

Engineering the Built Indoor Environment; Strategies for Achieving Energy Efficiency and Sustainable Thermal Environment in Nigeria

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Abstract

This paper raised ideas in literature as anchor for the development of a sustainable energy-built environment. The paper focused on improving knowledge in an area the Authors consider trending and still evolving. It believes a Net -Zero Energy approach is ideal and a radical method in attracting results. It advocated for the promotion of passive engineering measures in overhauling the built environment into a clean sustainable one and encouraged reduction in energy through the use of energy collectors such as the photovoltaic systems, supported by batteries, charger controls, inverters and generators. The paper recommended the enforcement of energy ethics and code in Nigeria and that professionals in the built environment continuously update their knowledge. They should upgrade by acquiring trainings in new and evolving technologies, attend conferences and workshops, and must show concern over their environments by adhering to environmental ethics which calls for functionality in their designs, and for compliance with planning laws and building regulations as required by the local authorities. The knowledge of energy management which advocates for reduction in energy use should be introduced and practiced by all and environmental professionals and taught in schools, The easiest and least expensive way to solve the “energy problem” is not to augment energy supply, but to reduce the amount of energy need, and this could be done through intelligent design solutions that get buildings to respond to climate.

Keywords: *Energy, Energy Efficiency, Energy Efficient Systems, Sustainable Indoor Environment.*

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Background to the Study

Earth remains the only planet safe to anchor and promote life because the environmental composition supports life unlike other planets. However, over the years human activities have diminished this unique attribute to a degree of great concern. Man has brought this divine biotic endowment to its knees that he is now greatly in quest of what do to avoid a total collapse. A major agent of the dilapidating environment is the way and manner energy are used. Energy is used in transportation, building, construction industries, with most of them coming from electricity. According to Botkin and Keller (1998) more than 90% of energy from electricity is sourced from burning fossil which has a great damaging effect on our climate due to high carbon emission. Buildings have contributed more in fostering and creating intimate contact amongst inhabitants. The building in sync with local climate using resources efficiently for the future. Buildings account for 30% of the energy consumed in Nigeria, 45% of energy consumption in United States, and globally (Alozie, 2020, Botkin & Keller, 1998). Commercial buildings in Nigeria consume approximately 240 Kwh/m of electricity annually, with most of the energy and as much as 45% used in air-conditioning in cities, 25-30% in lighting, 20-30% in other systems and equipment (Alozie, 2019)

Accordingly, Alozie (2022), recorded an alarming growth rate in buildings in cities and rural environments to be at 10-15% annually and concluded that the pressure on the Nation's energy resources follows same magnitude, as recorded in buildings. This makes the call for an alternative energy solution which will not only alleviate the present issues in supply but take care of the future necessary. This calls for wholistic energy management strategies that will help develop energy efficient and sustainable indoor environment. It calls for a review of zero energy concept in buildings as an integrated means in engineering the built environment into an energy efficient environment. Knowledge of the macro climate of a region, in combination with qualitative understanding of local microclimate, allows Engineers, Architect, Builders and Landscape Architects to modify indoor and outdoor environments in ways that improve human comfort, reduce building energy consumption and optimize site resource use (McDonald, 2004), this is absolutely important in modern living because energy is scarce and expensive (Alozie, Eze, Ehibudu & Nnsewo 2018, Botkin Keller 1998).

Energy is needed to drive machines that provide cooling and heating in buildings (Alozie, 2019a) The need to keep the indoor temperature of buildings within acceptable comfort zone has become obvious because nearly all the activities of man happen inside buildings (Antonidaes, 1998). The concept of energy is somewhat abstract.; one cannot see it, yet pays for it, to understand energy, it is easiest to think about individuals when they say "am tired, I don't have energy to work ". Perhaps energy could be further easily understood through the lens of the idea of "force" because we all have had the experience of exerting force, of pushing or pulling. Any of these activities makes use of energy in one state or the other, which supports the first law of thermodynamics which states that energy is neither created nor destroyed but transformed from one form to another.

In order to keep this cycle of transition from one state to another and sustainable, energy management principles must be learned, this agrees with the erudite analysis by Means (2011)

which underscored that the easiest and least expensive way to solve the “energy problem” is not to augment energy supply, but to reduce the amount of energy need. This Means (2011) suggested could be done through intelligent design solutions that get buildings to respond to climate. Intelligent building designs that respond to climate, consider heating and cooling factors, and find Net-Zero energy concepts needful.

Buildings have been repeatedly listed by scholars to account for more than 40% of total world energy usage. The implication therefore is that when buildings become energy efficient, the percentage of energy used in operating them will become small and perhaps insignificant especially in developing nations where energy is mostly nonrenewable. Energy sources in developing nations are mostly from burning fossil fuel. Burning of fossil fuel is an operation that increases global warming and causes climate change. When buildings in developing countries become energy efficient, green environment will begin to develop. This paper advocates for the professional in the built environment on whose shoulders the responsibilities of bringing man in harmony with his environment and the task of making this environment sustainable, is vested on, is expected to do so by reducing energy consumption through architecture and environmental engineering.

However, the paper further opines that energy reduction in the building sector, could be engineered through the combination of passive architecture strategies and active energy efficient devices such as Photovoltaics, Batteries, Charge Controllers, Inverters, and Generators. To justify the aim of the paper it became necessary to look into brief explanations of the following keywords: Energy, Energy- Efficient Design, Energy Efficiency, Energy Efficient Systems, Sustainable Indoor Environment and Thermal Comfort.

Energy

Energy is the ability to do work (Egan 2000) There are two definite energy sources: nonrenewable and renewable,

Non-Renewable

Approximately 90% of energy in United States and developed world come from oil, natural gas and coal because of their organic origin and they are referred as fossil (Botkin & Keller 1998) They are produced from plant and animal materials and are forms of stored energy that are part of our geological resource base. They are essentially non- renewable because they get exhausted with time and do not accumulate easily, sometimes may take centuries or may not accumulate at all.

Renewable Energy

The second energy type, which include solar (sun), geothermal (soil), hydrothermal (water), wind, biomass (plants) among others, referred as alternative designates, are gradually being used as one to fossils. Solar and wind are not depleted by consumption and are described as renewable (Ikike & Alozie, 2022)

Energy- Efficient Design

In popular imagination, energy efficient design has been understood to be a by-product of oil embargo initiated by the Organization of Petroleum Exporting Countries (OPEC) on October 1973, a date western consumers of fossil fuels became painfully aware of the energy intensive nature of their built environment and their fragile dependence on foreign energy sources (Moore, 2004). In most rigid form, energy – efficient design has been characterized as an attempt to reconstitute the practice of architecture as a purely instrumental science in its most expansive form. However, energy efficient design challenges society to understand buildings not as static objects of aesthetic value but rather as dynamic entities that participate in a complex system of natural energy flows and political consequences (Moore, 2004).

Energy efficient building is defined as a building that uses less energy to provide same product or service such as lighting, heating, and cooling, however, Alozie, (2019), defined energy efficiency as using less energy to provide same product or service such as lighting, heating cooling and transportation. Alozie, (2019) added that sustainability has become increasingly popular and important in the building industry in our present living that a movement to construct buildings in a more efficient and sustainable manner, which advocates reduction in energy use and the cost associated with its operation and maintenance became necessary.

Energy Efficiency

According to Alozie (2019), energy efficient design remains an integral of environmental sustainability which must be discussed as an arm of the universal sustainable theme. Energy that is consumed in order to meet with the different needs associated with peoples heating and cooling energy needs (energy needed to avoid overheating). Energy efficient buildings are buildings built and constructed to use minimum amount of energy to ensure comfortable living, such as designing buildings to take advantage of passive solar potentials.

Net-Zero Energy Building (NZEB)

Always referred to as next generation energy concept already operational in many locations in developed nations is taking energy efficiency to a higher step, beyond energy saving. These new edge cutting projects produce as much energy as they use over the course of a year, making them net-zero in terms of energy use. These buildings practice best energy efficient strategies, in combination with renewable source which is produced either on or off site. The buildings still remain connected to electricity grid (in case the renewable energy source supply is unavailable).

Net-Zero Energy Buildings are ultimately a necessary step towards energy independence. (U.S. Department of Energy “Net-Zero Energy Commercial Building, 2011) Reducing energy use in buildings saves resources and money while reducing pollution and Carbon Dioxide in atmosphere. The easiest and least expensive way to solve the “energy problem” is not to augment energy supply, but to reduce the amount of energy need, and this could be done through intelligent design solutions that get buildings to respond to climate.

Intelligent building designs that respond to climate consider heating and cooling factors. It understands the character of solar energy such as radiation, convection, and conduction as well as materials for windows and other openings. It involves integrated design that considers daylighting, passive and active solar heating and takes great advantage of renewable energy, (Means, 2011).

Sustainability, Sustainable Environment and Sustainable Architecture

Sustainability

The term sustainability recognizes the interdependency of economic, social, and environmental factors necessary to sustain life on earth. The defining quote has sustainable development to seek to meet the need and aspirations of the present without compromising the ability to meet the needs of the future (McDonald, 2004).

Henderson (2012), defined sustainability as being able to live today, without compromising nature and available resources, and the children, their children, and their children, living as well as they lived without also compromising resources. In a similar contribution, McDonald (2004) concluded that sustainable architecture involves both design philosophy and technology that imbibes lessons and findings from experts in research.

Sustainable Indoor Environment

Sustainable indoor environment is one that is low in toxins, contaminants, and odors. One with good air quality possible when spaces are well ventilated with outside air and protected from pollutants brought into the space or by pollutants off-gassed within the space. It is one with adequate natural lighting and developed to harness passive energy potentials. One that aims at producing zero carbon (Alozie, 2017)

Sustainable Architecture

Sustainable architecture is the expression coined for environmental responsive building practices. It differs from conventional design by considering the environmental impacts of design decisions throughout the entire building lifecycle, from cradle to cradle instead of cradle to grave (Alozie, 2019, McDonald, 2004). It provides a comprehensive examination of all aspects of architectural design, including selection of site, energy conservation, passive solar strategies, low-energy systems, building materials, indoor air quality, water conservation, waste minimization, lighting, and use of renewable energies, buildings and sites that utilize natural systems to minimize their global, regional, and local environmental impacts on land, (McDonald, 2004).

The roots of sustainable architecture can be traced to the ancient theoreticians that include Vitruvius, who discussed the benefits of designing with local climate and indigenous materials (Morgan 2017) The skill of preindustrial builders, the mastery of using on-site resources such as proper orientation, thermal mass, shading, ventilation and local construction materials, were abandoned after the invention of artificial lighting and air conditioning, except for several notable exceptions, such as organic movement architecture of the half twentieth century who disregarded the environmental context of buildings (McDonald, 2004) The energy crisis in 1973, hastened the return to energy-efficient design.

Thermal Comfort

Besides being aesthetically pleasing, the human environment must provide light, air and thermal comfort. Comfort is best defined as the absence of discomfort. People feel uncomfortable when they are too hot or too cold, or when air is odorous and stale. Positive comfort conditions are those that do not distract by causing unpleasant sensations of temperature, draft, humidity, or other aspects of environment (Vaughn Bradshaw, 2006).

American Society for Heating, Refrigerating and Air-Conditioning Engineers, ASHRAE (2004), defined thermal comfort as that express condition in which 80% of sedentary or partly active persons find themselves comfortable, in their environments, and that means absence of discomfort. Thermal discomfort in buildings results primarily from faulty architectural designs, construction, and operational management and this may need heating or cooling to recreate. No matter the option, energy is needed to correct. The duty of bringing thermal comfort in buildings is primarily the architect's responsibility. The architect needs to consider the following factors that may influence the indoor thermal comfort in buildings, local climate condition, orientation, ventilation, building material, planning regulation, among many others.

Energy Efficiency Device Systems Employed in Building Design

Energy efficient appliance and equipment use technologies that are less energy intensive to reduce the amount of electricity used per product. Energy efficiency refers to using less energy to provide an energy service for example energy efficient LED light bulbs are able to produce the same amount of light as incandescent light bulbs by using 75 to 80 percent less electricity. Some energy efficient devices have the ability to store energy and allow it to be used when needed, while others have the ability to moderate energy consumption. Some of such devices are discussed below.

Photovoltaics

Photovoltaics (PV), as the name implies, are devices that convert sunlight directly into electricity. PVs generate power without noise, without pollution, and without consuming any fuel. These are compelling advantages for several applications, especially where utility power is not available. One disadvantage of photovoltaics is that they require a large surface area to generate any significant amount of power. This is because the sunlight comes to us distributed over a wide area, and because today's PVs can only convert about 10% of the solar power to electricity. Efforts to make systems more efficient to convert more sunlight to electricity and to utilize unused roof space mitigate this problem. A second disadvantage is that PV is rather expensive due to the high-technology manufacturing processes (Vaughn Bradshaw, 2006)

Photovoltaic Cells & Modules

The electric power that PV produces is DC (direct current), similar to that coming from a battery. The voltage of each cell depends on the material's band gap, or the energy required to raise an electron from the valence band (where it is bound to the atom) to the conduction band (where it is free to conduct electricity). For silicon, each cell generates a voltage of about 0.6V. The voltage decreases gradually (logarithmically) with increasing temperature. The current

generated by each cell depends on its surface area and intensity of incident sunlight. Cells are wired in series to achieve the required voltage, and series strings are wired in parallel to provide the required current and power. As increasing current is drawn from the cell, the voltage drops off, leading to a combustion, called maximum power point (MPP), changes slightly with temperature and intensity of sunlight. Most PV systems have power conditioning electronics, called a maximum power point tracker (MPPT) to constantly adjust the voltage in order to maximize power output. Simpler systems operate at a fixed voltage close to the optimal voltage.

Batteries

There is an acute need to store electrical energy for many purposes beside PV systems and researches are investigating alternatives, Battery manufacturers continue to implement innovations to import performance. Batteries do have some dangers. They contain several toxic materials and are must be taken ensure that they are recycled properly. In some cases, batteries are shipped dry, with the electrolyte added on-site. During installation, care must be taken to ensure that battery electrode (battery acid) is not ingested by an installer or an unaware bystander storing battery electrolyte only in well-labeled, child-proof container can reduce this risk. Finally, batteries are capable of rapidly releasing their stored energy if they are shorted; care must be taken to avoid electrocution and fires caused by sparks. The amount battery capacity depends on the magnitude of the load and the required reliability. A typical battery capacity is sufficient to meet the load for 3 – 5 days without sun, but in applications that require high reliability, 10 days of battery storage may be recommended.

Charge Controller

The function of the battery charge controller is very important for system performance and battery longevity. The charge controller modulates the charge current into the battery to protect against overcharging and an associated loss of electrolyte. The low-voltage disconnect protects the battery from becoming excessively discharged by disconnecting the load. It seems unfortunate to disconnect the load, but doing so avoids damage to the battery, and not doing so would simply delay the inevitable, since the load would not be served by a ruined battery.

Inverter

Utility power in U.S. buildings is 120V or 240V AC (alternating current) of 60Hz frequency (50Hz in many countries overseas). Since many appliances are designed to operate with alternating current, PV systems are often furnished with power conditioning equipment called an inverter to convert the DC power from the PV array or the battery to AC power for the appliance in inverter technology have resulted in systems that deliver a pure sine wave form and exceptional power quality. In fact, except for the PV array, the components of a PV system are the same as those of an uninterruptible power supply (UPS) system used to provide critical users of power with the highest power quality. Inverters are available with all controls and safety features built in.

Generator

For small stand-alone systems it is often cost-effective to meet the load using only solar power. Many residential systems and some commercial ones include batteries and generators even if they are grid-connected so that they can run during a power outage. Such systems are called multi-mode systems and add about 30% to the cost of a grid-connected only system. However, during extended cloudy weather this approach requires a very large battery bank and solar array. To optimize cost, the PV system can incorporate a generator to run infrequently during periods when there is no sun. This hybrid PV/generator system take advantage of the low operating cost of the PV array and the on-demand capability of a generator. In this configuration, the PV array and battery bank would ordinarily serve the load, but also to power a battery charger to recharge the batteries. When the batteries are fully charges, the generator automatically turns off again. This system if cyclically charging batteries is cost-effective even without PV, as it keeps a large generator from running to serve a small load. A hybrid system would be designed to minimize life cycle cost, with the PV array typically providing 70% - 90% of the annual energy, and the generator providing the remainder. PV is also often combined with wind power, under the hypothesis that if the sun is not shining, the wind may be blowing.

Engineering The Built Indoor Environment; Energy Management Strategies for achieving energy efficient architecture and sustainable indoor Thermal Comfort

Architects and Engineers possess the skill to design buildings that will be energy efficient. Some energy: efficient buildings have the ability of generating its own energy, as in the case of Net-Zero.

1. Energy Buildings. Others depend on passive architectural design. Daylighting is an important component of energy efficient building design which the architect needs to harness from the inception of his design project and not as, afterthought.
2. Energy management in building is best initiated at design stage and carried through construction to completion.
3. Reducing energy use in buildings saves resources and money while reducing pollution and Carbon Dioxide in atmosphere. The easiest and least expensive way to solve the “energy problem” is not to augment energy supply, but to reduce the amount of energy need, and this could be done through intelligent design solutions that get buildings to respond to climate.
4. Intelligent building designs that respond to climate consider heating and cooling factors. It understands the character of solar energy such as radiation, convection, and conduction as well as materials for windows and other openings. It involves integrated design that considers daylighting, passive and active solar heating and takes great advantage of renewable energy, (Means, 2011).

Passive Architecture

Passive architecture seeks to increase the energy efficiency of a building by the use of a variety of active and passive design strategies can be incorporated. Active strategies usually consist of heating and cooling systems. While passive design measures include building orientation, air sealing, continuous insulation, windows, daylighting, and designing buildings to take

advantage of natural ventilation opportunities. Passive measures find ways to reduce the size of the heating and cooling system by keeping the heat (or cooled air) inside the building (Ortega, 2018)

According to Vujovic (2018), the key to passive design is to minimize the energy used by the building, including eliminating plug loads and specifying Energy Star equipment. Vujovic recommended doing an inventory of everything that uses electricity in the building, so even the plug loads can be included in design calculations.

Passive design strategies take advantage of natural energy opportunities as they relate to the location of the building's site, the local climate (and the site's microclimate if relevant), and properties of building material. According to Elrod (2018), active design strategies would then become part of the design process when mechanical and electrical systems are integrated into the building design. Elrod also added that the designers' strategies will typically add much less front — end cost to projects as compared to active design strategies by reducing heating and cooling loads so that causing a building's mechanical system to be downsized and sometimes reduces building's electrical lighting with the use of daylighting design strategies.

Passive design strategies at the architect's disposal include; building orientation, daylighting, natural ventilation, insulation and thermal mass, landscaping, vegetation, use of building materials, shading devices which include trees and sustainable construction concepts. It also advocates keeping to building laws, regulations and sustainable living practices (human ethics)

Building Orientation

Passive design depends a lot on the way the building is oriented, the most successful energy-efficient designs should face south or north to allow better solar energy management (Alozie 2014), Orientation of buildings to take advantage of how the sun moves across the sky is the easiest and most effective passive strategy. The same free heat streaming through windows in cold season, can work against comfort during summer, unless it is considered in the design. Alozie (2014), affirmed that overhangs, exterior shades and deciduous trees can help keep summer sun out while thermal mass such as concrete floor or wall inside the building can store heat in cold periods.

An elongated and narrow building allows for greater portion of the building to be exposed to daylight, which is usually the best form for passive design in terms of massing. South or north facing façade is the key element of good passive design. It is typically the best to have the longest facades face north and south so that a building can take advantage of indirect sunlight (without glare and direct solar heat gain) from the north, and controlled direct solar heat gain from the south (Elrod, 2018)

Direct solar heat gain at the east and west- facing glazing can be minimized with exterior shading devices during the months a building is mechanically cooled. It is easiest to control direct heat gain at south-facing glazing where exterior horizontal shading devices can shade

the building from direct solar heat gain in the summer months when the sun is highest in the sky and allow the building to take advantage of direct heat gain during winter months when the sun is lowest in the sky (Lee, 2018).

Daylighting

The climate in which a building is located may determine the type of window needed. According to Ortega (2018), in hot climates, the goal is to keep heat out of the building, so windows may have low- E coatings that exclude radiant heat and / or lower Solar Heat Gain Coefficients (SHGC). On the flip side, Ortega (2018) also said that in cold and mixed climates it could be a bit trickier since part of the year is hot and the other is cold. Accordingly, “some faces of a building are more prone to heat gain or loss, to this it is advised that window in colder climates should be specified depending on the wall they are situated.

Building orientation and exterior shading options are important considerations when locating windows and glazing. “It can be more difficult to control direct solar heat gain and glare at skylights, but it helps to orient skylights to maximize daylighting from the north. Elrod (2018), believes that north facing glazing is the best for quality daylighting, but daylighting strategies can also be very effective for south- facing glazing (and can help for west and east-facing glazing also. It is very important to use advanced window systems and technologies, including cutting- edge glazing and coatings that are available today. Alozie, (2014) noted also that it is also important to understand the impact of natural light, heat gain and glare on building systems design.

Alozie, (2019) observed that louvers and grilles can help protect the building envelope openings from unwanted debris, while allowing air to flow in and out of the building, also that louvers and grilles can also be integrated into exterior shading elements, which can help significantly in reducing solar heat gain during warmer months of the year. External shading, either operable or fixed, can block unwanted sun from entering the living space during summer, while allowing heat to enter during cold. This is because sun is at a different angle in the sky, these exterior shades and grilles can be tailored to the path of the sun for that particular location.

Natural Ventilation

Natural ventilation is most effective in climates where there is a comfortable ambient air temperature outside for a number of months of the year. Using natural ventilation as passive design strategy is less common in climates where there are fewer days out of the year that a building can be comfortably occupied without being mechanically heated.

When using natural ventilation as a passive design strategy, it is important to consider how air will move throughout the space given a number of factors such as the orientation of windows and other openings to be used for natural ventilation and the physics of how air moves (e.g., cold air sinks and hot air rises) The balance between active and passive systems can be achieved by relying on the passive systems before the set point for the active system is reached.

Insulation/ Thermal Mass

Adding insulation to a building is another passive design strategy. Designing a building envelope above the mere code requirement in terms of adding extra insulation is always a good passive design strategy. If a building is designed properly, the extra money invested in better insulation, better windows, and a better roof, will result in a reduction of the cost of the mechanical and electrical systems and passive design structure.

Insulation is particularly important for buildings in colder climates. Insulation helps the building envelope to resist the conductive flow of heat, and it is typically most effective when installed as continuous insulation (which significantly reduces thermal bridging as compared to cavity insulation). Continuous insulation means the building is essentially wrapped with blanket of insulation outside the structure to thermally separate the inside from the outside with no thermal bridges. This is important not just for energy performance and comfort, but for indoor air quality and mold elimination (Vujovic, 2018).

Landscaping and Vegetation and Building Materials

Good landscape elements enhance thermal comfort. The architect in considering the regional and microclimate of his project site, should specify landscape finishing that stores heat in the day and transfers into the interior at night where warmth is needed at night and in reverse specify those that enhances air flow especially at night. Concrete stores heat in the day and less of it should be used where cooling is needed. Grass, shrubs and trees filter air and enhance air flow. Trees in addition provide shade. Buildings shaded by trees are noted in Alozie, (2014) to record temperature 3 degrees lower than those not shaded. Climate friendly materials earlier discussed under insulation should be a priority of the architect.

Sustainable Construction Concept

“Sustainability” is one of the world's most discussed topics, whose meaning is often clouded | by differing interpretations and by a tendency for the subject to be treated superficially. For most companies, countries and individuals who do take the subject seriously the concept of sustainability embraces the preservation of the environment as well as critical development of related issues such as the efficient use of resources, continual social progress, stable economic growth, and the eradication of poverty.

In the world of construction, buildings have the capacity to make a major contribution to a more sustainable future for our planet. The Organization for Economic Co-operation and Development (OECD), for instance, estimates that buildings in developed countries account for more than forty percent of energy consumption over their lifetime (incorporating raw y material production, construction, operation, maintenance, and deconstruction). This is further assisted by the fact that for the first time in human history over half of the world's; population now lives in urban environments, and this makes sustainable buildings vital; cornerstones for securing long - term environmental, economic, and social viability (Henderson, 2012). The pace of change means we don't have luxury of time. With urban populations' worldwide swelling by around one million people every week, there's an urgent | need to come up with clever ideas that optimizes the sustainable performance of the buildings that we live and work in (Henderson, 2012).

Sustainable construction aims to meet present day needs for housing, working environments and infrastructure without compromising the ability of future generations to meet their own needs in times to come. It incorporates elements of economic efficiency, environmental performance and social responsibility - and contributes to the greatest extent when architectural quality, technical innovation and transferability are included (Henderson, 2012). Sustainable construction involves issues such as the design and management of buildings; materials performance; construction technology and processes; energy and resource efficiency in building, operation and maintenance; robust product and technologies; long - term monitoring; adherence to ethical standards; socially - viable environments; stakeholder participation; occupational health and safety and working conditions; innovation financing models; improvement to existing contextual conditions; interdependencies of landscape, infrastructure, urban fabric and architecture; flexibility in building use, function and change; and dissemination of knowledge in related academic technical and social contexts (Henderson, 2012).

Sustainable Living Practices

Sustainable development is the development which does not compromise the ability of future generation to meet their own needs (Enger and Smith, 2006), while sustainable living is fundamentally the application of sustainability to lifestyle choice and decisions. One conception of sustainable living expresses what it means as meeting present ecological, societal, and economical needs without compromising these factors for future generations. Another broader conception describes sustainable living in terms of our interconnected social domains: economics, ecology, politics and culture.

1. In the first conception, sustainable living can be described as living within the innate carrying capacities defined by these factors.
2. The second conception, sustainable living is described as negotiating the relationships of needs within limits across all the interconnected domains of social life, including consequences for future human generations and non - human species.

Sustainable design and sustainable development are critical factors to sustainable living. Sustainable design encompasses the development of appropriate technology, which is a staple of sustainable living practices. Sustainable development in turn is the use of these technologies in infrastructure.

The summary of all these, is that if developing nations must achieve the objective of designing buildings that will enhance energy management and sustainable living environment, the client, and his tenant must imbibe sustainable living practices like, recycling, reusing and moderation. The culture of preservation of nature and increasing green thinking indices, such promoting the conservation of nonrenewable materials like energy and good management of edible water. The improvement of air quality by discouraging the setting of wildfire and similar environmental degrading activities which challenges life expectancy. The architect and other green experts should design for waste management right from design source to disposal.

Conclusion

This paper is not exhaustive as researches in energy management which in other phrasing is energy efficiency and studies in sustainability are still unfolding issues which affects not only architecture, but all facets of life. Nevertheless, it the Authours believe that the paper will serve as a primer to studies in the area.

Recommendations

The paper recommends that professionals in the built environment continuously update their knowledge. They should upgrade by acquiring trainings in new and evolving technologies, attend conferences and workshops, and must show concern over their environments by adhering to environmental ethics which calls for functionality in their designs, and for compliance with planning laws and building regulations as required by the local authorities in which their projects are sited. Some of these architectural ethics and building regulations are listed below. The knowledge of energy management which advocates for reduction in energy use should be introduced and practiced by all and environmental professionals and taught in schools, sang as jingles from media houses and read from pulpits. The easiest and least expensive way to solve the “energy problem” is not to augment energy supply, but to reduce the amount of energy need, and this could be done through intelligent design solutions that get buildings to respond to climate. Intelligent building designs that respond to climate consider heating and cooling factors.

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