaminants including volatile organic compounds.

- Maximize the use of natural daylighting. Optimize solar orientation and design the building to maximize penetration of natural daylight into interior spaces. Provide shades or daylight controls where needed.
- Maximize the use of operable windows and natural ventilation. Provide dedicated engineered ventilation systems that operate independently of the buildings heating and cooling system. Ventilation systems should be capable of effectively removing or treating indoor contaminants while providing adequate amounts of fresh clean make-up air to all occupants and all regions of the building. Monitor indoor air conditions including temperature, humidity and carbon dioxide levels, so that building ventilation systems can respond when space conditions fall outside the optimum range.
- Provide a smoke free building. When smoking must be accommodated, provide completely dedicated smoking areas are physically isolated, have dedicated HVAC systems, and remain under negative pressure with respect to all adjoining spaces. Assure that air from smoking areas does not get distributed to other areas of the building does not re-enter the building through doors or vestibules, operable windows, or building fresh air intakes.. Locate outdoor smoking areas so that non-smokers do not have to pass through these areas when using primary building entrances or exits.
- Design building envelope and environmental systems that not only treat air temperature and provide adequate ventilation, but which respect all of the environmental conditions which affect human thermal comfort and health, including the mean radiant temperature of interior surfaces, indoor air humidity, indoor air velocity, and indoor air temperature. Following these principles and providing a building that is also responsive to seasonal variations in desirable indoor humidity levels, air velocity, and mean radiant temperatures can also result in significant energy savings as improved occupant comfort results in less energy intensive operation of the buildings air-side heating and cooling system.
- Maximize occupant health, comfort and performance by providing occupants with individual space/zone control of heat, ventilation, cooling, day-lighting and artificial lighting whenever possible.
- Prevent contamination of the building during construction. Take steps to minimize the creation and spreading of construction dust and dirt. Prevent contamination of the building and the buildings heating, cooling and ventilation systems during the construction process. Protect construction materials from the elements so that they do not become damp, moldy or mildewed.
- Provide a clean and healthy building. Use biodegradable and environmentally friendly cleaning agents that do not release VOCs or other harmful agents and residue. Prior to occupancy install new air filters and clean any contaminated ductwork and ventilation equipment. Use fresh outdoor air to naturally or mechanically purge the building of any remaining airborne gaseous or particulate contaminants.
- Materials and resources.
- Optimize the use of engineered materials which make use of proven engineering principles such as engineered trusses, composite materials and structural systems (concrete/steel, other…), structural insulated panels (stress skin panels), insulated concrete forms, and frost protected shallow foundations which have been proven to provide high strength and durability with the least amount of material.
- Identify ways to reduce the amount of materials used and reduce the amount of waste generated through the implementation of a construction waste reduction plan. Adopt a policy of "waste equals food" whereby 75% or more of all construction waste is separated for recycling and used as feedstock for some future product rather than being landfilled. Implement an aggressive construction waste recycling program and provide separate, clearly labeled dumpsters for each recycled material. Train all crews and subcontractors on the policy and enforce compliance.
- Identify ways to use high-recycled content materials in the building structure and finishes. Consider everything from blended concrete using fly ash, slag, recycled concrete aggregate, or other admixtures to recycled content materials such as structural steel, ceiling and floor tiles, carpeting, carpet padding, sheathing, and gypsum wallboard. Consider remanufactured office furniture and office partition systems, chairs and furniture with recycled content or parts.
- Explore the use of bio-based materials and finishes such as various types of agriboard (sheathing and or insulation board made from agricultural waste and byproducts, including straw, wheat, barley, soy, sunflower shells, peanut shells, and other materials). Some structural insulated panels are now made from bio-based materials. Use lumber and wood products from certified forests where the forest is managed and lumber is harvested using sustainable practices. Use resource efficient engineered wood products in lieu of full dimension lumber which comes from older growth forests.
- Evaluate all products and systems used for their ability to be recycled when they reach the end of their useful life. Preference should be given to products and systems that facilitate easy, non-energy intensive separation and recycling with minimal contamination by foreign debris.

- Recognize that transportation becomes part of a product or building materials embodied energy. Where practical, specify and use locally harvested, mined and manufactured materials and products to support the regional economy and to reduce transportation, energy use and emissions.

Conclusion:-

The impacts of climate change are real and are felt globally. The Nigerian built environment is vulnerable to the impact of climate change. There is need for Nigeria architects, engineers and their clients topromote and adoptgreen architectural practices for the built environment. This would mitigate some of the effects of climate change and lead toenvironmental sustainability, economic and social sustainability. The implication of these is possible added value to the quality of life of individuals and built environment.

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