INTEGRATION OF ECO-EFFICIENT MEASURES AND INNOVATIONS FOR SUSTAINABILITY OF FEDERAL UNIVERSITY SENATE BUILDING LOKOJA, NIGERIA

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ABSTRACT

Buildings are responsible for about 42% of global energy use, as the rapid economic growth has led to an increase in demand for buildings. Satisfying this demand comes with numerous environmental challenges, leading to an increasing concern of climate change. To this end, there is need to create buildings with high performance in relation to the environment. This thesis therefore seeks to provide insights on eco-efficiency and energy consumption of university senate buildings. The objective is to determine energy use pattern and identify eco-efficient measures and innovations that can be used for environmental sustainability of university senate buildings in Nigeria. Purposive sampling was used to collect data from selected federal universities in the north central region of Nigeria. Data was collected from these universities with the use of observation schedules, Energy audit and questionnaires distributed to the built environment professional. Findings revealed that, innovative approaches tailored towards sustainability of buildings when adopted would make university senate buildings in Nigeria key into the philosophy of eco-efficiency. Some of the key elements of eco-efficiency are resource conservation (water, energy and materials), cost efficiency by reducing the initial cost, cost in use and also recovery cost of materials in the entire building construction process. Based on these findings, the thesis recommends the adoption of eco efficiency as a key element for sustainable office buildings. In conclusion, the thesis advocates innovative approaches that would enable a paradigm shift in the design of university senate buildings as very fundamental.

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ABBREVIATIONS, GLOSSARIES AND SYMBOLS

BEP: Built Environment Professional

CO2: Carbon-di-oxide

CO: Carbon-mono-oxide

HVAC: Heating Ventilation, Air condition and Cooling

Kg: Kilogramme

kWh: Kilowatt-hour

LED: Light Emitting Diode

Natural Ventilation: the process of supplying air to and removing air from an indoor space without using mechanical systems

CHAPTER ONE

4.0 INTRODUCTION

4.1 Background to the Study

Buildings are one of the principal consumers of energy, as they consume resources, especially energy at each stage of the building project (Ascione, 2017). The consumption of resources is a demand for them from design and construction stages of building projects, through its entire operation process and also final demolition. This consumption of resources has led to an environmental problem as there is an upsurge of ecological imbalance and pollution caused by the usage and output from these resources needed in buildings, such as high consumption of energy, increased emissions of CO_2, and other unfavourable impact of buildings to the users and the environment, which have led to a major concern on climate change in nations around the world (Chwieduk, 2017).

Meanwhile, in Nigeria, buildings for administrative use has grown tremendously in contemporary time, and this trend, in the future will continue to grow due to the fast economic growth in the country (Ayodeji *et al.*, 2018). The educational sector is not left out of this growth as the demand for tertiary education in the country is on the rise, as there are also diversifications of various fields of study available within the academic institutions, leading to the spread and growth of tertiary institutions around the country. These has stimulated the need to develop the academic environments with the necessary facilities and structures to promote the operations and activities involved in such environments. Senate buildings are the main administrative buildings in the university environment where the major non-academic activities are carried out (Akpan, 2011).

The concept of Sustainability involves concerns for preserving the natural environment and reducing the negative impact of buildings on the natural environment. In recent times, Buildings have taken into account the advantages and disadvantages that are brought about by the new paradigm in technology, as well as environmental and societal changes (Thomas, 2012). Buildings play a vital role in sustainable development, as it is planned, designed constructed and operated for its appropriate functionality, with considerations to minimise adverse environmental impacts. However, it is necessary to design sustainable buildings to mitigate climate change (Delmastro *et al.*, 2017).

Eco-efficiency is the practice of increasing the efficiency of the major resources (energy, water and materials) that are being consumed by a building with the aim of reducing the impact of such building on the environment and human health (Tarja *et al.,* 2013). This involves reduction in wastes from buildings both in its construction and operation stages, minimizing the use of non-renewable resource, more recycling and reduction of hazardous emissions and by-products and incorporation of the environment into the building.

According to Sarkar (2013), in order to achieve eco-efficiency, the three main aspects of sustainability which are concerns for the environment, human needs and technology, have to be appropriately integrated and present within the built environment. Eco-innovation refers to both technological and non-technological innovations, or new products and services that have reduced impacts with little effects on the environments and also enhances the optimization of natural resources (Van, 2008).

4.2 Statement of the Research Problem

In 2010, statistics showed that buildings consumed 32% of the total global final energy use (Zhang *et al.*, 2017). It is feared that this figure above may double or potentially even triple in the future due to the recent emergence and growth of urban centres in nations around the world (Lucon, 2014). As this problem becomes more apparent, the built environment professionals have awoken to the need to preserve the natural environment, and hence seeks measures and innovations that can be used to avert these negative impacts.

The socio-economic development of any nation is indicated by many factors, inclusive of the growth of the institutional sector, which comes simultaneously with varied increase in the number of institutional buildings. Notwithstanding its numerous benefits to the society, it also imposes some negative environmental and social consequences that are present throughout the construction and operation stages of the buildings (Aditya *et al.*, 2017). Furthermore, Kneifel (2010) emphasised on the importance of increasing the energy efficiency of institutional buildings as it is a key resolution in alleviating the negative environmental effects. One main principle of enhancing energy efficiency in buildings is to use less energy for operations, as it will reduce the primary energy use within such building, without affecting the comfort and health of the building users (Nejat *et al.,* 2015).

According to Peter *et al.* (2012), the highest energy consuming components in buildings are the heating, ventilating and air-conditioning that are being used in the building. In a life cycle analysis of buildings carried out by Thormark (2006), it was deduced that the operational energy needed in a building accounts for 85–95% of the total energy consumption of such building, with a bulk of this consumption coming from the heating, cooling, and ventilation systems. However, there is a very limited practice in Nigeria towards environmentally sustainable public buildings and the need to optimise energy use or promote energy saving in office buildings as most offices rely greatly on mechanical means to attain comfort within buildings.

In order to achieve eco-efficiency in the building industry, Anna (2017) suggests an adoption of multi-disciplinary approach ranging from energy saving practices, efficient use of materials, minimization of material waste, control of pollution and harmful emissions. Conserving energy of between 20%-50% from the lighting and HVAC (heating, ventilation, and air conditioning) systems is possible. Although, the cost of energy use in Nigeria is not reliable as the energy sector growth has been found to be marred by inappropriate pricing which is not yielding the needed outcome (Tarja *et al.*, 2013) which would influence the economic growth of Nigeria as the economic growth of the country depends on energy consumption.

4.3 Aim and Objectives

4.3.1 Aim of the study

The aim of this study is to assess the energy use in university senate buildings with a view to propose a design that integrates eco-efficient measures and innovations for sustainability of university senate buildings.

4.3.2 Objectives of the study

i. To determine energy use of university senate buildings in Nigeria

ii. To identify eco-efficient measures and innovations that can be adopted to achieve sustainability in university senate buildings

iii. To assess existing eco measures employed in university senate buildings in Nigeria.

iv. To propose an architectural design that integrates eco-efficient measures and innovations for sustainability of university senate buildings in Nigeria.

4.4 Research Question

This research seeks to assess the following questions:

i. How can energy use in university senate buildings be reduced to make them energy efficient buildings?

ii. What eco-efficient measures and innovations can be integrated in the design and construction of university senate buildings to attain long term sustainability?

iii. What architectural design proposal can be employed that integrates eco-efficient measures and innovations for long term sustainability of university senate buildings

4.5 Scope of the Study

This study is limited to university offices used as senate buildings with particular references to assessing their energy use and eco efficient measures employed in the design of the buildings. The senate buildings to be assessed are four university senate buildings within the north-central geopolitical zone in Nigeria which are: Federal University Lafia, Federal University Lokoja, Federal University of Technology Minna, and University of Abuja. Hence, this study emphasised on the contributions of eco efficient innovations in the buildings that are possible to influence the design of the buildings for sustainability.

4.6 Limitations of the Study

The research was carried out with the challenges of restricted access to some of the facilities and features in the senate buildings due to the security protocols of the senate buildings because of the vital nature of the building. Also, most of these universities have a bulk metering system whereby individual buildings are metered to other buildings. Hence it proved a challenge in getting exact data or figures on the exact quantity of energy consumed by the senate buildings independently.

4.7 Justification of the Study

With global warming being a major threat to the environment in recent years, regions around the world are experiencing climate change with visible adverse effect on the environment (Richard *et al.,* 2013). There is need for architects and designers to produce sustainable building designs and construction as Buildings consume resources to a large extent, especially energy, and these resource in return constitutes a major cause of pollution in the environment as well as negative effect on the health and well-being of individuals (Aditya *et al.*, 2017).

Office buildings pose a high tendency of energy consumption, carbon dioxide (CO_2) emissions and other unfavourable impact of buildings on the environment and its users due to the activities that are being done within them. Eco-efficiency is a tool to attaining sustainability, hence there is a need to incorporate this into built environments as this will help to implement the policy on design of sustainable buildings for the purpose of preventing further environmental degradation (Peter *et al.,* 2012).

4.8 Contribution to Knowledge

This study will equip designers and other built environment professionals (BEP) with requisite knowledge on the importance of eco-efficiency in built environments, provide necessary information on eco-efficient measures that can be integrated in the design of administrative buildings and also create knowledge on new eco-innovations that are available for the design and construction of administrative office buildings generally both within and outside university environments to promote sustainability of such buildings and its surrounding environment.

4.9 Study Area

The study area for the research centres on the domain of federal universities in the north central region of Nigeria, covering Kogi, Niger, Kwara States and the Federal Capital

Territory, Abuja. Figure 1.1 and Figure 1.2 shows the maps of Nigeria and that of the States in North Central Nigeria respectively.

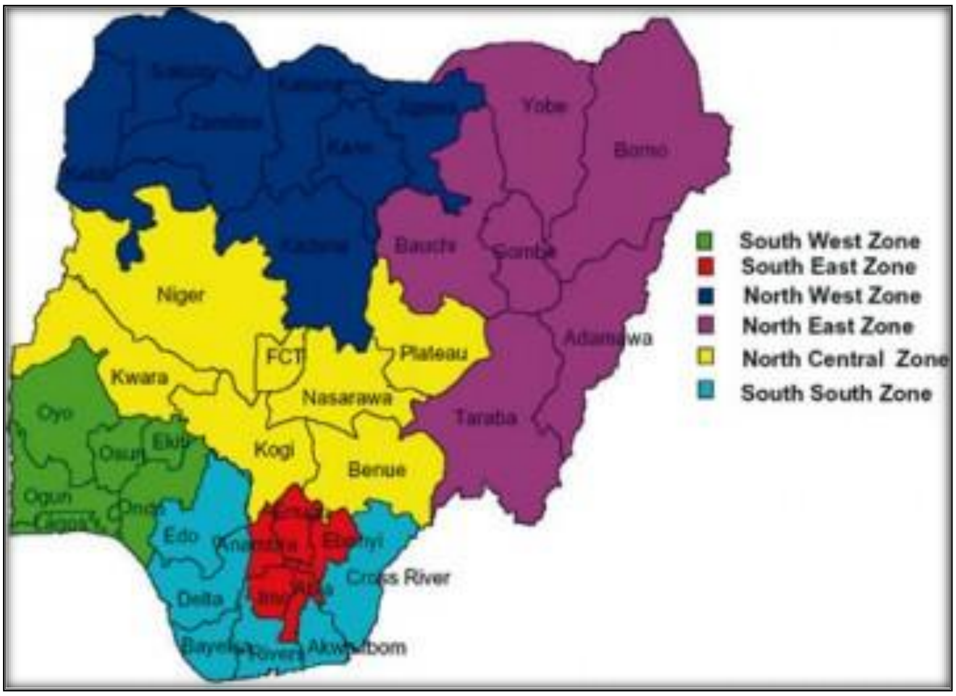


Figure 1.1: Six Geo-political Zones in Nigeria
(Source: Google Image, 2019)

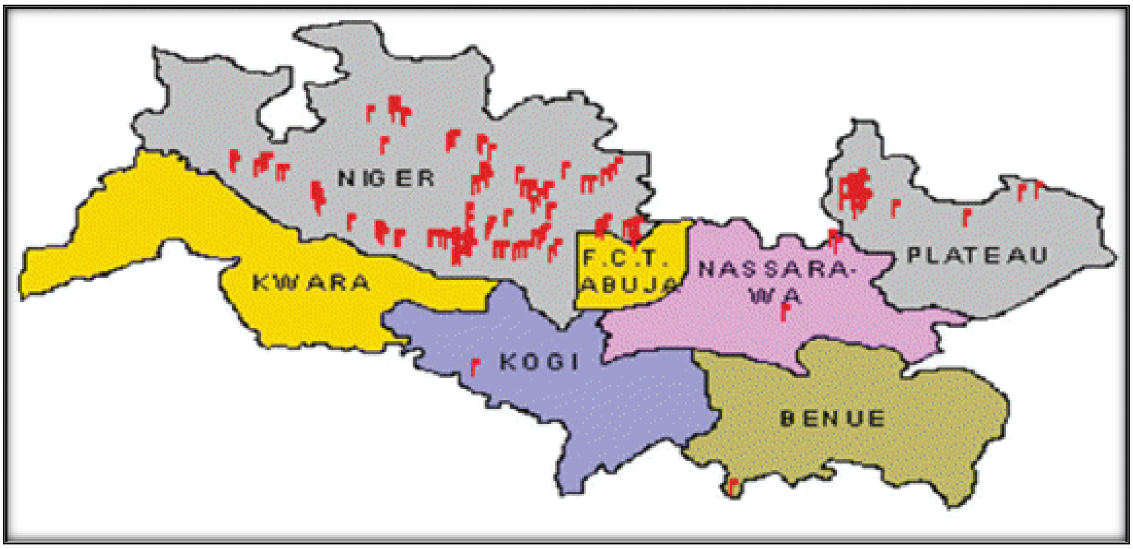


Figure 1.2: States in North Central Nigeria
(Source: Google Image, 2019)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter discusses extant literature on eco-efficiency of buildings, eco-innovations and green technologies; its method of application to buildings to stimulate and promote sustainable environmental development. It also highlights the indicators of eco-efficiency as it can be identified in built environment, as well the methods of measuring these indicators.

2.2 Conceptual Review

In this section, conceptual framework of eco-efficiency, eco-innovations and sustainability is discussed from the opinion and perspective of past literature on eco-efficiency.

2.2.1 History/origin of eco efficiency

The concept of eco-efficiency emerged in the 1970s, where it was referred to as 'environmental efficiency'. The idea was firstly presented in 1990, by Strun and Schaltegger, and was then promoted and formerly introduced by the Business Council for Sustainable Development; BCSD (now called World Business Council for Sustainable Development; WBCSD) in 1992 who helped sustain the concept (Pekka and Tarja, 2005). Many organisations around the world have awoken to the dangers of their activities on the environment and have therefore embraced the concept of eco-efficiency, which is being applied as part of the operating principles of their organisations.

Eco-efficiency is a more general expression of the concept of resource efficiency, which summarily entails a reduction in the consumption and impact of resources on the environment while maintaining an utmost building performance and output (Hendrick and Robin, 2000). Milan *et al.* (2015) explained that Eco-efficiency is associated with a cradle-to-grave flow, which refers to the environmental impact created by the activities of a firm or buildings from the beginning of its life cycle to its end or disposal.

Eco-efficiency is a concept perceived as an indicator of environmental sustainable development, solely aimed at minimizing wastes and conservative consumption of natural resources. Therefore, eco-efficiency is said to be reached when basic resources that satisfy human, social and economic needs are provided with the consciousness of reducing negative impacts and intensity of such resource (WBCSD, 2010).

2.2.1.1 Definitions of eco efficiency

The World Business Council for Sustainable Development (WBCSD), suggests that eco-efficiency is achieved when the resources, goods and services that satisfy economic and social needs as well as improvement of quality of life, is provided or delivered with the aim of reducing negative impacts and intensity of such resource throughout the use of such resource to an acceptable level (WBCSD, 2010). Furthermore, Kibert (2016) defined eco-efficiency as the efficient use of ecological resources to meet the demands and needs of humans.

From the perspective of Sarkar (2013), eco-efficiency is the technique of increasing the efficiency with which buildings consume essential resources in a manner that there is a reduced impact on the environment and health of individuals within such environments. Therefore, to achieve eco-efficiency, the basic resource that constitutes the functionality of a building needs to be maximized in its use to avoid waste. Moving on, Tuker *et al.* (2003) defined eco-efficiency as a strategy profitable to the social aspect of an economy, aimed at minimizing the use of materials and resources, which in turn reduces undesirable impact of such material on the environment. From Tucker's school of thought, the main aim of eco-efficiency is to 'get more from less' and this presents a qualitative economic growth. Hence, using lesser quantities of resources have the potential to produce a higher degree of economic affluence.

Therefore, for the purpose of this dissertation, eco-efficiency, as related to the building industry, can be defined as a strategy of used to reduce the impact of buildings and resources used in the construction and operation of such buildings on the environment by increasing the efficiency of resources used in and on the building to maximise the use of such resources adequately and avoid wastage of any form. This therefore optimises the sustainability of the building by conserving resources and saving while maximizing the building's output.

2.2.1.2 Eco-innovation

The concept of eco-efficiency of buildings is discussed relatively with eco-innovation as organisations around the world have taken advantage of the evident advancement in technology globally as a means to achieve sustainability of buildings. Eco-innovation is a new concept in itself, which constitutes the use of innovative technology as a solution to environmental sustainability problems. Innovation, according to Baldwin *et al.* (2016) is the development and intentional introduction of new and useful ideas by individuals, teams and organisations. Sev (2009) defined innovation as the art of to solving problems and promoting materials values by the application of creative ingenuity through a product, service or experience. Likewise, Peter *et al.* (2012) stated that innovation is a change that introduces a new dimension. Hence, eco-innovation in buildings can be used as a tool to create a new dimension to proffer solution to environmental problems caused by buildings and its activities.

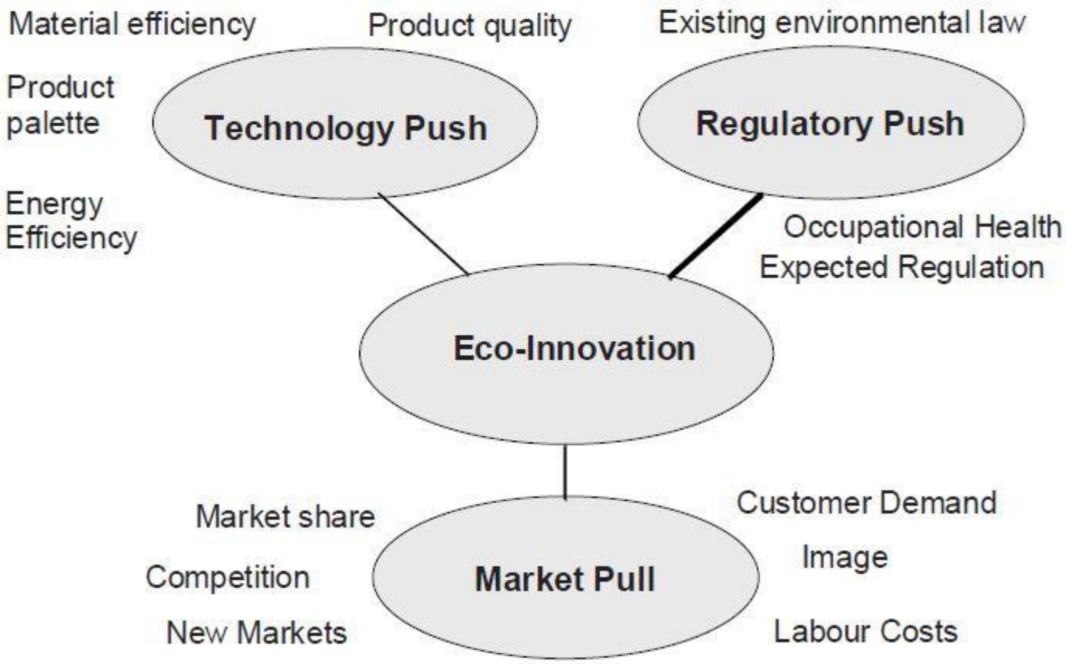


Figure 2.1: Drivers of eco-innovations
(Source: Bossink, 2004)

Thomas (2012) defined eco-innovation as Sustainable innovation which is the process of developing new concepts and ideas that promotes the reduction in environmental burdens. Eco-efficient innovation is described by Van (2008) as delivery of products and processes that meet tomorrow's rather than yesterday's Environmental expectations. Hence, eco innovation can be said to be the introduction of a new idea or technique to solve the negative of impact of buildings on the environment.

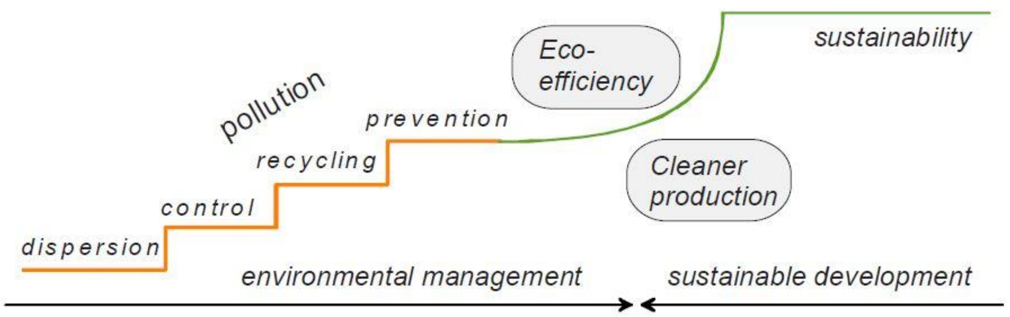


Figure 2.2: Eco-efficiency and cleaner production as steps towards sustainability (Source: Van, 2008)

2.2.2 Benefits of eco efficiency

The practice and application of eco-efficiency offers some practical benefits to humans, and the environments in diverse ways such as:

i. Cost reduction resulting from the efficient usage of resources

ii. Reduced risk and liability by scheming out the need for toxic substances

iii. Revenue Increment through the emergence of innovative products

iv. Sustainability of buildings

v. protection and conservation of the natural environment

vi. resources conservation

2.2.3 History/origin of sustainability

The concept of environmental sustainability emerged as a guiding paradigm to bring about a change in the built environment due to the recent concern on climate change. The unparalleled labyrinth of complexities in our society today has given rise to countless negative effects on ecological, economic, and social sectors with minimum solution. This therefore led to the evolution of diverse initiatives aimed at addressing different aspects of the environmental challenges. One of which is the Sustainable development which was proposed as a means to create an environment that meets the will protect and conserve the present eco system, without compromising the ability of future generations to meet their own needs (US environmental protection agency, 2010). The terms ‘sustainable development’ and ‘sustainability’ became prominent many decades ago and has since then been embraced and practiced by many organisations around the world. Although, critics acclaimed its vagueness and ambiguity, the definition of sustainable development that was proposed by the World Commission on Environment and Development (WCED) was a spotlight in developing a global view with respect to the future. Likewise, some critics in the 80s proclaimed that the concept of sustainable development would eventually fade out within a short time (Mendler & Odell, 2000). Contrary to this, the influence of this concept has increased significantly both nationally and internationally, and has existed as a core element in in policy documents in many organisations in the world, leading to the widening of the concept of sustainable development.

Architecture however, embraced the concept of sustainability as it came to the understanding that buildings play an important role in a nation’s development and constitute about 43% of environmental issues in regions around the world. This then birthed the concept of sustainable design, as a means of integrating architecture with electrical, structural and mechanical systems, taking advantage of other renewable energy sources (Eubanks, 2007). Sustainable development have since been integrated in architecture through diverse critical means such as the use of traditional building materials, energy-efficient appliances, as well as the practice of reusing and recycling materials. Sustainable design, according to Anna (2017), involves the design of buildings that require lesser resources to build and operate while meeting the demands and satisfaction of the occupants. This results in the existence of buildings that are durable, attractive with reduced operation and maintenance costs, improved comfort and convenience and low environment impact.

Sustainable buildings therefore should work towards achieving zero net environmental impact by elimination of pollution, reduced use of non-renewable resources, creating healthy and accessible indoor and urban environments, protection of the natural environment, creating a built environment that is resilient, flexible and adaptive to climate change, enhancing decentralized electricity and water systems, supporting a move towards understanding and implementing positive development and supporting sustainable modes of travel (Sameni *et al.*, 2015).

2.2.3.1 Definition of Sustainability in relation to Architecture

The WCED defined sustainable development as a concept that is framed to meet the desires of the present (proffer present environmental solutions) without compromise to the future generation.

According to Carlucci *et al.* (2015), sustainable design is a design approach that reduces negative impacts of building on the natural environment thereby enhancing the indoor and outdoor environment of such building. Eubanks (2007) defined Sustainable design as a means of integrating architecture with electrical, structural and mechanical systems, taking advantage, whenever possible, of other renewable energy sources such as photovoltaic, wind, geothermal, etc. The use of native building materials, energy-efficient appliances, as well as reusing and recycling materials (including the building at the end of its planned life) are all facets of sustainable building design principles.

The goal of sustainable design for the built environment is to integrate the natural environment into the design and construction of buildings, to reduce the impact of natural resources used in the building, minimise the demand and consumption of non-renewable resources, protect and conserve resources such as water, enhance indoor environmental air quality, and improve the general operation and maintenance practices within and around the built environment (U.S. environmental protection Agency, 2010).

2.2.3.2 Basic principles of sustainable design

Walker *et al.* (2016) stated that sustainable design principles involves understanding place, connecting with nature, understanding natural processes, understanding environmental impacts, embracing co-creative design processes and understanding people. Similarly, Hamdy *et al.* (2016) opined that sustainable design principles involves optimization of site potential; optimizing energy use; protection and conservation of water; selection and use of environmentally preferable products; enhancement of indoor environmental quality; and optimization of operations and maintenance practices. Hence, the principles of sustainable design can be summarized as follows;

i. To mitigate against diminution of natural resources
ii. To prevent the degradation of the natural environment caused by buildings throughout their life cycle.
iii. To construct buildings that is liveable, healthy, secure, and positively usable (Cuce, 2016).

2.2.4 Relationship between eco-efficiency, eco-innovation and sustainability

The three aspects of sustainability, according to Santamouris (2016) are economic, social and environmental stability, and these three factors are put in place, sustainability of such a place or building is said to be optimized. Furthermore, Sakar (2013) stated that these three aspects of sustainability have to be in place and balanced to achieve eco-efficiency in a building. Likewise, the organisation for economic co-operation and development (OECD) proposed that there are three dimensions to eco innovation which are its targets (the main focus), its mechanisms (methods for introducing changes in the target) and its impacts (the effects on environmental conditions).

Therefore, linking these together, eco-efficiency involves an integrated approach which takes into consideration the aspects of sustainability; the environment's concerns, (environmental sustainability), social concern (human's needs) and economic concern (technology), while integrating innovations aimed at providing a positive impact on the target which are the aspects of sustainability and application of the right mechanisms to create positive outcomes on the targets. Fig 2.3 shows a vicious cycle relating Eco efficiency to the main aspects of sustainability.

Figure 2.3: The relationship between eco-efficiency and sustainability (Source: Sakar, 2013)

2.2.5 Eco-efficiency indicators (EEI) in buildings

Eco-efficiency in itself is an important indicator for sustainable development (Barthelmes *et al.*, 2016). Therefore, Lizana *et al.* (2017) suggested adopting a multi-disciplinary approach to ensure that the building industry of the future attains long-term sustainability. Hence, since it has been established in previous sections of this chapter that eco-efficiency is in summary the conservation of resources, certain resources that are needed in and for building construction and operation should be efficiently managed. Building activities can be controlled and improved to make it less environmentally damaging in many ways, without affecting the buildings ability to perform its maximum function for which it was designed and constructed. To achieve this therefore, the whole life cycle of a building should be the context under which these practices are carried out (Feng *et al.*, 2018).

Figure 2.4: Strategies to achieve eco-efficiency of buildings.
(Source: Sakar, 2013)

Peter *et al.* (2012) identified three general objectives that form a framework for achieving or implementing eco-efficiency within the built environment (Figure 2.4), bearing in mind the principles of sustainability; technology, environment and human needs. This can be summarized into economic, environment and social concern. From the definitions of eco-efficiency highlighted in the subsection above, and the relationship between eco-efficiency and the aspects of sustainability, the indicators of eco-efficiency can therefore be deduced as resource conservation (environment concern), cost efficiency (technology/Economic concern) and design for human adaptation(for social/human needs).

RESOURCE CONSERVATION

- Energy
- Water
- Material
- Land

COST EFFICIENCY

- Initial cost
- Cost in use
- Recovery cost

HUMAN SATISFACTION

- Protecting health
- User satisfaction

Figure 2.5: Eco-efficiency indicators in buildings
(Source: Peter *et al*., 2012)

2.2.5.1 Resource conservation

The rising increase in the depletion of non-renewable natural resources has created an increased concern on being resource efficient (Lempriere, 2016). Resource conservation simply means using less resources or materials to achieve more. It is also the management and judicious use of natural resources by the current generation while maintaining capacity to meet the needs of future generations (Greenwood. 2015).

The concept of resource conservation has become a concern in sustainable development because certain resources are key component in a building's construction and operation, and some of these resources are becoming rare (Zhao and Pan, 2017). Hence, the use of available natural resources should be treated cautiously. It is important to conserve or substitute major resources with renewable resources to enhance its availability. The resources that play major role in a building construction project are energy, water, material and land. Table 2.1 highlights the various methods to be considered in conserving various resources in buildings.

Table 2.1: Resource conservation methods in building construction

	Energy conservation	Material conservation	Water conservation	Land conservation
1.	Selection of materials and construction methods	Considerations for waste	Using efficient plumbing fittings	Adaptive reuse of existing building
2.	Insulate the entire building envelope where applicable	Adoption of durable material	Design for dual plumbing	Locate construction project close to existing infrastructure
3.	Design for energy efficient deconstruction and recycling	Specify natural and local material	Collecting rain water	Development of non-arable lands
4.	Design for low energy intensive transportation	Design for Pollution prevention	Employ re-circulating Systems	
5.	Developing energy efficient	Specify non-toxic material	Designing low-demand landscaping	
6.	Use of passive energy design		Pressure reduction	

(Source: Greenwood, 2015)

a. Energy Conservation

The International Energy Agency (IEA) have predicted that within the next 10years, there will be a 53% increase in the general global energy consumption (Aditya *et al.*, 2017). According to Delmastro *et al.* (2017), buildings consume large amount of energy during its entire life cycle, and amount of energy used by the buildings affects the flow of greenhouse gases (GHGs) and other hazardous chemical gasses to the atmosphere.

This consumption can be reduced by proffering measures that will increasing the energy efficiency of such building (Nejat *et al.*, 2015).

With this realization, energy conservation has gained more attention in the building sector over the years as the sector has an extensive potential of primary energy saving and reduction of emissions to the environment. Energy demand in buildings involves both operational and embodied energy. The operational energy is the energy needed to maintain the atmosphere inside that building, while the embodied energy of a building is the total energy required in the creation of a building either direct (construction and assembly process) or indirect (manufacture of materials and components of the building) (Ruparathna *et al.*, 2016).

Therefore, the energy consumption of a building can be considered to be made up of numerous inputs of operational and embodied energy throughout a building life cycle. It is important that buildings are designed and constructed to be energy efficient. This can be achieved by reducing the energy demand of the building. As the operational energy decreases, more attention has to be paid to the embodied energy. An energy efficient building should provide maximum comfort for the occupants, the building should be designed and constructed to perform the main function for which it has been designed and constructed (Akande *et al.*, 2015). The following sub-section discusses methods and measures that can be applied to minimize the demand and consumption of energy in a building.

1. Choices of materials and construction methods

Jones *et al.* (2015) highlighted that the recent innovation of certain conservative construction materials, especially for energy, has promoted the possibility of minimising energy consumption in a building through reduced solar heat gain or loss, thus reducing operational energy (loads from mechanized heating and cooling system). Also, the use of building materials with low embodied energy will promote reduction of energy consumed through material processing, manufacturing and transportation (Akande *et al.*, 2015).

2. Insulating the building envelope

The amount of heat lost through the building envelope can be reduced by insulating buildings (Ascione, 2017). Building insulation can be done efficiently by adopting the air-tightness strategy by blocking vents and openings, then insulting floors, ceiling and walls, or coating the walls with modified plaster. This practice can be adopted in cold regions to reduce the demand for mechanised heating.

3. Designing for energy efficient deconstruction and recycling of materials

This strategy involves reducing energy consumed in manufacturing of materials. Buildings designed for deconstruction are built with a minimal use of chemically disparate binders, to better separate constituent materials (Chwieduk, 2017). This will facilitate reuse and recycling of materials and promote a zero-energy building sector.

4. Designing for low energy intensive transportation

Land transportation causes air pollution as cars exhaust fumes into the environment. Bearing this in mind, the amount of energy needed for transportation can be reduced by making it easy to get places without driving and offering attractive bicycle and walking paths. The design of low energy buildings should be combined with parking lots that are quite some distance from the main building for less air pollution.

5. Developing energy efficient technological processes

To achieve energy optimization in a building, adequate measures need to be taken by the project team right from the instigation of the project. Dixon *et al.* (2015) suggested the priming of individuals to consider their energy usage at work as there seem to be more wastage of energy in public offices. This was closely supported by Kylili & Fokaides (2015), wherein he advocated that the effectiveness of social messages on energy conservation in a building promotes energy conservation behaviour among commercial building users.

6. Adoption of passive energy design strategies

Architects and designers can adopt some passive energy design strategies such as increased natural ventilation and lighting, landscape, enhanced evaporation and cooling by providing water bodies within and around the building, and proper building orientation. This will improve the thermal and visual comfort in the building and also reduce the energy consumption caused by the use of mechanical cooling and lighting systems (Akande *et al.*, 2015).

b. Materials Conservation

The extraction and consumption of natural resources for building materials or as raw materials for production of building materials has some negative impacts on the ecosystem (Akande, 2010). In achieving eco-efficiency, the use of non-renewable building materials should be minimised. The preceding subsections discusses measures that can be applied to achieve material conservation in building construction (Kylili & Fokaides, 2015).

1. Design for Waste Minimization

Waste is generated in the buildings either as used or unwanted materials generated from construction or demolition processes. There exist three key methods suggested by Akande *et al.* (2015) to be used in prevention and reduction of waste in building construction, and they are reducing and recovering construction waste, Reuse and Recycling of waste, and waste storage and disposal. Therefore, renovation and demolition of buildings can be performed by building deconstruction which enables the recovery of building parts as functional components so that they can reused for other construction purposes (Lee *et al.,* 2010). Non-hazardous debris can also landfilled in areas where they are applicable (Greenwood, 2015).

2. Use of durable materials

The use of durable building materials enhances the sustainability of a building (De-silva *et al.,* 2004). Materials with a longer life reduces the natural resources required for manufacturing and the amount of money spent on installation and the associated labour. The greater the material durability, the lower the time and resources required to maintain it (Mora, 2007).

3. Use of Natural and Local Materials.

Natural building materials, compared to manmade materials contain lower embodied energy and toxicity than man-made materials (Akande, 2010). Many natural materials are theoretically renewable. When natural materials are incorporated into building products, the products become more sustainable as they lessen the environmental burdens and reduce air pollution produced by vehicle fumes in the process of transportation.

4. Design for Pollution prevention.

Pollution caused by activities of the building industries comes in form of air, water and soil. At the construction site, soil pollution is mainly a problem, and also in the extraction of some minerals, and raw materials for production of some building materials (Kibert, 2016). Likewise, the transportation of some of these materials causes Emissions which are the major cause of photochemical smog (Kim and Rigdon, 2008). Hence, manufactures are employed to use environmentally sustainable methods in production of materials and also ensure the production of sustainable materials (Baldwin *et al.,* 2016).

5. Use of Non-Toxic or Less-Toxic Materials.

Toxic construction materials such as paints, sealers and adhesives affect indoor air quality of buildings as some of them contain volatile organic compounds (VOCs) (Kim and Rigdon, 2008). Hence, building materials with lower or non-existent levels of toxic substances should be used to eliminate environmental health problems.

c. Water Conservation

The United Nations World Water Development Report (WWDR) indicates that water for human use is becoming scarce (United Nations Educational, Scientific and Cultural Organisation (UNESCO), 2013). The depletion of water resources is becoming an environmental issue of the utmost concern worldwide with the fast growing economy of many nations. Buildings and its activities rely heavily on water at every stage to operate as water is consumed in the extraction, manufacture and delivery of materials to site, and the on-site construction process, which is referred to as 'embodied' water (McCormack *et al.,* 2007). The following sub-sections discusses strategies that can be applied to reduce the amount of water consumed throughout the life cycle of a building.

a. Utilizing water-efficient plumbing fixtures

Plumbing systems in buildings can be provided with recent innovations such as ultra-low flow toilets and urinals, waterless urinals, low-flow and censored sinks, low-flow showerheads, and water-efficient dishwashers and washing machines, to minimize wastage of water (Anna, 2017).

b. Design for dual plumbing

This method involves the use of recycled water or grey water system that recovers rain water for toilet flushing or site irrigation and also irrigation of ornamental plants within the building. Grey water is produced by activities such as hand washing, and does not need to be treated intensively as sewage (Ilha *et al.*, 2009).

c. Employ re-circulating systems

The use of re-circulating systems for centralized hot water distribution can be used to conserve water which is typically wasted by users while waiting for warm water to flow from a warm water faucet (Brown, 2003).

d. Designing low-demand landscaping

Water used for maintaining landscape can be minimised by using plants that require lesser amount of water to survive (Markarian, 2005). Also, the use of underground drip irrigation systems can be employed to reduce water loss caused by evaporation of surface water.

e. Pressure Reduction.

The reduction of water pressure from a fixture is a strategy to enhance conservation as it reduces water flow and also prevents wastage (Peter *et al.*, 2012).

f. Land Conservation

Land is an important resource upon which the construction industry depends. Land pollution is a growing problem in both the developed and developing worlds, as a large extent of pollution is being experienced, caused by series of industrial pollutants, Soil erosion, contamination of ground water , and acid rain which is imposing danger on land (Zakari *et al.,* 2014). Also, building construction contribute to this pollution due to excavation activities and mining for raw material production and urban expansion caused by the growing construction of buildings has imposed a growing problem on land consumption.

Therefore, Land conservation imposes a great issue, as little can be done by the construction industry, since the growth of urban centres is on increase. Hence, to achieve conservation, construction of new buildings can be reduces by adopting the practice of renovation and reuse of existing buildings (Haberl, 2004). Also, enhancing easy access to facilities such as medical facilities, shopping areas and recreational facilities, would prevent the expansion of built environment and occupation of agricultural and eco-sensitive areas (Marcella *et al.*, 2014).

2.2.5.2 Cost efficiency

One of the key aspects of sustainability is to promote the utmost efficiency and reduction of financial cost of any building. Cost efficiency of buildings is a major interest for the owner, the users and society, as they have all come to a realization that the economic operation of a building considered from the inception of the design, in selecting materials and finishes that will be suitable from the construction stage and also in terms of its maintenance throughout the period of use of such building (Tucker *et al.,* 2003).

Lucon (2014) identified three principle life cycles cost that can be considered at the onset of a construction project which are the initial cost, the cost in use and the recovery cost.

a. Initial Cost

The initial cost covers the entire cost of creating, or remodelling, the building (Esin and Cosgun, 2007). It is the cost incurred by the client at the inception stage, which includes the cost of acquiring land, consultants' fee, the cost of the construction materials and the cost of construction (Cao *et al.*, 2016).

Conservation of initial cost can be achieved by the following measures:

1. Selection of readily available and less expensive building materials that are durable and can serve its maximum purpose.
2. locally-available materials should be adopted as they are readily available and cheaper to acquire compared to the imported material
3. Cost saving construction technology should be employed to a large extent in the construction process (San-Jose and Cuadrado, 2010).
4. Durable building materials should be used to minimize expensive replacement and retrofitting (Richard *et al.*, 2013).
5. The use of recycled materials and also materials gotten from deconstruction processes such as windows and doors should be used (Ortiz *et al.*, 2009).

b. Cost in Use

The cost in use of a building is the running cost or operation cost. It is the cost incurred in maintenance and running the building (Tarja *et al.*, 2013). The running cost of a building is dependent on the durability of materials and appliances used in the building (Gibbs and O'Neill, 2015). Materials and appliances with long service life often times cost more than those with a lesser life span, hence in trying to reduce the initial cost by buying cheaper materials, the designer may unknowingly be increasing the cost in use of the building. Therefore there should be a synergy in balancing the initial cost and running cost of a construction project.

Cost reduction in the use of building can achieve by taking into consideration the following:

1. Considerations should be given and easily provisions made for the servicing and maintenance of HVAC system and these maintenance points should be easily assessed and identifiable.
2. Building facility maintainers should be well qualified and made available within the building to detect faults and damages quickly to solve such problems immediately.
3. Choosing minimum-maintenance materials by selecting building materials that require little maintenance (painting, retreatment, and waterproofing).
4. During the design stage, adequate provisions should be made to protect materials from destructive elements such as sun, temperature variations, rain or wind. Measures should also be provided for cases of flooding or storm damage.
5. Provide easy-to-understand and easy-to-use building control systems for occupants and building operators should be provided to ensure effective operation of energy efficient technologies and components.

c. Recovery Cost

Recovery cost encompasses the cost of demolishing the building and recovery of materials (Pan and Ning, 2015). Recovery cost in most cases is rarely considered due to the fact that the building might have been sold off before the building is.

However, in the case of recycling of buildings, the following methods should be implemented to reduce or eliminate recovery cost:

1. Recycling potential and ease of demolition should be considered during the design phases and noted into the development budget. Recycling also creates jobs as well as saving valuable resources, thus protecting the natural environment (Richard *et al.,* 2013).
2. Renovation and reuse of an existing project will significantly reduce waste that may be generated from demolition and also conserve energy used for manufacturing materials and construction (Arpke and Strong, 2006).
3. Reuse of individual components, such as windows, doors and interior fixtures can help increase the cost effectiveness of the building by paying attention to the life cycle cost of building project in terms of both design and choice of materials (Markarian, 2005).

2.2.5.3 Design for human adaptation

One of the main purposes of a sustainable building is to provide healthy and comfortable environment for human activities (Sakar, 2013). A building must exhibit adequate functionality and fulfil the purpose for which it was designed and constructed. To promote and enhance human adaptation in buildings, by Peter *et al.* (2012) proposed the following considerations to be adopted in designing and constructing eco-efficient buildings.

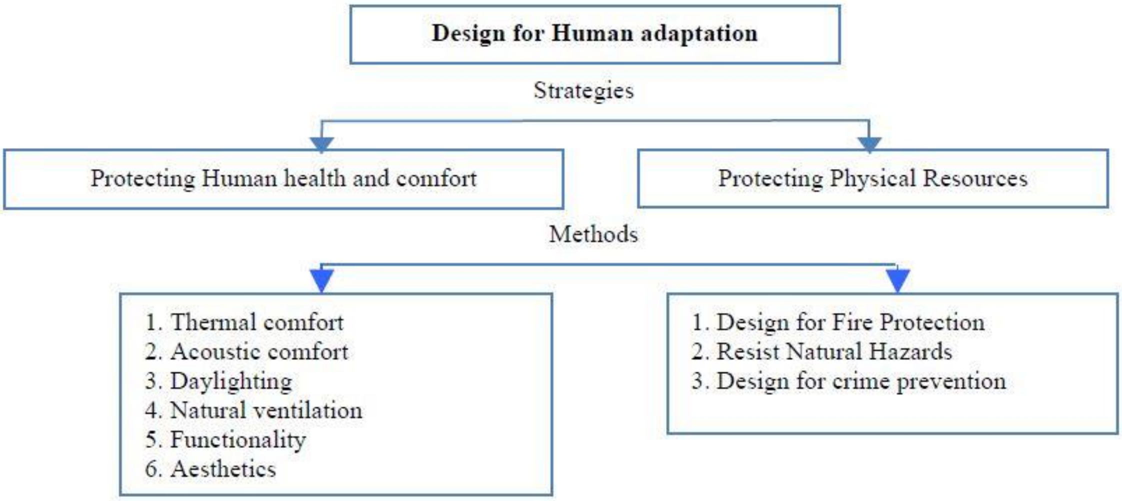


Figure 2.6: Indicators for designing for human adaptation
(Source: Peter *et al*. 2012)

a. Protecting Human Health and Comfort

Well-being (health and comfort) of a building occupant is an important aspect determining the quality of life of individuals, especially in a modern society, where individuals spend more than 90% of their time indoors at their places of work, and also more than 70% of their time indoors at home (Emmitt and Yeomans, 2008).

One of the key aspects of a sustainable building deal with the significance of the health of individuals, and this is better achieved by improving the building performances (indoor air quality, thermal comfort, lighting quality and acoustics). A sustainable industry must balance human needs with the carrying capacity of natural and cultural environments. According to Sev (2009), a product may save energy and perform well; however, if it does not positively affect the occupants' comfort and enhance productivity, it is not a sustainable product. Hence, the following key aspects of a building should be effectively considered to harmonise the environment, buildings and their occupants.

1. Thermal comfort

Thermal comfort affects occupant’s productivity and also determines satisfaction. Architects and designers should have an exclusive goal of maintaining thermal comfort for the users of a building. Zhao and Pan, (2017) highlighted some environmental parameters that are factors of thermal environment which are: Temperature (air, radiant, surface), humidity, air velocity and the personal parameters (activity level and clothing worn by the individuals). Akande (2010) described that when heat gain is unchecked, buildings can be uncomfortable. Therefore, considerations such use of reflecting roofing sheets, tinting of windows and provision of solar shading are some of the measures that can be used to optimize thermal comfort and improving energy efficiency within a building envelope (Chen, 2015).

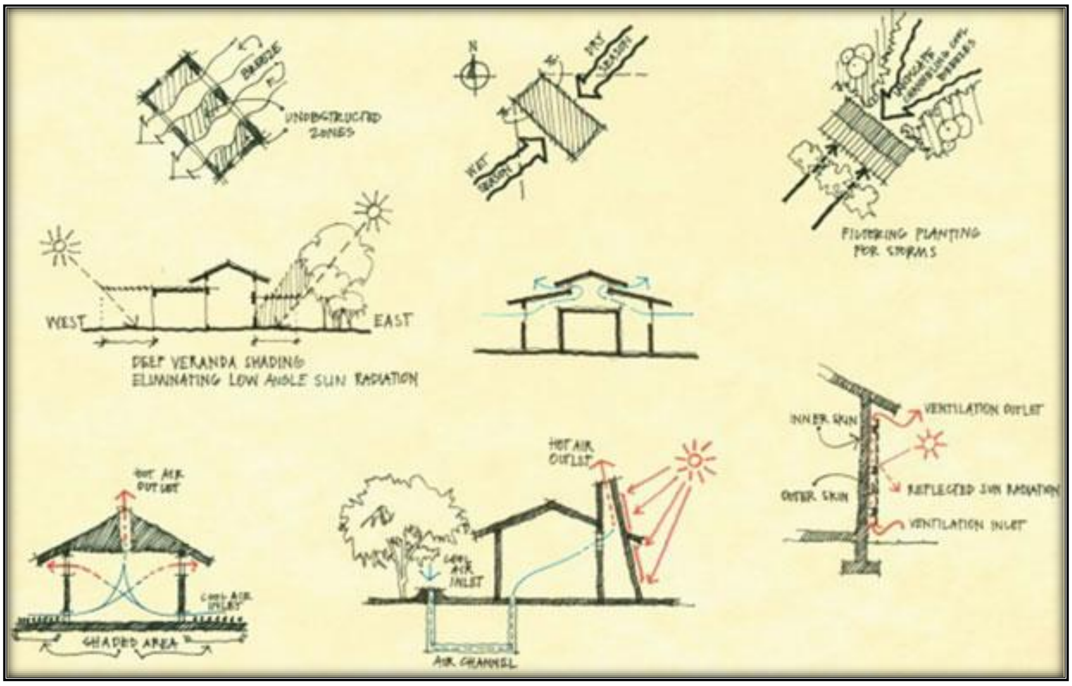


Figure 2.7: Building blocks and passive cooling techniques
(Source: Chen, 2015)

2. The acoustical environment

Acoustic comfort within a building is an important factor for occupants comfort, as all noise sources from equipment and the exterior environment of the building must be controlled. This can be done by insulating walls, Proper selection of windows and materials are acoustic proof in nature such as acoustic ceiling tiles and straw-bale construction and also zoning of HVAC units (Edwards, 2006).

3. Day lighting

Day lighting involves designing buildings for optimum use of natural light, sufficient to see properly in the building without excessive contrast or glare (Giordano *et al.*, 2017). Day lighting is beneficial both to health and well-being. Although, excess exposure to direct sun causes discomfort and ill health, particularly with highly reflective surfaces (Jianxin *et al.*, 2011). Hence shading devices can be used while giving adequate considerations for natural ventilation.

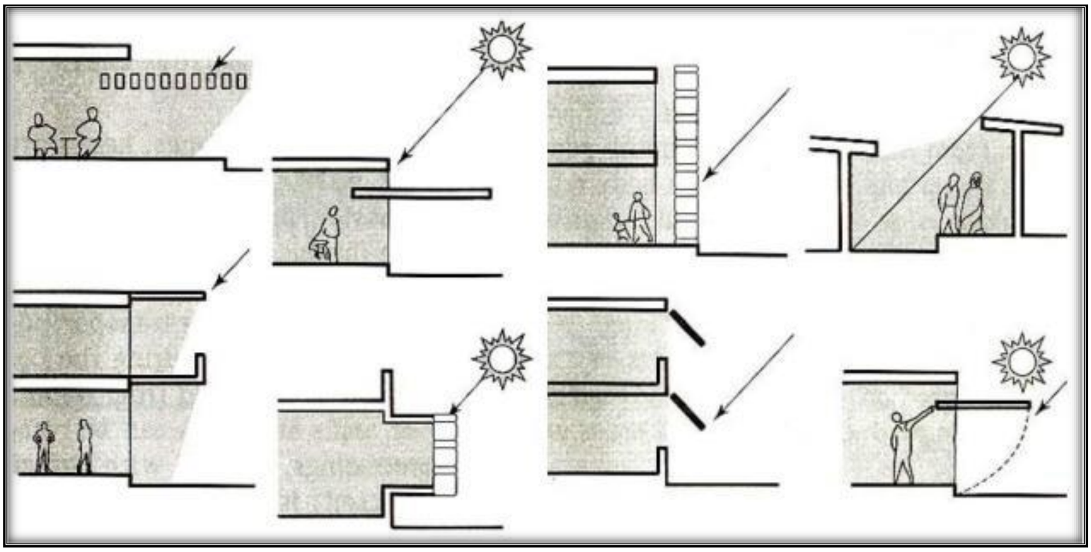


Figure 2.8: Different types of shading devices like the overhangs, louvers and awnings
(Source: Feng *et al.*, 2018)

4. Natural ventilation

Natural ventilation involves providing high indoor quality without the use of mechanical means. Natural ventilation provides natural air within built up spaces, reduces unpleasant odours and pollutants, and also enhances the thermal comfort of built spaces (Milan *et al.,* 2015). Natural ventilation also reduces the initial and running cost of a building as it reduces the use of mechanical equipment, and it also enhances the productivity of building occupants due to comfortable indoor working environment (Lempriere, 2016). Some key factors to improving natural ventilation are the climate suitability, window orientation, size and operable windows (Edwards, 2006).

5. Building aesthetics

The aesthetics of a building contributes to the psychological comfort of occupants. Hence, buildings should encompass a pleasing architectural setting, visual interest, provision of artistic elements such as wall paintings, sculptures, provision of natural elements in and around the building such as water fountain, flowers and therapeutic plants, aquarium and mosaic walls (Kneifel, 2010). The effect of beauty may be hard to measure, but it emphasizes the aesthetical requirement as a sustainable aspect.

b. Protecting Physical Resources

The protection of physical resource of a building is an important aspect of eco-efficiency as building designs must incorporate resilient measures building against natural and man-made disasters such as fire incident, earthquake and flooding and crime attack. The following subsections highlights the measures that can be applied to protect physical resources within and around building environments.

1. Plan for Fire Protection.

Fire safety measures should be considered from the concept design stage of any project, and this can be done in the form of passive fire protection measure. These measures include insulating wall partitions, compartmentalization of buildings to prevent the quick spread of fire, provision of fire escape routes that are well emphasized and distinguished for easy identification in the case of fire outbreak.

2. Resist Natural Hazards.

Some techniques that can be used to protect buildings in the case of natural hazards are by elevating buildings above floor levels in flood prone areas, and making buildings watertight to prevent water entry.

a. Crime prevention

Effective secure building design involves implementing countermeasures to deter, detect, delay, and respond to attacks from human aggressors. According to National Crime Prevention Council (2003), the principles of Crime Prevention through Environmental Design (CDTED) include natural access control, natural surveillance, and territorial behaviour. Access control uses doors, shrubs, fences, gates, and other physical design elements to discourage access to an area by all but its intended users. According to Shedid and Elhennaway (2015), the restriction to the entrance of a building, an asset or a room to approved individuals is referred to as access control. Access control can comprise casual (spatial description), official (security operative) and automatic (locks and bolts) approaches.

Surveillance is achieved by placing windows in locations that allow intended users to see or be seen while ensuring that intruders will be observed as well. Surveillance is enhanced by providing adequate lighting and landscaping that allow for unobstructed views (North Yorkshire Police, 2014). Finally, territory is defined by sidewalks, landscaping, porches, and other elements that establish the boundaries between public and private areas. These three methods work together to create an environment in which people feel safe to live, work, travel, or visit (Zhang *et al.*, 2017).

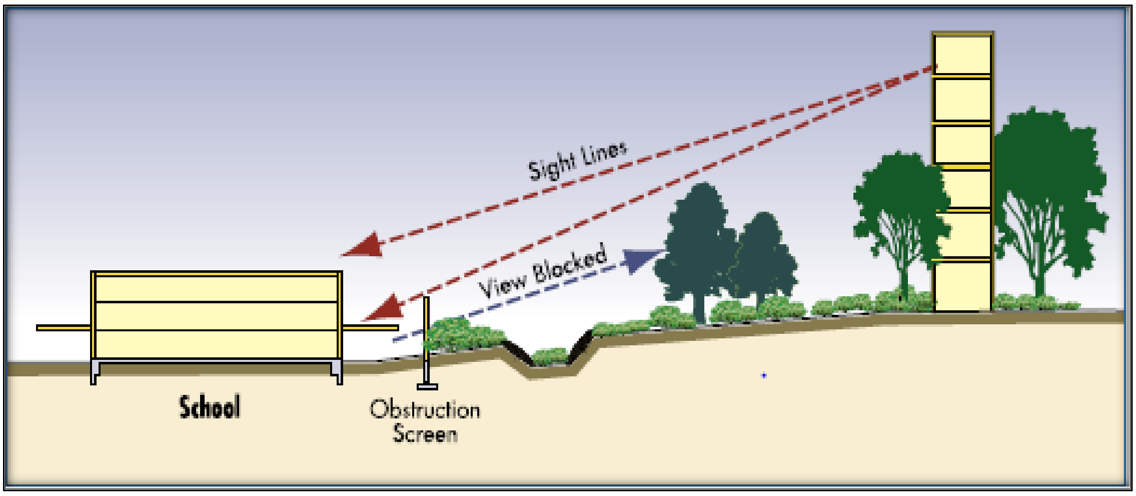


Figure 2.9: Interrupted sight lines
(Source: North Yorkshire Police, 2014)

2.3 Theoretical Review

This section analyses Eco-efficiency and the application of environmentally sustainable innovation, or eco-innovation for short, from the perspective of extant theories of innovation, in order to establish dominant structures of such innovations and current weaknesses, as well as fruitful ways forward.

2.3.1 Theories that link Eco efficiency and sustainability of building: eco efficiency in the context of sustainability

The theoretical background of Eco-efficiency comes from ecological economics (Chen, 2015). Eco-efficiency therefore seeks to combine economic efficiency and material efficiency these tools assess environmental impacts of buildings during their life cycle, each from a different perspective, and thus help users to gain familiarity with assessment procedures. Certain tools have been proposed by some scholars to serve as a guiding measure to promote and input eco efficiency in buildings and other economic processes. Certain tools exist that are used as sustainability assessment tool such as leadership in energy and environmental design (LEED), building research establishment environmental assessment method (BREEAM), building environmental assessment method (BEAM) Plus, sustainable built tool (SBT), and BEPAC (Milan *et al.*, 2015).

2.3.1.1 Sustainability assessment tools

LEED and BREEAM are established by non-profit third party. Some of these tools have a weighting system while some other do not have weighting systems. These weighting systems were used to establish the difference between green buildings and smart which is that both green buildings and smart building all belong to the set sustainable buildings Not all smart building are green buildings in the sense that green buildings are those buildings that have been rated by a rating (weighting system) while a smart building might reduce the impact on the environment but if not rated it is no considered as a green building (Greenwood, 2015).

The BREEAM method of building sustainability assessment is exceptional in the sense of result objectivity and is the most advanced therefore applied in many countries. The method is based on the elimination of inaccuracies of previously developed and applied methods and on increased usage precision. BREEAM is a leader in building sustainability assessment, with separate versions for the evaluation of different building types, so its applicability is very broad. Although BREEAM method has been globally recognized as one of the leaders in the field, this expert approach is based on assessment of qualitative indicators, so it is not objective enough, therefore the outcome depends on the qualification of the experts and other uncertain factors (Ascione, 2017).

However, it should be noted that the wording of a number of multi-criteria is not appropriate in the description of BREEAM method and may be difficult to understand, therefore it should undergo correction. According to some criterion, result can be satisfactory or sometimes even good, so Delmastro *et al.* (2012) suggests that BREEAM 2008 method cannot answer, which solution is the best in existing conditions and present situations and it is need better instrument for assessment sustainability of building behaviour.

2.3.1.2 Life cycle cost analysis (LCCA)

Life cycle cost analysis (LCCA) is an economic assessment approach that is able to predict the costs of a building from its operation, maintenance, and replacement until the end of its life-time. The effective implementation of life-cycle costing involves utilizing a thoughtful, comprehensive design along with construction practices with selected environmental considerations. Life cycle cost (LCC) is therefore an important tool for achieving cost efficiency in construction projects (Jones *et al.*, 2015).

2.3.1.3 Life cycle assessment (LCA) Design

Life cycle assessment, as defined by Lucon (2014), is a method to assess the impact on the environment of a product (including buildings) from "cradle to grave", that is from acquiring raw materials for product manufacture to its disposal at the end of its useful life. This includes components that are replaced in part or in whole over the life of a building, depending on the usage patterns, refurbishment or occupancy. A full life cycle assessment includes all resource depletion, emissions and impacts of pollutants released to air, water and soil during creation, operation and disposal. Consequently, a comprehensive database of resource and emissions data for a wide range of processes is required for such assessment.

The ability to assess environmental impact automatically from 3-dimension computer aided drawing (3D CAD) enables building design professionals to make timely and informed decisions. These impacts are long term since buildings are constructed with design lifetimes of many decades and so the minimisation of environmental impacts at the design stage is an optimal approach. The principal objective is to develop a building assessment tool (LCA Design) that includes databases and decision-support tools accepted by government and industry as the preferred environmental performance appraisal tool for commercial buildings. Specifically, the objectives are to:

i. Create life cycle assessment databases required for specific manufactured building products (CO2 emissions; air toxics emissions)

ii. Develop a product selection decision-support system interface software for environmental and cost assessment of commercial building designs.

The resultant software tool enables industry to optimise decisions on the environmental impact of buildings by providing a uniform level of information and to access environmental and cost information for different product combinations and designs. It will meet a growing need from designers and regulators for real-time performance appraisal of designs (Bossink, 2004). The indicators are also used to monitor improvement trends in performance as changes are made to the intended product. The impact categories express the environment impacts as quantities, so that processes and products can easily be compared. What is common is a demand for vast detail about resource consumption and emission generation at every process in product manufacture (Lucon, 2014).

2.4 Empirical Review

In this section, empirical evidence from past literature linking Eco efficiency of buildings is reviewed as it pertains to this study. In the preceding paragraphs, the various aspects that previous studies relating to eco efficiency.

2.4.1 How can Eco efficiency indicators be measured

The indicators of eco efficiency, which have been identified and broadly categories into three aspects namely resources conservation, cost and human consideration can be measured using the following methods. The concept, based on definition above, is often expressed by a rather simple formula:

$$\textit{Eco-efficiency} = \frac{\textit{Eco-efficiency Economic value}}{\textit{Environmental impact}}$$

Where; Economic value concerns products or services, Quantity of goods or services produced or provided to customers, while and Environmental impacts may take into account all relevant influences such as energy consumption, material consumption, water consumption, GHG emissions and ozone depleting emissions (Marco and Hermes, 2014).

The formula is easy, to understand, but its input values are still subject of research. There are various recommendations for the exact meaning of these indicators and how they should be quantified. In general, eco-efficiency means producing more with less or more value with less impact.

The WBCSD has identified seven success factors for eco-efficiency (WBCSD 2009):

a. Reduce the material intensity of goods and services
b. Reduce the energy intensity of goods and services
c. Reduce toxic dispersion
d. Enhance material recyclability
e. Maximize sustainable use of renewable resources
f. Extend material durability (and product service-life)
g. Increase the service intensity of goods and services.

2.5 Summary of Literature

University senate buildings can be said to be the power house of university administration. Eco-efficiency came to the limelight in 1992 from its sustenance by WBCSD, after it was firstly proposed in the 1970s by Strun and Schaltegger. Its benefits include conservation of natural resources, reduced cost, Sustainability of buildings and protection of the environment. Eco-efficiency is the efficiency with which natural ecological resources are used to meet human needs while avoiding wastage. Eco-efficiency, eco-innovation and sustainability are directly related as eco-efficiency involves an integrated approach which takes into consideration the aspects of sustainability; the environment's concerns, social concern (human's needs) and economic concern (technology in the form of innovation).

The indicators of eco-efficiency are resource conservation cost efficiency and design for human adaptation. Eco-efficiency is said to be achieved if these three factors are in place and balanced. The basic resource that calls for conservation in recent times are energy, materials, water and land. In ensuring cost efficiency, the initial cost and cost in use have to be considered and measures applied to conserve them from the early stge.

Likewise the comfort and safety of building users is very paramount. Hence, necessary measures should be taken at early stage of the design to ensure eco-efficiency of buildings. These indicators can be measured by comparing the economic value of a resource or product with the impact of such resource or product on the environment.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the research method used to fulfil the objectives of this thesis, the method of data collection, the instruments used, the sampling methods and techniques, population of study and the variables of the study.

3.2 Research Method

For the purpose of this research, descriptive survey method was used for data collection. A Descriptive survey method attempts to systematically describe relevant data relating to the state of a situation or problem, and give deductions that are justifiable from the discovered facts. The analysis of this research involved the use of both qualitative and quantitative tools for data collection, analysis and presentation.

3.3 Instrument of Data Collection

Relevant data for the purpose of this study was sourced using primary and secondary data collection methods, and they include the following;

3.3.1 Primary data

Primary data were obtained directly by the author through fieldwork from purposive sampling of senate buildings of universities in north central region of Nigeria (as shown in Table 3.1) by case studies, administration of questionnaires, and direct personal observations.

Table 3.1: Universities located in the north central region of Nigeria

S/no	Name of University	Category/Funding			State
		Federal	Private	State	
1.	Benue State University			✓	Benue
2.	University of Agriculture	✓			Benue
3.	University of Mkar, Gboko		✓		Benue
4.	African University of Science and Technology		✓		FCT
5.	Baze University		✓		FCT
6.	Nile University of Nigeria		✓		FCT
7.	University of Abuja	✓			FCT
8.	Veritas University		✓		FCT
9.	Federal University, Lokoja	✓			Kogi
10.	Kogi State University, Ayingba			✓	Kogi
11.	Salem University, Lokoja		✓		Kogi
12.	Al-Hikmah University, Ilorin		✓		Kwara
13.	Crown hill University, Ilorin		✓		Kwara
14.	Kwara State University			✓	Kwara
15.	Landmark University, Omu-Aran		✓		Kwara
16.	Summit University, Offa		✓		Kwara
17.	University of Ilorin	✓			Kwara
18.	Bingham University,		✓		Nasarawa
19.	Federal University Lafia	✓			Nasarawa
20.	Nasarawa State University, Keffi			✓	Nasarawa
21.	Federal University of Technology Minna	✓			Niger
22.	Ibrahim Babangida University, Lapai			✓	Niger
23.	University of Jos	✓			Plateau

(Source: Author, 2019)

3.3.1.1 Case study

The contextual investigation was done on existing senate structures, pictures of the structures were taken and rough drafts were made to accomplish a practical insight of the study. The primary goals of doing contextual investigations was to have a vivid comprehension of what the outline is about by gaining from existing buildings and furthermore to make them better. The targets are to distinguish the current issue and figuring out how to take care of the issue.

3.3.1.2 Questionnaires

The questionnaires administered in the course of the research were to the key built environmental professionals (BEPs) on their opinion on the design and delivery eco-efficient office buildings. The importance of sustainability and application of eco-efficient measures in office buildings by the BEPs were analysed from the questionnaires administered.

3.3.1.3 Direct Personal observation

The observations made in the course of the research work were from building envelope and design techniques applied to achieve eco-friendliness, energy efficiency and sustainability within the building.

3.3.2 Secondary data

Re-evaluation of relevant literature offered the grounds for full theoretical background of the research. Information found out were analysed and presented the bases for the factors for observation, planning and design criterion for eco-efficient and sustainable institutional senate buildings. The data assembled will be utilized to determine proposal for eco-efficiency in institutional office structures.

3.4 Data Collection and Sources

Throughout the period of information accumulation for the thesis work, different methods were utilized in order to gather relevant data with respect to the proposed task which are:-

i. Qualitative data

ii. Quantitative data

3.4.1 Quantitative method

This involved the collection of data with questionnaires, observation schedules and energy audits. The results obtained from this method were analysed, compared, and summarized as appropriate in answering the research questions. Hence, the quantitative method attempted to find out the energy use pattern in the university senate buildings, study the importance of eco-efficiency as a tool in achieving sustainability in university office buildings from the BEPs, and discover eco-efficient measures and innovations that can be incorporated to university senate buildings for long-term sustainability.

3.4.2 Qualitative method

The qualitative method investigated the energy use pattern in senate buildings, with the use of interviews of the building users. The findings described and explained the sequence of energy demand and consumption in the buildings and possible points of achieving low energy use and improving the building sustainability.

3.5 Population of the Study

According to Da-Rocha and Sattler (2009), the root group from which a sample is to be derived from which is the whole mass of observation is termed the population the study. The Federal Universities in the North Central region of Nigeria were chosen as the study population. The North Central in Nigeria is made up of Seven States which are: Kogi, Kwara, Nasarawa, Plateau, Niger, Benue and the Federal Capital Territory, and each has a Federal University which are: University of Jos, University of Ilorin, Federal University of Technology Minna, Federal University Lafia, Federal University Lokoja, University of Agriculture Makurdi, and University of Abuja, FCT.

3.6 Sampling Technique and Sample Size

Da-Rocha and Sattler (2009), suggested that a sample is a chosen group of some elements derived from the entirety of the population. The study engaged the employment of purposive sampling based on the ease of the researcher. Purposive sampling method involves the delibrate choice of stated units of the entire population to get a sample which is a representative of the whole population. Four samples were obtained from the study area within the North Central part of Nigeria as shown in table 3.2.

Table 3.2: List of selected sample for the Study

S/No	SAMPLE	LOCATION
1	Federal University Lafia	Lafia, Nasarawa state
2	Federal University Lokoja	Lokoja, Kogi state
3	Federal University Of Technology Minna	Minna, Niger State
4	University Of Abuja	Federal Capital terittory

(Source: Authors field work, 2019)

3.7 Variables for the Study

Variables are parameters that scholars investigate. For the purpose of this research, the variables to be considered are design dependent variables which will point out which of the elements of sustainable design had been applied in the cases and their effect in energy reduction. They are;

i. The building envelop and orientation

ii. Daylight in the building

iii. Natural ventilation

iv. Site and external spaces

v. construction materials

vi. Building shape and form

vii. Construction materials

viii. vegetation

ix. Existing energy source

3.8 Method of Data Analysis and Presentation

Observation was completed by taking photographs and taking physical estimation of the current eco-efficient measures where arrangement was made in the research region and furthermore demonstrating existing condition that put these structures in a sustainable state. Information gathered were analysed utilizing a basic descriptive statistical system on statistical analysis application SPSS and Microsoft excel, through tabular presentations, outline designs. Maps, charts, figures and photographs utilized as plates against models set up from literature reviewed, text books, e-books, journals, interviews and significant publications on the web. This consequently offered legitimization to proposals to outline considerations to eco-efficient measures and innovations for senate structures or institutional facilities.

The research methodology on Table 3.3 describes the flow of the research process based on the objectives from one to four from the point of identification to the point through the research questions, the identification of the appropriate research instruments that could be relevant for gathering data from the research samples from the study area. The data obtained was then analysed and presented using the measures found most relevant for each of the objectives.

Table 3.3: Research Methodology Table

	Objective 1	Objective 2	Objective 3	Objective 4
Objectives	Determine the energy use pattern in senate buildings of universities in Nigeria	Identify eco-efficient measures and innovations that can be adopted to achieve sustainability in university senate buildings	assess existing eco-measures employed in university senate buildings in Nigeria	Propose a design that integrate eco-efficient measures for sustainability of university senate buildings in Nigeria.
Research questions	How can energy use in university senate building be reduced to make them energy efficient building?	What eco-efficient measures and innovations can be integrated in the design and construction of university senate building for long term sustainability?		What architectural design proposal can be employed that integrates eco-efficient measures and innovations for long term sustainability of university senate buildings
Research instruments	Energy audit	Questionnaire	Observation schedule	Design
Sample size	5	78	5	1
Data analysis	Tables and charts	tables and charts	Figures and charts	Figures and Charts

(Source: Author fieldwork, 2019)

3.9 Summary/ Deductions

For sufficient data to be gathered for the intended design, descriptive survey method is the method which would help the researcher in collecting adequate data for the proposed design. To make predictions, conclusions and commendations, descriptive survey will be the requirement to discovering responses to problems relating to this type of research.

CHAPTER FOUR

4.0 FINDINGS AND DISCUSSION

The data obtained from the field survey from existing senate buildings were analysed using various statistical analysis tools. A total of five senate buildings were purposively selected to assess how eco-efficient measures were incorporated in each structure, and what innovations are present to enhance eco-efficiency and environmental sustainability of the universities. The results were analysed based on the following project objectives;

i. To determine energy use of university senate buildings in Nigeria (energy audit).
ii. To identify eco efficient measures and innovations that can be adopted to achieve sustainability in university senate buildings (literature, questionnaire).
iii. To assess existing eco measures employed in university senate buildings in Nigeria (case studies).
iv. To propose an architectural design that integrates eco efficient measures and innovations for sustainability of university senate buildings in Nigeria (design).

4.1 Energy use of University Senate Buildings in Nigeria

Energy audit was carried out in the selected university senate buildings. Information on the consumption rate of energy was gotten from lighting points and electricity bills on a monthly basis even though only less than 20% had a separate metering system for the buildings. Most of the senate buildings were metered with bulk metering hence, causing a hindrance on getting exact figures on the quantity of electricity consumed monthly by the individual building.

The Energy Use Pattern due to the use of air conditioners, laptops, computer systems, photocopying machines, lighting bulbs and water heaters, in all of the offices added to those used in other spaces in the hotel including the water pumping machines can cause a high level of energy consumption for lighting, thermal comfort and hydrological purposes.

The energy audit was carried out by counting the number of lighting points, electric units, and electrical appliances used within each office space on each floor as well as the average working time per day for each of these offices. From the data gotten from the observation schedule used on the 5 different university senate building, the average number of offices is 53.60 and an average occupancy rate of 61.50% per day within the working hours.

Analysis from the questionnaires gave an average working time of 8hrs as most of the universities work from the period of 8am-4pm, 9am-4pm, 8am-5pm and 9am-4pm. It was assumed that there is electricity supply available in 24hours for the periods of occupancy, hence, the estimated energy demand for lighting and space cooling was calculated, bearing in mind that some of the offices remain active outside the stipulated period of work, while some security lighting were active in the night time and some cases, the security lights were left on for about 24hours. More so, With an Air conditioner taking about 1200watts, Light Emitting Diodes Compact Fluorescent Lamps (LED CFL) lambs needing about 15watts for 800lumens (1000Bulbs.com, 2018). Therefore, when one (1) office consumes, four (4) LED CFL lambs and one (1) air conditioner. The energy demand for that room would be the sum of four (4) 15watts CFL lamps and a 1200watts air conditioner would be 1260Watts (1.26kWatts). Then, energy demand for an office per day (for 8hours) would be about 10.08kWh per day approximately.

Table 4.1: Energy use and demand by design for lighting, electrical appliances and space cooling for offices

School	Energy consumption (monthly mean)	Estimated daily Energy consumption	Offices/ Spaces	Energy design demand per day in full capacity	Occupancy Rate (%)	Working hours	Energy design demand per day at occupancy rate
Federal University Lafia	2211.42	72.65	76	2388.96	30	7	716.69
Federal University Lokija	1983.13	65.15	23	1905.12	50	8	952.56
Federal University of Technology Minna	5330.50	175.13	69	1814.4	20	7	362.88
University of Abuja	3859.57	126.80	48	786.24	50	8	393.12
University of Jos	1589.00	52.21	47	635.04	33	8	209.56
Average	**2647.19**	**86.97**	**43.33**	**1310.40**	**40.50**	**15.62**	**482.22**

(Source: Author's fieldwork, 2019)

The energy audit proved that the energy consumption is far from the estimated energy demand by design in a full day, hence, the current electric energy consumption rate cannot be said to be reflective of the true energy use of the buildings as the estimated energy demand for the hotels per day on Table 4.1. The data indicates the fact that the electricity energy supply is about 82% insufficient for the buildings per day in reading their energy use and the energy cost on alternative sources like the diesel and petrol generators to meet the outstanding 395.25kWh per day on average for 24hours would require a high operating cost. The estimated energy demand and the occupancy rate and building capacity indicates a steady drop in estimated energy demand by design with the number of offices available.

4.2 Eco-efficient Measures and Innovations that can be adopted to achieve Sustainability in University Senate Buildings

A total of 130 questionnaires were distributed to the built environment professionals to assess their opinions on strategies, measures and innovations that can be employed in university office buildings to promote eco-efficiency and long term sustainability. 88 of these questionnaires were retrieved while 78 was analysed for the purpose of this research. Also, suggestions from scholars pertaining to eco-efficiency of buildings was critically considered to understand and highlight some of these strategies that can be incorporated in the design of a Nigerian university senate building, as well as how best these methods can be applied to achieve eco-efficiency of such buildings.

As discussed earlier in the chapter 2 of this thesis, the key components of eco-efficiency are resource conservation, cost efficiency and designing for human adaptation (comfort and safety).

4.2.1 Conservation of resources in the design, construction and operation of university senate buildings

Resource conservation, as discussed in subsection 2.2.5.1 in chapter 2 of this thesis is one important aspect of eco-efficiency as materials, energy, land and water needs to be conserved. Findings from the energy audit showed that energy consumption in university senate buildings are on the high end and there is need to conserve this resource. Likewise, water is not given adequate attention as to preventing wastage and increasing optimum use.

To conserve energy, in Nigeria, especially the north central region, one important measure is to use passive design method that is incorporating some measures in the initial design stage to reduce energy demand in buildings as indicated in Table 4.2.

Table 4.2: Passive cooling design methods that can be applied in university senate buildings

	Passive Design Method	Feature
1.	Building orientation	Orienting the longer side of the buildings to north-south Direction while the shorter side to east-west direction to minimise solar heat gain and long sun glare.
2.	Courtyards	Provision of an open space, usually at the centre of buildings to serve as medium for exchange Generated hot air with the fresh cool air.
3.	Water bodies	Provision of water bodies such as fountains and pools around the building to increase passive evaporative cooling
4.	Passive spaces	Provision of spaces such as skylights to enhance natural lighting as well as air flow.
5.	Wall openings	Various sizes of windows and air vents based on required amount of air for stack effect Ventilation, natural lighting and evaporative cooling.
6.	Shading devices	Provision of vertical or horizontal shading devices on windows to prevent sun glare as well as minimise heat gain.
	Roof garden	Plantings provided at the roof of the building to absorb solar radiation rays
	landscaping	By increasing the amount of vegetation around the building to foster cooling

(Source: Author's fieldwork, 2019)

Materials with low embodied energy such as bricks can be used so as to reduce energy demand on cooling. These materials can be conserved by ensuring its durability as this would also lower the time and resources needed to maintain such materials.

Land on the other hand can be better conserved around these senate buildings by providing adequate landscape and drainage to control erosion, also, a proper refuse disposal system should be introduced around such buildings to control pollution.

4.2.2 Enhancing cost efficiency in the design, construction and operation of university senate buildings

Cost in buildings can be optimised by;

i. Use of durable and less expensive materials. Locally sourced materials can also be used

ii. Provide measures and adequate space for cleaning, maintenance, service and repair of major elements of the HVAC, plumbing fixtures, and electrical wirings and to ensure that the access points to these materials are accessible.

iii. Use of materials that require minimum maintenance. This means that the materials being employed should have long term sustainability

iv. Provide measures to prevent materials from damage by natural forces and elements such as sun, temperature, wind and rain.

4.2.3 Considerations for human adaptation in the design, construction and operation of university senate buildings

Human comfort is the most important aspect of a buildings function, as when this is not fulfilled, the building can be said to be non-functional and hence failed in its purpose. For a university senate building, being an office complex, it is important to provide adequate comfort to the uses as this will help promote efficiency in work as well as increase productivity. Some important aspects to consider in enhancing safety within the building is to include fire safety security measures into the design of the building.

4.3 Existing Eco measures Employed in existing University Senate Buildings in Nigeria

A case study was carried out with the aid of an observation schedule on the 5 selected university senate buildings. This was carried out with the aid of observation schedules to check for eco measures and also innovations provided in the building to enhance energy efficiency in the buildings.

From the analysis of results, it was discovered that the buildings employed largely the use of passive design techniques to enhance energy efficiency in the buildings. The predominantly used in the buildings was found to be the use of courtyard spaces to enhance ventilation within the offices.

Plate I: Use of well landscaped courtyard in FUT Minna Senate Building (Source: Author's fieldwork, 2019)

Also, there exists overhangs and vegetation used to provide shading. Shading provided by the overhangs and vegetation help in passive cooling and reducing solar heat gain that penetrates the building via solar radiation.

Plate II: Overhangs and vegetation in FUT Minna Senate Building
(Source: Author's fieldwork, 2019)

The presence of reveals or recesses before a window was found in use in 25% of the buildings as shown in Figure 4.6. They affect the energy use in the hotel for lighting (at daytime) and cooling as they impede a percentage of the UV Rays and solar gains that could get through into the building.

Plate III: Vertical shading device and large window area in FU Lafia Senate Building
(Source: Author's fieldwork, 2019)

Plate IV: Vertical shading device and large window area in FU Lafia Senate Building (Source: Author's fieldwork, 2019)

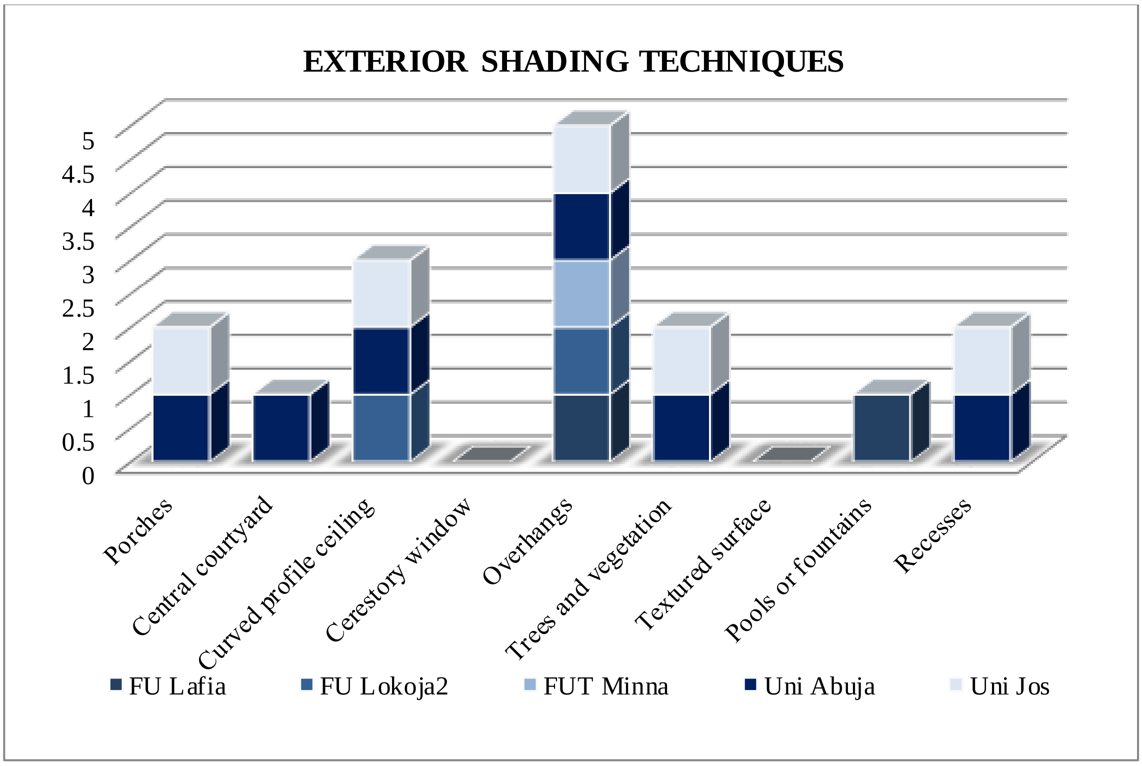


Figure 4.1: Windows to walls area
(Source: Author fieldwork, 2019)

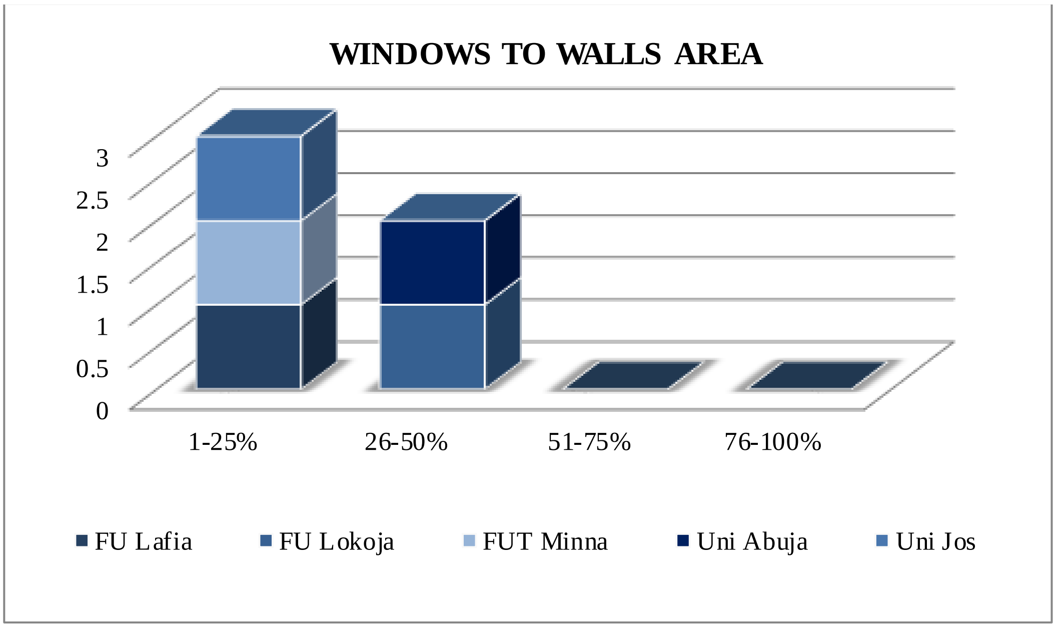


Figure 4.2: Windows to walls area
(Source: Author fieldwork, 2019)

Plate V: Use large window area in University of Jos
(Source: Author's fieldwork, 2019)

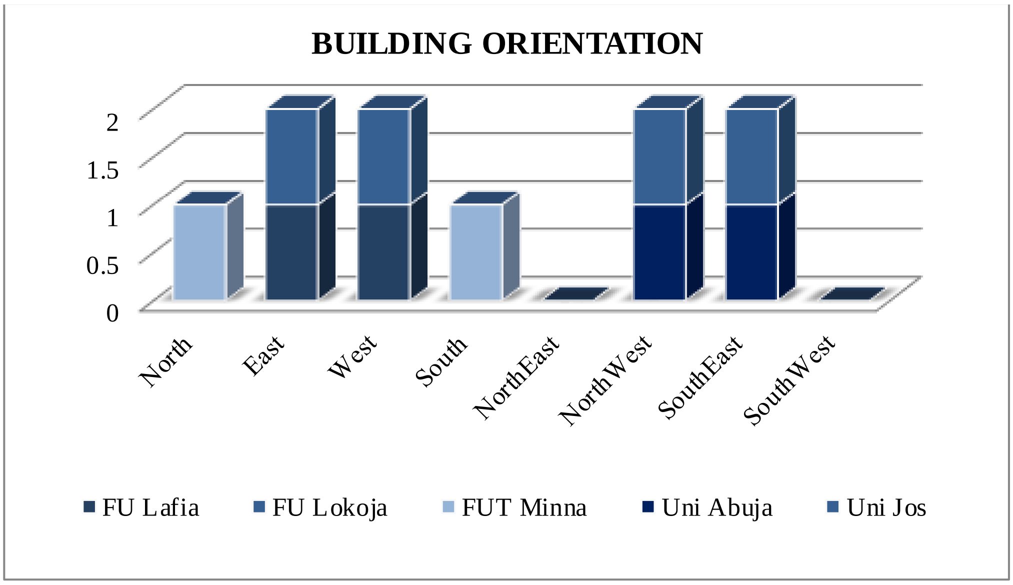


Figure 4.3: Windows to walls area
(Source: Author fieldwork, 2019)

Table 4.3: Passive cooling design methods applied in the university senate buildings

	PASSIVE DESIGN features	FU Lafia	FU Lokoja	FUT Minna	Uni Abuja	Uni Jos
1.	Courtyards	Present	Present	Present	Present	Present
2.	Water bodies	X	X	X	X	x
3.	Passive spaces					
4.	Roof garden					
5.	Landscaping	Present	Present	Present	Present	Present

(Source: Author fieldwork, 2019)

Plate VI: use of courtyard in University of Jos
(Source: Author's fieldwork, 2019)

4.4 Proposed Architectural design that integrates Eco efficient measures and innovations for sustainability of University Senate Buildings in Nigeria

The design of the proposed university senate building is to be located in the federal university permanent site, Felele, Lokoja, integrating eco-efficient measures and innovations to increase the energy conservation within the building and promote long term sustainability of the building. The site is located in Lokoja, the capital city of Kogi state which lies within the north central geo-political region of Nigeria.

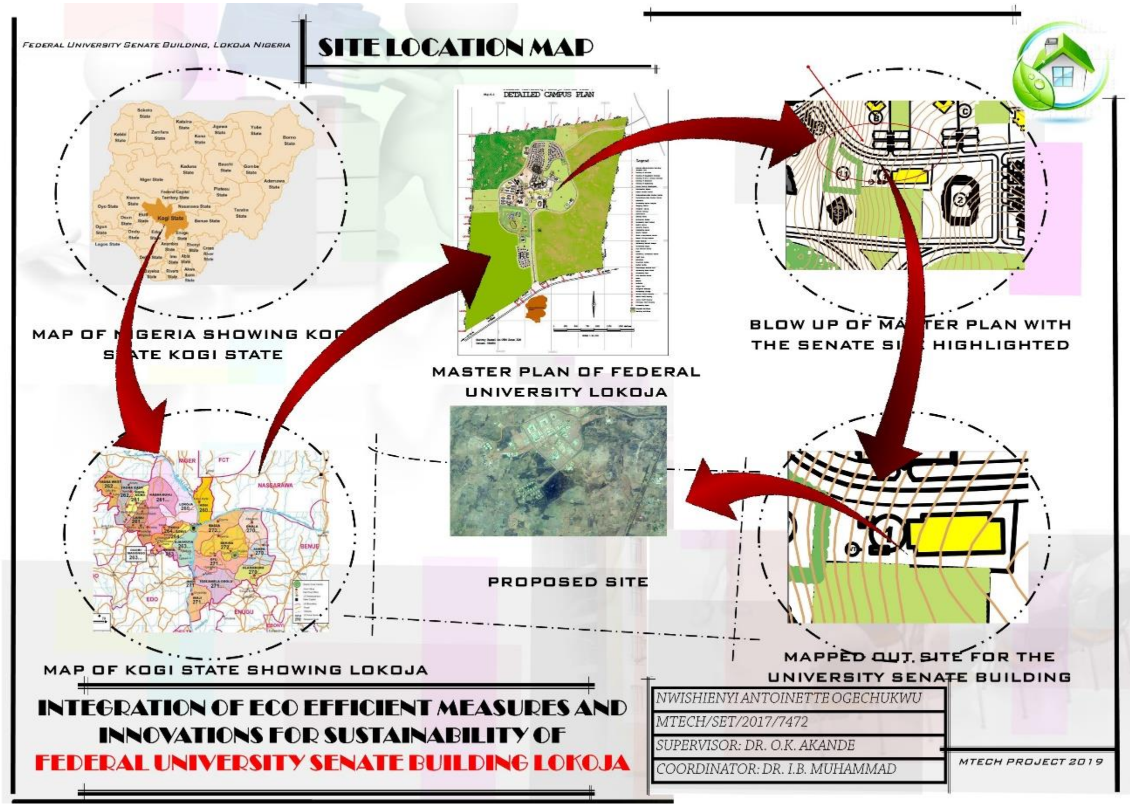


Figure 4.4: The site location map of the proposed senate building (Source: Author fieldwork, 2019)

The site, which is located on the permanent site of the university, Felele, is characterized by few existing features. There exist a good access form the Lokoja express road into the site. The master plan of the university has mapped out various locations for different buildings as well as the road connections around the university premises.

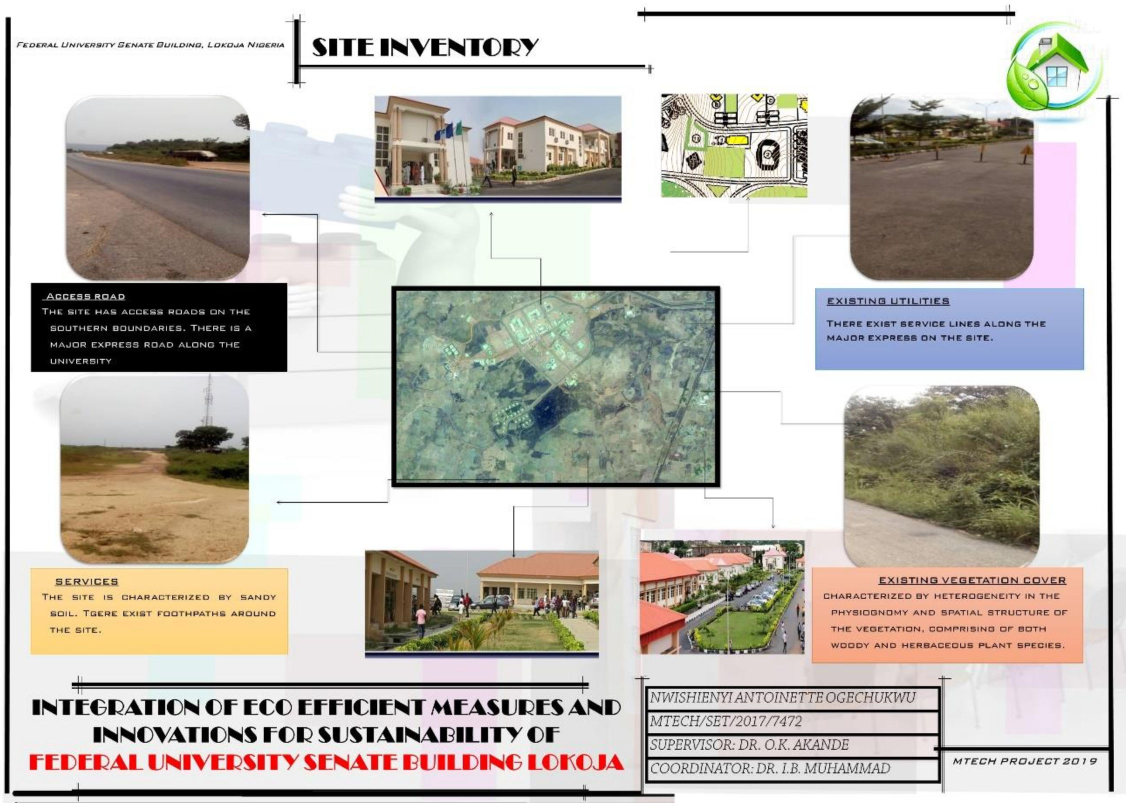


Figure 4.5: The site inventory of the proposed senate Building for Federal University Lokoja
(Source: Author fieldwork, 2019)

4.4.1 Measures for resource conservation

4.4.1.1 Energy conservation

Use of passive techniques to conserve energy in the building was majorly employed as it is one of the cheapest techniques. This involves integrating passive measures into the design from the inception stage as proposed by Chwieduk (2017). To achieve this, the following passive measures were critically included in the design;

1. Use of low embodied energy construction materials

Materials proposed for use in the construction of the building are bricks, as they are materials with low embodied energy.

2. Passive energy saving techniques

The senate building was planned and designed with the incorporation of some passive energy saving techniques such as provision of adequate wall openings such as windows as an inlet of cool air and vent as the outlet of the warm air thereby maintaining the office cool through principle of stack effect. An The atrium is provided to serve as the collector of the warm air from the offices and discharging it through the vent as that air is light since it is warm, it will move up and escape to the atmosphere through the vents in the atrium.

Figure 4.6: Atrium, windows and vents in the proposed design
(Source: Author, 2019)

Courtyard system is provided in the design, serving as medium for bringing in fresh air to the offices and releasing the warm air to the atmosphere. It serve as a medium to locate the fountain as the water can serve as a means for evaporative cooling within the building.

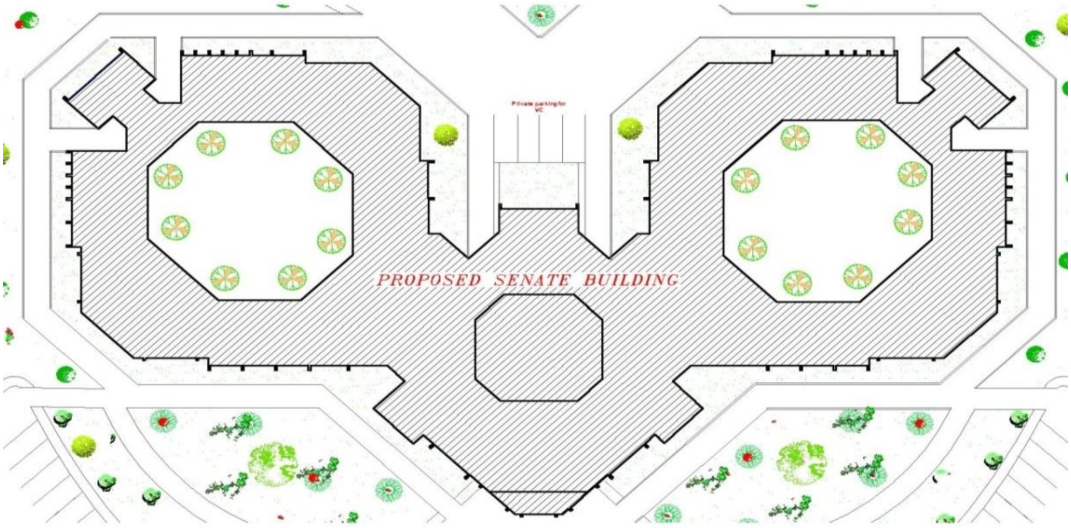


Figure 4.7: The courtyard spaces with fountains
(Source: Author, 2019)

3. Building Orientation

The orientation of the building is another variable considered with the longer side facing north-south direction to reduce the heat gain through solar radiation. Most of the openings to the offices are located on these sides to reduce the cost of shading the building from the solar radiation intensity. The shorter sides face east-west direction with enough shading devices to prevent the effect of solar radiation intensity.

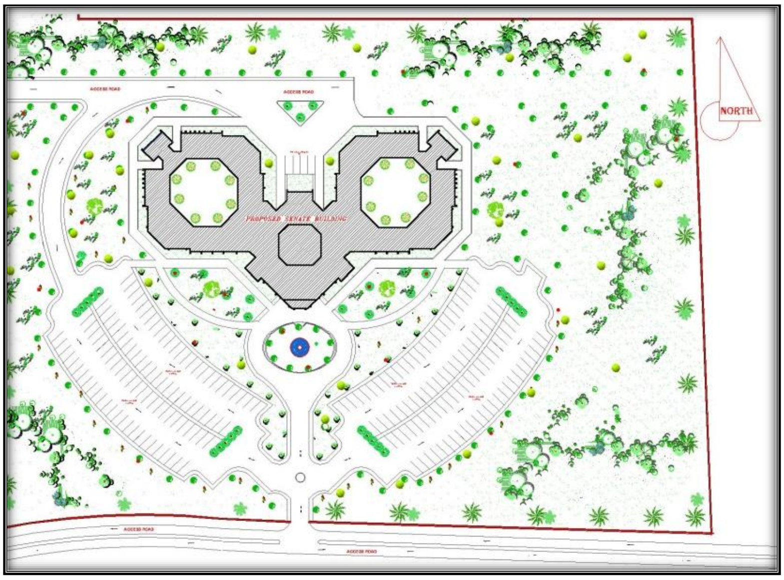


Figure 4.8: The orientation of the building on the site
(Source: Author, 2019)

4. Shading devices

The design employed the use of both the horizontal and vertical shading device. The vertical shading device is used on the longer sides to shade the sides from the solar radiation intensity. While the combination of the two shading devices is used on the shorter sides to create barrier and also to shade the courtyard from direct solar radiation intensity which leads to solar heat gain.

Also, aluminium shading panels are used to shad the opening around the office areas from solar radiation, dust and heavy wind while allowing adequate passage for natural air. Trees are also planted to also shade the building from direct solar heating.

Plate VII: The use of vertical and horizontal shading devices, as well as an aluminium panel shading from sun and dust
(Source: Author, 2019)

5. Smart Innovative Technologies

The use of some cert technologies is also proposed for the design of the building as this would help conserve energy and materials, as well as provide eco-efficiency within the building. Some of the innovative technologies include use of light sensors in powering on and off the lights and other electrical applications when not in use and in the absence of humans within such spaces.

6. Roof garden

The roof garden is incorporated in the design to serve as an absorbent of the radiant heat from the solar on the roof of the building. The roofing sheets refract some amount of heat to the interior of the building and reflect some to the surrounding environment thereby increasing the temperature of the environment. The plants absorb the rays as part of their photosynthesis process and release fresh air to the surrounding environment.

Plate VIII: The presence of green roof for the proposed design
(Source: Author, 2019)

Some active energy control measures are also included in the building such as smart sensor buildings for lighting, smart water taps, employing an energy manager in the building, users sensitization of energy conservative practices.

4.4.1.2 Material conservation

To ensure material conservation within the buildings, durable materials are proposed for the construction of the building to enhance long-term sustainability and ensure the building lasts and materials are not wasted or changed very frequently.

4.4.1.3 Water conservation

To promote water conservation, it is important to create manual for the technicians to reduce the water pressure within the building as this will help control water wastage. Also, the plantings to be provided should be of low demand in terms of water such as the use of more xerophytes for landscape plant. Rain water collection and treatment is another measure proposed in this design as it can be used in toilets for flushing and other applicable areas.

4.4.1.4 Land conservation

The site land is being conserved as waste is to be disposed of the site and treated appropriately to control land pollution. Also, the land is maximised in terms of space to create space for future expansion and development around the site. Landscape lawns, trees and shrubs are also encouraged on the site to control erosion and other unfavourable weather effects on land and this also will increase the eco-efficiency of the environment around the senate building.

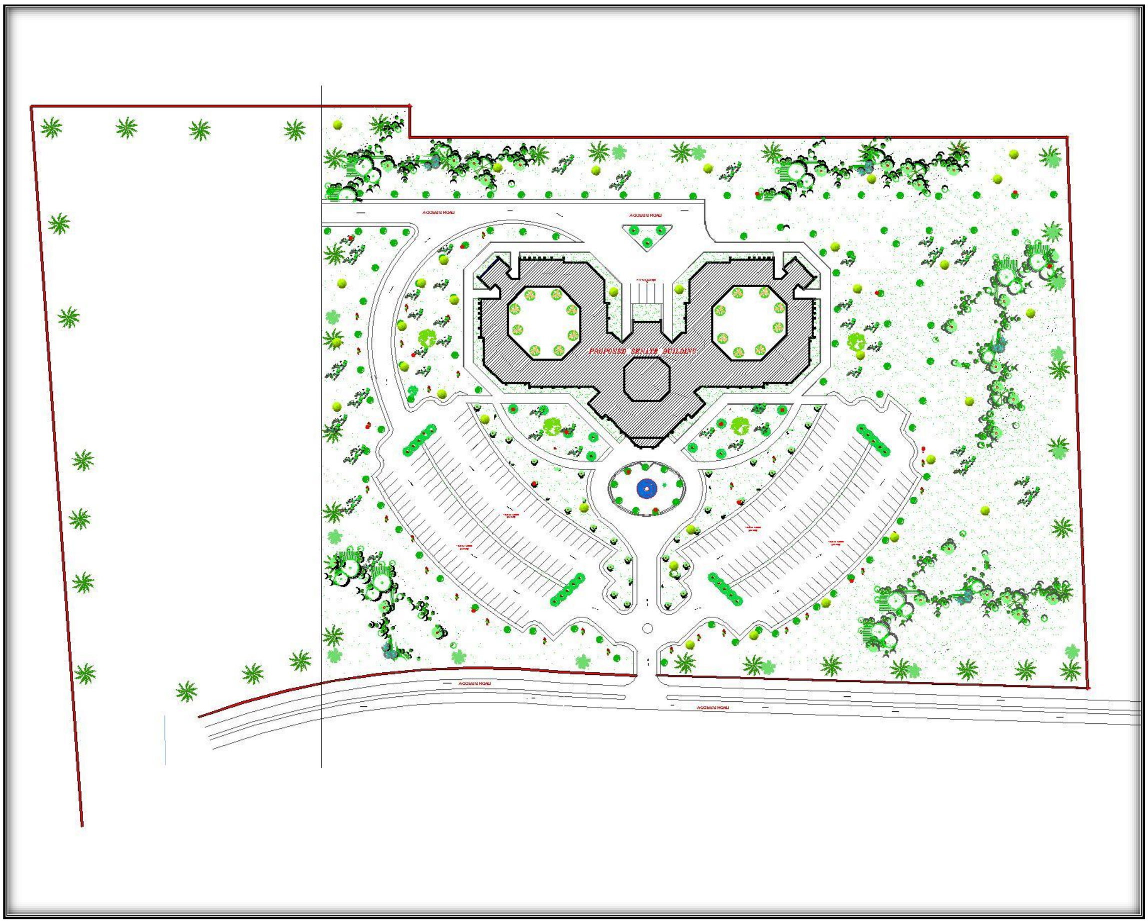


Figure 4.9: The conservative use of land on the proposed site
(Source: Author, 2019)

4.4.2 Measures for cost efficiency

Locally available materials are proposed to be used in the construction of the building to reduce initial and running cost.

Measures for adequate cleaning and maintenance of facilities and equipment such as the HVAC units, electrical connections and plumbing fixtures in the buildings. Hence, troughs are provided for the AC units to aid easy access to servicing.

Materials that require minimum maintenance are also proposed such as paintings to reduce cost of frequent maintenance of the buildings.

Plate IX: Use of conservative durable materials
(Source: Author, 2019)

4.4.3 Measures to enhancing human comfort and adaptability

Most of the measures to improve thermal and human comfort in the buildings have been discussed under subsection 4.3.1 above under energy conservation. These measures include for Thermal comfort, natural lighting, and Ventilation to increase efficiency and productivity.

Also, some important measures for human safety was considered such as Fire prevention measures and Security measures. For these, both active and passive measures were used such as creating fire/emergency exit (doors and escape stairs), installation of fire sprinklers.

Plate X: Maximum window to wall ratio for natural lighting and ventilation, with windows shaded to reduce solar radiation and glare
(Source: Author, 2019)

4.4 Summary of Findings

In summary, the findings made in the course of the research showed that there is an increase in the consumption of energy in senate buildings due to the use of air conditioners, television sets, laptops and computer sets, photocopy machines, lighting bulbs, water pumping machines and water heaters for lighting, thermal comfort and hydrological purposes, when on a critical review, these demands can be minimised. Also, the practice of bulk metering in most universities makes it difficult to identify checkmate energy consumption within individual buildings. The Built Environment Professionals (BEPs) generally believed the use of passive techniques through design is relevant for the realisation of resource conservation of university office buildings. Majority of the BEPs suggested the use of openings (this includes the consideration of their sizes, location, quality, types and quantity) to aid in enhancing day-lighting in the senate buildings as well as enhance natural ventilation and proper landscaping for passive cooling to be achieved in such buildings.

Therefore, from the design of a senate building for federal university Lokoja permanent site, made with the integration of some eco-efficient design principles and innovations discussed in the above chapters and subsections, as well as some resource conservation techniques, These measures are capable of increasing the conservation of resources (energy, materials, water and land), cost efficiency of the building as well as human safety and comfort within the building.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, eco-efficiency and energy conservation in buildings in recent time is gaining momentum owing to the adverse of climate change amongst other factors. However, buildings of the future or current time strive to be eco-efficient compliant as they have been found to be cost-effective and highly innovative. Thus, this thesis makes a case for research into eco-efficiency of university senate buildings and posits that the investigation of energy use and the promotion of eco-efficiency innovation are important elements to enhance sustainability of university senate buildings in Nigeria. The sensible use of non-renewable resources would complete this responsible approach.

5.2 Recommendation

Based on the findings from literatures, this study makes the following recommendations:

Eco-efficiency and energy conservation requires attention and action from built environment professionals and users of public buildings such as university administrative senate buildings as such buildings needs to be designed to demand little energy and to achieve local generation of energy. Therefore, the professionals engaged in the design of these buildings should ensure that these buildings satisfy the conditions of having minimal or low environmental impact by integrating innovative technologies in managing energy use in such buildings.

Whilst it has been recommended that traditional and modern methods of conserving energies is efficient, this study recommends a more robust approach of combining both methods viz-a-viz a balancing of the cost-benefits derivable from them. Since energy conservation is not a onetime issue as it is a continuous process; thus it is recommended that university administrative senate buildings should constantly be designed and delivered in line with growing global trends of environmental sustainability. This would not only reduce cost but also ensure demand reduction and efficiency in delivery of required energy services.

Furthermore, conflicting user's behaviour in university administrative senate buildings should be given attention to sensitize the users on the effect of global warming and the need for energy saving practices while using the buildings. Additionally, adopting new technologies such as sensors that would automatically switch on/off lights amongst others could be the new paradigm.

Lastly, this study recommends an empirical examination of Nigerian university senate buildings and the green initiatives of such universities. This would help with empirical evidences as to whether or not these universities adopt eco-efficient measures.

REFERENCES

Aditya, L., Mahlia, T. M. I., Rismanchi, B., Ng, H. M., Hasan, M. H., Metselaar, H. S. C. & Aditiya, H. B. (2017). A review on insulation materials for energy conservation in buildings. *Renewable and Sustainable Energy Reviews*, 73, 1352-1365.

Akande, O. K. (2010). Passive Design Strategies for Residential Buildings in a Hot Dry Climate in Nigeria. *WIT Transactions on Ecology and the Environment (Eco-Architecture III),* 128,61-71, doi:10.2495/ARC100061.

Akande, O. K., Fabiyi, O. & Ikenna C. M. (2015). Sustainable Approach to Developing Energy Efficient Buildings for Resilient Future of the Built Environment in Nigeria. *American Journal of Civil Engineering and Architecture*. 3, no. 4 144-152.

Akpan, N. A. (2011). *Organization Structure of Public Universities.* In Bassey S.U., & Bassey, U.U. (Eds.), Management of Higher Education in Africa. Uyo: Abaam Publishing.

Anna, P. B. (2017). Towards sustainable cities through an environmental, economic and eco-efficiency analysis of urban sanitation and drainage systems.

Arpke, A. & Strong, K. A. (2006). Comparison of life cycle cost analyses for a typical college using subsidized versus full-cost pricing of water. *Ecol. Econ*, 58, 66–78.

Ascione, F. (2017). Energy conservation and renewable technologies for buildings to face the impact of the climate change and minimize the use of cooling. *Solar Energy*, *154*, 34-100.

Ayodeji, O. O., Victory, A., Patience, T., Bolatito, A. & Abisola, O. (2018). Evaluation of Application of Eco Friendly Systems In Buildings In Nigeria, *International Journal of Civil Engineering and Technology,* 9(6), 568–576.

Baldwin, A., Poon, C., Shen, L., Austin, A. & Wong, I. (2016). Designing out Waste in High-Rise Residential Buildings: Analysis of Precasting and Prefabrication Methods and Traditional Construction. In *Proceedings of the International Conference on Asia-European Sustainable Urban Development, Chongqing, China, Centre for Sino-European Sustainable Building, 74,* 12-21..

Barthelmes, V. M., Becchio, C. & Corgnati, S. P. (2016). Occupant behaviour lifestyles in a residential nearly zero energy building: Effect on energy use and thermal comfort. *Science and Technology for the Built Environment*, *22*(7), 960-975.

Bossink, B.A.G. (2004). Managing drivers of innovation in construction network. *Journal of Construction Engineering and Management*, 130 (3).

Brown, C. (2003). *Residential Water Conservation Projects: Summary Report*; Report HUD-PDR-903; Prepared for U.S. Department of Housing and Urban Development, Office of Policy Development and Research: Washington, DC, USA.

Cao, X., Dai, X. & Liu, J. (2016). Building energy-consumption status worldwide and the state-of-the-art technologies for zero-energy buildings during the past decade. *Energy and buildings*, *128*, 198-213.

Carlucci, S., Cattarin, G., Causone, F. & Pagliano, L. (2015). Multi-objective optimization of a nearly zero-energy building based on thermal and visual discomfort minimization using a non-dominated sorting genetic algorithm (NSGA-II). *Energy and Buildings*, *104*, 378-394.

Chen, Y. J. (2015). Achieving Robustness and Eco-Efficiency in Sustainability for a Distribution Network. *International Conference on Advanced Manufacturing and Industrial Application (ICAMIA 2015).* DOI: 10.2991/icamia-15.2015.4

Chwieduk, D. A. (2017). Towards modern options of energy conservation in buildings. *Renewable Energy*, *101*, 1194-1202.

Cuce, E. (2016). Toward multi-functional PV glazing technologies in low/zero carbon buildings: Heat insulation solar glass–Latest developments and future prospects. *Renewable and Sustainable Energy Reviews*, *60*, 1286-1301.

Da-Rocha, C. G. & Sattler, M. A. (2009). A discussion on the reuse of building components in Brazil: An analysis of major social, economic and legal factors. *Resour. Conserv. Recycl. 54*, 104–112.

Delmastro, C., Martinsson, F., Dulac, J. & Corgnati, S. P. (2017). Sustainable urban heat strategies: Perspectives from integrated district energy choices and energy conservation in buildings. Case studies in Torino and Stockholm. *Energy*, *138*, 1209-1220.

De-Silva, N., Dulaimi, M.F., Ling, F.Y.Y., & Ofori, G. (2004). Improving the maintainability of buildings in Singapore. *Build. Envrion. 39*, 1243–1251.

Dixon, G. N., Deline, M. B., McComas, K., Chambliss, L., & Hoffmann, M. (2015). Using comparative feedback to influence workplace energy conservation: A case study of a university campaign. *Environment and Behaviour*, *47*(6), 667-693.

Edwards, B. (2006). Benefits of green offices in the UK: Analysis from examples built in the 1990s. *Sustain. Dev.*, *14*, 190–204.

Emmitt, S. & Yeomans, D.T. (2008). Specifying Buildings: A Design Management Perspective, 2nd ed.; Elsevier: Amsterdam, The Netherlands.

Esin, T. & Cosgun, N. A. (2007). Study conducted to reduce construction waste generation in Turkey. *Build. Environ.*, *42*, 1667–1674.

Eubanks, E. (2007). Built Environment Image Guide Sustainable Design Principles *Technology & Development*.

Feng, J. C., Yan, J., Yu, Z., Zeng, X. & Xu, W. (2018). Case study of an industrial park toward zero carbon emission. *Applied Energy*, *209*, 65-78.

Gibbs, D., & O'Neill, K. (2015). Building a green economy? Sustainability transitions in the UK building sector. *Geoforum*, *59*, 133-141.

Giordano, R., Serra, V., Demaria, E. & Duzel, A. (2017). Embodied energy versus operational energy in a nearly zero energy building case study. *Energy Procedia*, 111, 367-376.

Google Image (2019). Mother Land Nigeria. Retrieved from https://nationalonline.org/2019/01/08/10-02-2019-amphibious -house.

Greenwood, D. (2015). In search of Green political economy: steering markets, innovation, and the zero carbon homes agenda in England. *Environmental Politics*, 24(3), 423-441.

Haberl, H. (2004). Human appropriation of net primary production and species diversity in agricultural landscapes. *Agric. Ecosyst. Environ.*, 102, 213–218.

Hamdy, M., Nguyen, A. T. & Hensen, J. L. (2016). A performance comparison of multi-objective optimization algorithms for solving nearly-zero-energy-building design problems. *Energy and Buildings*, *121*, 57-71.

Hendrik, A. V. & Robin, B. (2000). Measuring eco-efficiency: a guide to reporting company performance. *World Business Council for Sustainable Development*.

Ilha, M.S.O., Oliveira, L.H. & Gonçalves, O.M. (2009). Environmental assessment of residential buildings with an emphasis on water conservation. *Build. Serv. Eng. Res. Technol.*, *30*, 15–26.

Jianxin, H., Jiangtao, D. & Wayne, P. (2011). The Assessment of Advanced Day lighting Systems in Multi-Story Office Buildings Using a Dynamic Method. *Low energy architecture*, 13, 1867- 1874.

Jones, P., Hou, S. S. & Li, X. (2015). Towards zero carbon design in offices: integrating smart facades, ventilation, and surface heating and cooling. *Renewable Energy*, *73*, 69-76.

Kim, J. & Rigdon, B. (2008). *Qualities, Use, and Examples of Sustainable Building Materials*; National Pollution Prevention Center for Higher Education: Ann Arbor, MI, USA, pp. 48109–41115.

Kibert, C. J. (2016). *Sustainable construction: green building design and delivery*. John Wiley & Sons.

Kneifel, J. (2010). Life-cycle carbon and cost analysis of energy efficiency measures in new commercial buildings. Energy Build, 42:333–40.

Kylili, A. & Fokaides, P. A. (2015). European smart cities: The role of zero energy buildings. *Sustainable Cities and Society*, *15*, 86-95.

Lee, J., Mahendra, S. & Alvarez, P.J.J. (2010). Nanomaterials in the Construction Industry: A Review of Their Applications and Environmental Health and Safety Considerations. ASCNAno 4(21010)7 p.3580-3590.

Lemprière, M. (2016). Using ecological modernisation theory to account for the evolution of the zero-carbon homes agenda in England. *Environmental Politics*, *25*(4), 690-708.

Lizana, J., Chacartegui, R., Barrios-Padura, A. & Valverde, J. M. (2017). Advances in thermal energy storage materials and their applications towards zero energy buildings: A critical review. *Applied Energy, 203*, 219-239.

Lucon, O. (2014). Buildings in Climate change: mitigation of climate change. *Intergovernmental panel on climate change.*

Marcella, R. M., Maristella, G. D., Vanessa, G., Hawllynsgton, G. F., Dimaghi, S., & Blandina L. (2014). Material eco-efficiency indicators for Brazilian buildings. *Smart and Sustainable Built Environment*. 3 No. 1, 54-71.

Marco, M. & Hermes, M. (2014). Is Eco-Efficiency Enough for Sustainability? *International Journal of Performability Engineering*, 10, No. 4, 337-34

Markarian, J. (2005). Wood-plastic composites: Current trends in materials and processing. *Plast. Addit. Compd.*, 7, 20–26.

McCormack, M.S., Treloar, G.J., Palmowski, L. & Crawford, R. H. (2007). Modelling direct and indirect water consumption associated with construction. *Build. Res. Inf.*, *35*, 156–162.

Mendler, S. F. & Odell, W. (2000). *The HOK Guidebook to Sustainable Design*; John Wiley & Sons: New York, NY, USA. 2000.

Milan, V., Heli, K. & Ruben, P. B. (2015). Integrated Approach towards Sustainable Constructions. *Journal of sustainable development.*

Mora, E. (2007) Life cycle, sustainability and the transcendent quality of building materials. *Build. Envrion. 42*, 1329–1334.

National Crime Prevention Council (2003). *Crime prevention through environmental design guidebook*. Washington, D.C: National Crime Prevention Council.

Nejat, P., Jomehzadeh, F., Taheri, M. M., Gohari, M. & Majid, M. Z. A. (2015). A global review of energy consumption, CO2 emissions and policy in the residential sector (with an overview of the top ten CO2 emitting countries). *Renewable and sustainable energy reviews*, *43*, 843-862.

North Yorkshire Police (2014). *10 Principles of Crime prevention*. Retrieved on the 6th of January, 2018 from safety and security advice centre: http:/www.northyorkshire.police.uk/tenprinciples.

Ortiz, O.; Castells, F. & Sonnemann, G. (2009). Sustainability in the construction industry: A review of recent developments based on LCA Constr. *Build. Mater.* 2009, *23*, 28–39.

Pan, W. & Ning, Y. (2015). A socio-technical framework of zero-carbon building policies. *Building Research & Information*, *43*(1), 94-110.

Pekka, H. & Tarja, H. (2005). Eco-efficiency indicators for actors and products of building sector. *World Sustainable Building Conference, Tokyo, (SB05Tokyo)* 04-049.

Peter O. A., Ezekiel, A. C. & Paul, O. O. (2012). Design of a Sustainable Building: A Conceptual Framework for Implementing Sustainability in the Building Sector *Buildings, 2*, 126-152;

Richard C. D., Qing Y., Wei F., Tao Y., Hongwei M., Yutong L., Yongcong G. & Jialiang W. (2013). Sustainable Building in China—a Green Leap Forward? *Buildings 3*, 639-658; doi: 10.3390/buildings3030639

Ruparathna, R., Hewage, K. & Sadiq, R. (2016). Improving the energy efficiency of the existing building stock: A critical review of commercial and institutional buildings. *Renewable and sustainable energy reviews*, *53*, 1032-1045.

Sameni, S. M. T., Gaterell, M., Montazami, A. & Ahmed, A. (2015). Overheating investigation in UK social housing flats built to the Passivhaus standard. *Building and Environment*, *92*, 222-235.

San-Jose, J.T.L. & Cuadrado, R. J. (2010). Industrial building design stage based on a system approach to their environmental sustainability. *Construct. Build. Mater.*, *24*, 438–447.

Santamouris, M. (2016). Innovating to zero the building sector in Europe: Minimising the energy consumption, eradication of the energy poverty and mitigating the local climate change. *Solar Energy*, *128*, 61-94.

Sarkar, A. N. (2013). Promoting Eco-innovations to Leverage Sustainable Development of Eco-industry and Green Growth *European Journal of Sustainable Development,* **2**, 1, 171-224.

Sev, A. (2009). How can the construction industry contribute to sustainable development? A conceptual framework. Sustain. Dev., 17, 161–173.

Shedid, M. A. & Elthennaway, M. E. (2015). The three dimension based on physical access control detection system. *The International Journal of Technical Research and Application*. 3, 109-116.

Tarja, H. D., Pekka H. & Kai T. (2013). Eco efficient building process. *Building and Environment*, *93*, 56-71.

Thormark, C. (2006). The effect of material choice on the total energy need and recycling potential of a building. *Build. Envrion.*, *41*, 1019–1026.

Thomas, H. (2012). Dimensions of Environmentally Sustainable Innovation: the Structure of Eco-Innovation Concepts. *Sustainable Development Sust. Dev*. 15, 148–159

Tucker, S. N., Ambrose, M. D., Johnston, D. R., Newton, P. W., Seo, S. & Jones, D. G. (2003). LCADesign: An integrated approach to automatic eco-efficiency assessment of commercial buildings. *CIB W078 conference*. 23-25

UNESCO (2013). *Water for People, Water for Life: The United Nations World Water Development Report;* United Nations Educational, Scientific & Cultural Organization & Berghahn Books: Barcelona, Spain.

US Environmental Protection Agency (2010). *Sustainable Design and Green Building Toolkit for local governments*. EPA 904B10001

Van B. R. (2008). Eco-Efficiency: concepts and rationale. *United Nations ESCAP*. 17.-18.4.2008 Bangkok, Thailand.

Walker, G., Karvonen, A. & Guy, S. (2016). Reflections on a policy denouement: the politics of mainstreaming zero-carbon housing. *Transactions of the Institute of British Geographers*, 41(1), 104-106.

World Business Council for Sustainable Development, WBCSD, (2010). Vision 2050, the New Agenda for Business. World Business Council for Sustainable Development. ISBN: 978-3-940388-56-8.

Zakari A., Bashir F. M. & Badiru Y. Y. (2014). Are Smart Buildings Same as Green Certified Buildings? A Comparative Analysis *International Journal of Scientific and Research Publications,* 4, (11), 2250-3153.

Zhang, Y., Wang, J., Hu, F. & Wang, Y. (2017). Comparison of evaluation standards for green building in China, Britain, United States. *Renewable and sustainable energy reviews*, *68*, 262-271.

Zhao, X., & Pan, W. (2017). Co-productive interrelations between business model and zero carbon building: A conceptual model. *Built Environment Project and Asset Management*, *7*(4), 353-365

APPENDIX A: QUESTIONNAIRE/INTERVIEW

Department of Architecture
Federal University of Technology Minna

Integrating Eco Efficiency in University Senate Buildings

Dear Sir/Ma,

I am a Masters student from the above named university and department, conducting a research on the above stated topic. As a part of my research, I am conducting a survey regarding eco efficiency of university senate buildings in Nigeria. You have been contacted as a stake holder in the built environment and its profession and the users of senate buildings. I would therefore value your participation in this survey.

Your utmost cooperation in this exercise would be greatly appreciated. The information collected is meant for educational use in to aid my research in my Masters thesis. Due to the constraint and deadline of this task, I graciously ask you response as soon as possible.

Thanks in anticipation.

Please indicate by ticking appropriately the options that implies to you

1. What is your Profession in the building industry?
   a. Architect
   b. Builder
   c. Structural engineer
   d. Quantity surveyor
   e. Project manager

2. What is your highest level of education?
   a. PhD
   b. Masters Degree
   c. Bachelors Degree
   d. Ordinary Or Higher Diploma
   e. Other(Specify If Any)
   ……………………………………………………………

3. How long have you been in the professional practice?
   a. 1-5years
   b. 6-10yers
   c. 11-15years
   d. 16-20years
   e. More than 20 years

4. What professional qualification do you hold
   a. ARCON
   b. NIOB
   c. COREN
   d. NIQS
   e. NIPM

5. How many office design or construction projects have you been directly involved in as a professional?
    a. none
    b. 1-5
    c. 6-10
    d. 11-15
    e. More than 15

6. Please rate by ticking appropriately your level of understanding of an eco-efficient or ecofriendly design

	1	2	3	4	5
Poor understanding					
Fair understanding					
Satisfactory understanding					
Good understanding					
Excellent understanding					

7. Please rate your level of integration of eco efficiency in your design of office buildings
    a. never
    b. rarely
    c. sometimes
    d. often
    e. always
8. In your opinion, what stops designers from implementing eco efficient office buildings
    a. client
    b. inadequate knowledge
    c. unavailability of resources
    d. funds/cost of implementation
    e. time
    f. others (specify)
    ………………………………………………………………………………
9. In the design and construction of a senate building, which of the following are key focuses a professional should concentrate on

	Strongly disagree	disagree	neutral	agree	Strongly agree
Designing an administrative office with environmental sustainability in mind					
Building a prototype of an eco-efficient and ecofriendly office building					

Integrate a comprehensive range of innovative energy and water efficient features					
Harness the use of natural light and natural ventilation for interior spaces					
Designing to ensure good indoor air quality and thermal comfort of building users					

10. How important do you think Eco efficiency is to today's Nigerian society?
    a. Not important at all
    b. Slightly important
    c. Moderately important
    d. Very important
    e. Extremely important
11. What is your reason for your answer above
    …………………………………………………………………………………………
    …………………………………………………………………………………………
    …………………………………………………………………………………………
    …………………………………………………………………………………………
    ……………………………………………………………
12. Please indicate your level of utilization of any of the following in your professional practice with regards to office building projects

	No utilization	Negligible utilization	Limited utilization	Adequate utilization	High utilization
Use of renewable energy for power generation					
Users' needs					
Low carbon design					
Easy accessibility and convenient approach					
Satisfied users preferences					
Increased public awareness of environmental protection					
Create green environment					
Enhance sustainable energy development					

Have efficient energy saving systems					
Have bright airy and spacious surroundings					
Have green planting surroundings					
Proper waste management					

PART II: Energy Conservation in the Designs of office Buildings

13. How often fans and HVAC (heating ventilation and air conditioning) systems should be used to ensure that energy is conserved?
    a. 1-6 hours
    b. 7-12 hours
    c. 13- 18 hours
    d. 19- 24 hours
14. Are passive design techniques on passive cooling in a building effective for energy conservation?
    a. Yes
    b. No

15. How important is day-lighting in energy conservation in the following parts of an office building?

	Very unimportant	Unimportant	Important	Very important
Corridors				
offices				
Meeting rooms				
Reception area				
Stairs area				

16. Can passive cooling (natural ventilation inclusive) be useful in energy conservation in the following parts of an office building?

	Very unimportant	Unimportant	Important	Very important
Corridors				
offices				
Meeting rooms				
Reception area				
Stairs area				

17. How can office buildings in Nigeria be designed to optimize energy conservation?

18. What techniques can be applied to cause better day-lighting in office buildings across Nigerian universities

19. What ecofriendly measures can be applied to reduce energy consumption in office buildings across Nigerian university?

APPENDIX B: BUILDING ENERGY AUDIT

Section 1

Name of school ……………………………………………………………………
Location: ……………………………………………………………………
No of floors
Date of energy audit ……………………………………………………………………

Section 2 (general information)

1. Official building opening time ………………………………………………………………………………..
2. Official building closing time ……………………………………………………………………………….
3. No of hours worked in a day ………………………………………………………………………………..
4. No of das worked in a week …………………………………………………………………………………..
5. Total no of office spaces ……………………………………………………………………………………..
6. Total internal floor area of the building ……………………………………………………………………
7. Daily maximum occupancy in the building.…………………………………………………………
8. categories of office spaces

Name of space	**Number in the building**	**Floor area**	**capacity**	**Period of time used**

9. No of staff employed in the building % ……………………………………………………………………..
10. Average number of visitors per day …………………………………………………………………………

Section 3 (lighting in the building)

1. What lighting technique is applied in the building?
   a. Natural b. artificial c. combination of both natural and artificial
2. What type of artificial lighting system is used in the building?
   a. Incandescent b. fluorescent c. compact fluorescent d. mercury e. low pressure sodium f. metal halide g. high pressure sodium h. halogen
   i. mercury.

3. Location of the lighting systems per floor

space	Type of lighting systems	No. available		

4. What type of lighting control is used in the building
   a. Manual b. automatic c. daylight (photocells) d. sensors
5. What period of time are the external lights on?
   a. 0-6 hrs b. 7-12hrs c. 13-18hs d. 19-24hrs

Section 4. (Cooling and Ventilation)

1. How is the building ventilated?
   a. natural b. mechanical c. hybrid (natural and artificial)
2. What type of cooling devices are available in each space

space	Type of cooling device	Number per space	

3. When are the office cooling aids on in dry season?
   0-6 hrs b. 7-12hrs c. 13-18hs d. 19-24hrs
4. When are the office cooling aids on in raining season?
   0-6 hrs b. 7-12hrs c. 13-18hs d. 19-24hrs

Section 5 (Electricity information as found on electricity invoice)

1. Installed electrical power, kW
   ……………………………………………………………………..
2. Electrical demand (max demand)
   kW…………………………………………………………
3. Electricity consumption from the national grid

Monthly Demand Consumption													Total
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
kWh													
Cost													

4. Alternative source of electricity petrol/diesel

Monthly Demand Consumption													Total
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
litres													
Cost													

5. The use of water pump in the use of water

Month Water Demand Consumption													Total
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Litres													
Cost													

APPENDIX C: Observation schedule

1. Name of school ____
2. Building type (if storey, the number of storeys would be required)________`
3. Number of office spaces in the building____________________________
4. How many hours in a day is the builfing active……………………………
5. Time of opening and closing of thr building…………………………………
6. Average number of occupants in the building……………………………………………
7. What materials were used for the construction of the following
   i. Floor____________________
   ii. Walls____________________
   iii. Windows____________________
   iv. Doors____________________
   v. Ceiling____________________
   vi. Roofs____________________
8. Energy sources bought and used
   a. Electricity
   b. PMS (petrol)
   c. Diesel
   d. Natural gas
   e. PVC systems
   f. Other:
9. Building orientation
   a. North
   b. East
   c. West
   d. South
   e. North-east
   f. North-west
   g. South-east
   h. South-west
10. Use of electric lighting optimized? (use of daylight, motion detectors, automatic switch, dimmers)
    a. Yes
    b. Partly
    c. No
11. The depth of reveals on openings
    a. 1-150mm
    b. 151-300mm
    c. ≤301mm
    d. none
12. Location of openings

Types	Sizes	Numbers	At shaded spaces	Exposed to daylight
Doors		_________		_________________
Windows	_________		_________________	
Porches		_________		_________________
Curtain walls	_________		_________________	

Below in item 10 and 11, are some exterior shading devices and passive design elements for shading, lighting ventilation and cooling. Tick if found

13. Below are some exterior shading techniques known, tick if found present

a. central courtyard
b. Light shelves
c. Curved profile exposed ceiling slab
d. High ceilings
e. Clerestory windows
f. Sun-pipes
g. Skylights
h. Awnings
i. Overhangs for shading,
j. Shading by trees and vegetation,
k. Shading by texture surfaces.
l. Solar chimneys,
m. Air vents,
n. Wind tower
o. Diode roof
p. Roof ponds
q. Passive downfall evaporative cooling (PDEC),
r. Roof surface evaporative cooling (RSEC)
s. Earth air tunnel
t. Earth berming
u. Pools or fountains in or near the building
v. Horizontal openings near floor level
w. Elevated rooms above the ground
x. other shading devices used

1. North elevation
2. East elevation
3. West elevation
4. South elevation
5. North-east
6. North-west
7. South-east
8. South-west

n	A	B		C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1																										
2																										
3																										
4																										
5																										
6																										

14. What type of cooling/ventilating systems are used to provide comfort in the building

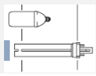
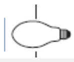
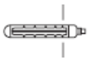
15. What type of window systems are used?

a. Casement window
b. Pivoted window
c. Side hung window
d. Sliding window

e. blinds

16. what type of metering is uses
    a. bulk metering
    b. individual metering
17. Are there any cracks/openings on the walls and ceiling? If yes where

18. Lamps used

TYPE	Number	Wattage	Energy Use	Spaces	Duration of use
1. INCANDESCENT 					
2. FLUORESCENT 					
3. COMPACT FLUORESCENT 					
4. HALOGEN 					
5. METAL HALIDE 					
6. MERCURY 					
7. HIGH PRESSURE SODIUM 					
8. LOW PRESSURE SODIUM 					
9. OTHER					
TOTAL ENERGY USE					

19. What type of cooling system are used to enhance users comfort in the building

20. Are there any form of regulation on occupant's behaviour to save energy? If yes what are they?

21. HVAC system

Type	Number	Wattage	Energy use	Duration of use
Ceiling fan				
Standing fans				
A.C. system				
Duct fans				
Other				
TOTAL ENERGY USE				