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## Study of Energy Efficient Building Design Techniques: Covenant University Health Centre

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**Abstract.** Energy efficiency, which is a key factor of sustainable building design is very beneficial to building occupants. This has made the focus on sustainability in the design, to be highly desirable. Studies show that two third of the energy used in existing residential buildings in Nigeria is generated via electricity, however; due to epileptic power supply, high cost of energy and high carbon emission, there is a need to minimize energy demand in the facility. This research evaluated sustainable design strategies and their effects on energy efficiency in warm humid climate of Nigeria. The climate, building envelope, heating, ventilation and air conditioning and lighting systems constitute are the main factors responsible for energy intake of a building. The research was based on case study of Covenant University Health Centre and data was collected through visual survey. The case study revealed that the building, at the time of construction did not consider sustainable design strategies in terms of materials of the building envelope, wall and window shading as well as natural means of cooling. Only lighting was considered.

**Keywords:** Building envelope, Energy efficiency, Greenhouse gases emission, Sustainable design, Natural lighting, Reinforced concrete building.

### 1. Introduction

Energy is at the focus of a sustainability and poverty reduction efforts today. It affects environmental and social-economic all aspects of development, such as man's livelihood, productivity, health, education, access to water and other basic human needs. It is difficult for the Sustainable Development Goals (SDGs) to be met without sustainable energy services in developing countries [1]. It is to be noted that the building sector is the most significant sector for energy consumption and greenhouse gas emissions. From the United Nation Environmental Programme (UNEP) report on Sustainable Buildings [2], it is evident that the building sector is responsible for about 30-40% of the global energy usage, with the prediction that it would be on the rise over the course of the next decades. This implies that achieving energy efficiency in the buildings could offset the greenhouse gases (CO<sub>2</sub>, CO, CH<sub>4</sub>) that would be generated from the building sector globally, hence, saving the planet from global warming and other negative effects of these gases [3]. In tropical regions such as Nigeria, the task of energy consumption is aggravated due to the extreme temperature and strong solar radiation which leads to increased usage of more energy, therefore, the greater need for more efficiency methods of energy conservation [4]. The core of energy efficiency is not the outright cut-off from energy consumption, rather the use of energy in a manner that would minimize the amount of energy that would have been used for a particular operation. These techniques and designs aid in the reduction of the demand of energy while keeping the users completely comfortable and satisfied.

Generally, our buildings and the way we construct them contribute to global warming and our dwellings contribute to the release of greenhouse gases. In the light of various problematics facing the world such as, resource exhaustion, the depletion of fossil fuel energy, water quality and availability problems,



economic instabilities and extreme weather events accompanying human-induced climate change phenomenon, the priority of the world is to ensure that energy consumption is sustainable.

The world has realized that if we want to preserve human existence on this planet, there is need to collectively work together as a team towards making the earth habitable for human living. A clear picture of climate change challenges faced by our current society is explained in Figure 1.

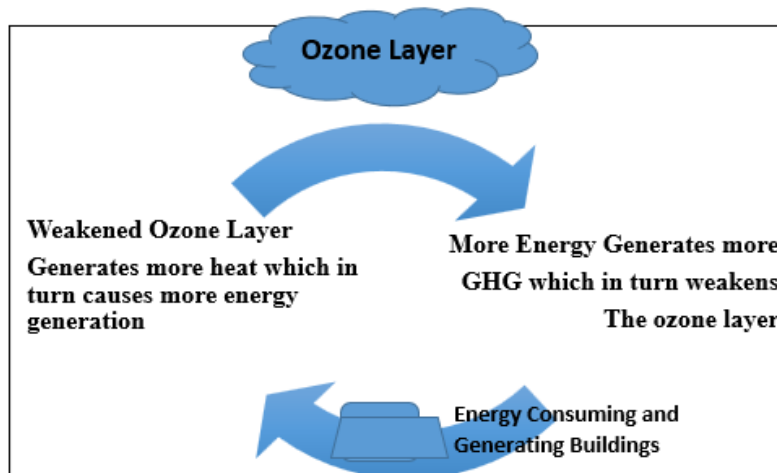


Figure 1: Energy cycle showing GHG movement.

This a diagrammatic representation of our current situation shows the relationship between energy generations and consumption of building and the build-up of greenhouse gas in our environment. From the diagram we can see that the more the energy consumption (already generated energy which expels GHG in manufacturing) the more the generation of greenhouse gases that would in turn reduce the strength of the ozone layer, and when this ozone layer is weakened, more heat is radiated to the earth from the sun, and when more heat is radiated to the earth more energy would be required to offset it for comfortable living (space cooling). It must also be noted that the more energy that would be generated, the more the financial implication for the producers and end users. This is a cycle of disaster that needs to be short-circuited before we are unable to continue life on planet earth. Purchasing less energy consuming (energy efficient) appliances will not solve the problem as the demand for more energy would still exist. The only solution will lie in energy efficient designs, aimed at reducing the need for energy consuming devices in the first place. These designs will be a very great solution since they will directly affect the building sector, which is the largest energy consuming sector.

Based on these facts, this research aims at reviewing the energy efficiency of building designs methods, their impact and shortcomings for the conservation of energy in the building sector hence reducing greenhouse gas emission. This will entail determining to what extent these methods have been applied in buildings in Covenant University and give recommendations for existing and upcoming structures to improve energy efficiency. This research focuses on energy reduction and GHG emission reduction with the intent of contributing towards the offset of global warming.

## 2. Concept on energy efficient building design

Energy can be transferred from an object to other objects or transformed into different forms [5]. It can also be defined as the ability of a system to perform work. Currently, fossil fuel such as oil, gas, coal which is the most used energy have limited supply. The other disadvantage of non-renewable fuels is

the generation of CO<sub>2</sub>, the major cause of climate change. For a nation wishing to tackle developmental challenges, provision of adequate energy for her citizens is inevitable [6]. Daylight is can be more effectively utilized, thereby reducing the need for artificial lightning. Natural ventilation systems based on sophisticated modeling of airflows are becoming common. The effects of these developments on building will become more apparent as environmental controls tighten on the society with incremental environmental costs such as carbon taxes [7]. In the past 20 years, residential energy use has increased sporadically and the major contributors of this sporadic development consist of growing population, shrinking house hold size, leading to more households and higher demand for energy services like air conditioning [8].

Figure 2, shows that the home sector is accountable for greater energy consumption in from year 1996 to 2005 with variation of 55%-61% [9].

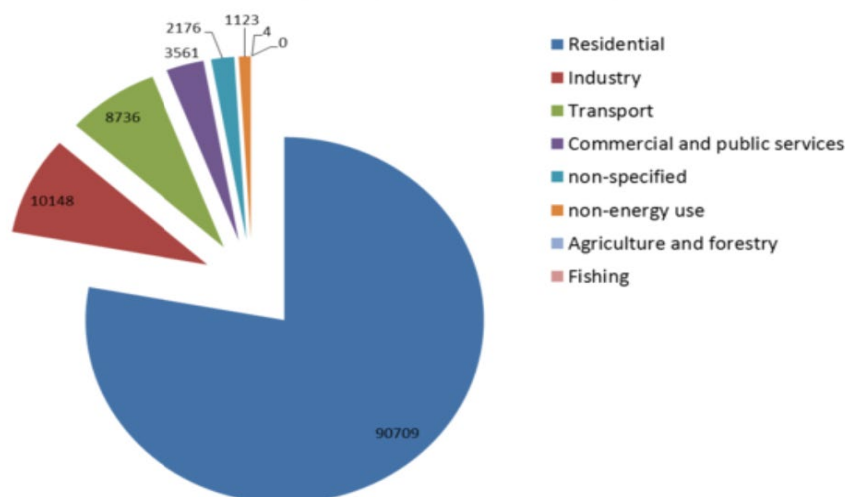


Figure 2: Nigerian energy usage for various economic sectors (Source: IEA [9])

Sustainable energy refers to the approach of generating and utilizing energy more efficiently as to provoke less harmful to the environment. It can also be explained as the approach to achieve current energy needs without compromising the availability for future generations [10]. The advantages of adapting sustainability in energy consumption include more comfortable homes, saving of money on electricity bills and very importantly is the reduction of climate change [11].

### 2.1 Techniques for Reducing the Consumption of Energy in Buildings.

In the past, the design stage of buildings had put strength and aesthetics as the top consideration, however with growing concerns for climate change and energy consumption the best way to ensure energy efficiency in buildings is by designing to suit the local climate of the area. The techniques include orientation of building and room layout, placing of window, skylights, shading, insulation, ventilation, landscaping and using heat enthralling building materials. While some of these techniques may escalate the initial cost of construction, the result will be future savings in energy bills.

A good energy efficient building design will allow the sun's heat into the edifice in cold weather and excluding it during the hot weather [12]. Before construction of a building, the best site is to choose a good orientation with no obstructions. Living room is placed on the north side, while the other rooms to the south [13]. Proper placement of window, sizing and shading are fundamental for energy efficient designs. Windows are very essential as solar collectors and for trapping heat from the sun which is useful to the occupants during the cold season but not useful during the hot season. Windows allow daylight, serve as ventilators during the hot season, funneling cool air in and getting rid of heat accumulated during the day. Good design creates a balance between adequate cross ventilation and controlling sun's access, while allowing natural light to enter [14].

Insulation makes the building easier as it reduces the volume of warmth fleeing during the cold season and heat entering during the hot season. By insulating one can significantly reduce cost of cooling Greenhouse gas emission. Selection of insulation type is based on the R-value, which is a measure of resistance to heat transfer.

Correct choice of building materials can make a noteworthy difference to the energy performance and level of comfort of a building [15]. Dense materials such as Rammed earth, brick, concrete and stone, retain heat and cool down gradually because they have high thermal mass. Thermal mass is very beneficial in buildings with good solar access to north facing windows. Limited solar access leads to increased building heating requirements during cold season. In hot seasons, thermal mass helps to keep the home cooler during the day.

From these brief reviews, it can be seen that it is possible to improve the energy efficiency of buildings, leading to the much desired benefits that accompany sustainability.

### **3. Research Methodology**

#### **3.1 Method of Research**

Evaluative research method was adopted for this study. This research tries to verify the effectiveness of a building design projects as to compare against stipulated standards [16]. This entails basic research tools of data collection and analysis such as visual survey, interview, secondary data and simulation. This empirical inquiry investigates a contemporary phenomenon within its real life context [17]. Case study method adopted is characterized by a purposeful selection of the cases to study and the type of data to collect [18]. For a correct application of this method of research, detailed documentation of the history and environment of study is very essential [19]. The case study for this research is based on site planning and landscaping; spatial organization of buildings; structure and materials; and building services. This will then be followed by the application of general data collection technique.

#### **3.2 Case Study**

Covenant University Health Centre was choosing as the case study. The Covenant University Health Centre is a newly erected structure in the University. The building is in a functional state and it is made up of 2 floors, consisting of: a very spacious and open reception, 3 waiting halls, 2 general wards, 10 private wards, various offices, laboratory, buttry, medicine store and expanse parking lot. The principal instrument used in collecting data in this research is visual survey. The survey was guided by serious literature review guidelines as checklist. Outcome of this survey was documented by plates, tables and accompanying reports. Tours were made around the site, noting the architectural features materials, spatial arrangements and finishes.. Photographs were taken of relevant of some relevant parts, together with sketches to show the spatial organization of the facilities.

### 3.3 Variables of Study

For this research, the variables considered are design dependent variables which will point out which of the elements of sustainable design had been applied and their effect in energy reduction. The variables considered are design dependent variables such as the building envelope, natural ventilation, daylight in the building site and external spaces, building shape and form, orientation and planning, wall shading, local climate and existing energy source.

### 3.4 Data Analysis

Descriptive data analysis, visual survey and ranking system were adopted. A checklist was also employed to assess and record the extent to which sustainable design strategies were employed in the based on a 5-point scale ranking system ranging from very inadequate to very adequate (from 1 to 5 points).

## 4. Results and Discussions

This research was conducted to find out the extent to which sustainable design strategies were applied in the design of a building in Covenant University, i.e., Covenant University Health Centre. Here, the data gotten from this case study were described and a checklist was employed to assess and record the level of sustainability based on a 5-point scale ranking system.

### 4.1 Findings from the visual survey

The sources of energy consumption within the Covenant University Health Centre were observed to be: room and hall lighting, televisions, computers and accessories, water dispensers and medical machinery.

Some sustainable design strategies were applied to the building elements. The building envelope and its components are key determinants of the amount of heat gain/ loss and wind that enters into a building. The dominant building material used are concrete and glazing (reflective glasses) for walls, marble tiles for floor, white patterned suspended ceiling in some spaces. Variety of colours were used in different spaces within the building: milk coloured walls for the library, auditorium, and seminar rooms respectively, dark and light blue coloured walls for the mini halls, orange and milk coloured walls for the foyer and light and dark shades of green coloured walls for the restaurants as shown in plates 1 to 3.



PLATE 1: Approach view



PLATE 2: Rear view



PLATE 3: Internal view

The interior of each of the spaces had access to natural daylight through the use of large windows which spans more than half the length of the space as shown in plates 3 to 5. Due to inadequate natural lighting, fluorescent bulbs are used consistently to enhance the brightness of the rooms.



PLATE 4: Buttery/Restaurant Window blind



PLATE 5: Health Centre butterfly/Restaurant

Natural ventilation was provided for through the use of large windows some of which are openable as seen in plates 3 to 5, however they were not adequate, hence the functional spaces within the conference centre made use of air conditioning systems as seen on 6.



PLATE 6: East View

The building environment is surrounded by hard and soft landscape. Paved road and interlocking tiles make up the driveway and walkways, as seen in plates 7 to 8 respectively. Green areas and plants contributed to beautify and to cool the environment.





PLATE 7: Landscape



PLATE 8: Parking lot

There are eave projections in some areas especially along the restaurant extension, but they don't shade the windows, venetian blinds do from within. No horizontal or vertical shading device as shown in plates 9 to 10 respectively.



PLATE 9: East view showing eaves



PLATE 10: Front View Windows

#### 4.2 Extent of Sustainable Strategies Applied on the Building Element

Here, the extent to which sustainable design strategies were applied on the building elements were evaluated. The result is shown in Table 1 with a ranking system based a 5-point scale, varying from very inadequate, inadequate, average, adequate to very adequate. Table 2 contains the summary of the findings.

The average score was 2.75, which is below the energy efficiency average score indicated in [18].

#### 5. Conclusion

This research explored the concept of sustainable design in an attempt to enhance energy efficiency in buildings. This was achieved by an in-depth review of sustainable design strategies, energy efficiency factors, their application and investigating the extent to which these strategies were applied in Covenant University Health Centre designs. The sustainable design strategies include use of low energy materials for the building envelope and its components, taking full advantage of daylighting in to eliminate/reduce the need for supplementary artificial lighting during the day time, reducing to minimum air conditioning during periods in which natural ventilation is adequate and use of shading devices where necessary and proper orientation of the building on the site. It can be concluded that the building energy efficiency of the building was below average, particularly for building envelope and wall/window shading. The buildings did not maximize the site's potentials. as to achieve the best possible orientation for functional areas. Shading devices need be introduced. Issues of sustainable planting and landscaping should be considered by planting more trees and grasses to enhance the cooling of the immediate environment. For hotter regions such as Nigeria, improving room ventilation through better positioning of windows and increased window size would improve energy efficiency.

TABLE 1: Sustainable design strategies applied at Covenant University Health Centre								
S/N	Variables	Checklist	Level of application					Remark
			1	2	3	4	5	
1	Building Envelope	Suitability of materials to the climate				✓		No insulation material was used on the external walls. Use of light colours and the entire exterior surface of the building envelope was rough.
		Use of external insulation	✓					
		Use of smooth surface finishes		✓				
		Use of light colors			✓			
2	Natural Lighting	Wall to window ratio(40%)					✓	Use of extensive large windows made of single clear glass cause heat gain.
		Use of spectrally selected glass		✓				
3	Natural Ventilation	Use of openable windows			✓			Natural ventilation was provided for but was inadequate.
4	Site and external spaces	Use of interwoven landscape			✓			Presence of soft and hard landscape, but not interwoven.
		Use of impervious surfaces		✓				
5	Building form	Large building surface area				✓		Appropriate building form based on climate
6	Wall/ Window Shading	Use of horizontal and vertical shading devices		✓				Building was not properly shaded, only the use of fixed overhangs at some point, this exposes it
		Use of interior blinds					✓	

		Use of recessed walls	✓					to direct solar radiation
		Use of overhangs			✓			
		Use of plants			✓			
7	Existing energy source	Use of photovoltaic cells	✓					Extensive use of PHCN, however, energy was totally reliant on fossil fuel due to epileptic power supply.
		Use of natural gas	✓					

TABLE : Summary of Findings			
S/N	Variables	Total	Average
1	Building Envelope	9	2.5
2	Natural Lighting	7	3.5
3	Natural Ventilation	3	3
4	Site and external spaces	5	2.5
5	Building form	4	4
6	Wall/Window Shading	14	2.8
7	Existing energy source	2	1
		44	19.3

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