ENERGY EFFICIENCY ASSESSMENT OF HIGHER EDUCATION BUILDINGS IN BAUCHI, NIGERIA

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ABSTRACT

Purpose: Energy efficiency, often referred to as efficient energy use, is aimed at reducing the amount of energy required for cooling, heating, ventilation and lighting in buildings to create desirable thermal comfort conditions. Global energy and climatic challenges have necessitated new ideas and investments in developing energy-efficient strategies in the building industry. The building sector is responsible for over 40% of total primary energy consumption across the globe and almost 30% of the world's total Carbon Dioxide (CO2) emissions and therefore plays a critical role in addressing global energy and climate change issues. Retrofitting is needed in buildings to make them more energy efficient. This study investigates energy efficiency in higher education buildings with a view to developing a conceptual energy efficient framework for sustainable higher educational building design in Nigeria.

Design/Methodology: The emphasis is on the Building envelope and shading in higher educational buildings. This research adopts a mixed research method, it collates and analysed data on the perception of users and designers, in inculcating sustainable design solutions. Interviews were conducted and questionnaires distributed, analysed using the Likert scale grading system to test the relationship between users' perception of energy efficient buildings and amounts of energy conserved.

Findings: The findings validated perceptive benefits of the passive and sensible cooling loads to the Primary and Total Energy Demand of educational buildings in Nigeria. The study also indicates the lack of conscious consideration to the environmental and socio-cultural impact of buildings on the environment but more attention seems to be focused on building costs, labour and materials in Nigeria.

Originality/Value: The results of the study also form part of a conceptual Energy Efficiency Framework to which Architects are expected to adhere to as a rule guiding their design for energy efficient Higher Education buildings.

Keywords: Architecture, Buildings, Energy Efficiency, Higher Education & Sustainable Design.

1. INTRODUCTION

Global energy and climate debate necessitate new ideas and investments in energy efficient strategies in the building industry (Garkuwa, 2017). The building sector consumes over 36% of overall primary energy consumption across the globe

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(International Energy Agency, 2015). Also, the building sector is responsible for about 40% of the world's overall Carbon Dioxide (CO_2) emissions and therefore plays a critical role in addressing global energy and climate issues (International Energy Agency [IEA], 2015). The use of energy in buildings has increased in recent years due to the growing demand in energy used for heating and cooling in buildings. Without energy, buildings could not be operated or inhabited (Löhnert et al., 2007). According to Baird et al., (2018) improvements have been made in insulation, plant, lighting and controls which are significant features that help towards achieving an energy efficient building.

Increasing energy demand and reduction in available energy are leading to mandatory energy efficiency strategies in every sector globally (Petersen & Svendsen, 2010). It was noted by Nielsen & Mortensen (2016) that energy consumption by the building sector calls for an increased attention towards energy efficiency measures. According to Sadineni, Madala, & Boehm (2011) accepting appropriate energy efficiency strategy can meaningfully decrease energy consumption in buildings. Hence, efforts in the previous decade have centred on reducing buildings' share of carbon emissions through energy efficiency and conservation measures (Kumar & Raheja, 2016). Both governments and scientists across the globe have discovered the need and the potential for energy efficiency in buildings (Sadineni et al., 2011). This has led to numerous mechanisms and policies proposed and implemented especially in developed countries towards an energy conscious building design and development (Jason, 2004; Yuksek & Karadayi, 2017).

Presently, higher education buildings in Nigeria have an important role in the reduction of greenhouse gas emissions from our built environment and in assisting the mitigation and adaptation of our society to climate change (Oyedepo, Leramo, Adekeye, Kilanko, Babalola, Balogun, & Akhibi, 2015). Nonetheless, operating and managing the building infrastructure of organizations such as universities is complex because their diverse infrastructure and non-uniform building conditions can make it difficult to prioritize the resources needed to upgrade particular buildings and systems (Oyedepo et al., 2015). Large institutions such as universities consume huge amounts of energy on daily basis (Oyedepo et al., 2015). Oyedepo et al. (2015) also establish that improving energy practices at higher education buildings can decrease their environmental impacts.

Amongst the most critical challenges facing the society is influence of man's activities on climate change and its consequences for economies and communities (Parkinson & Birgitta, 2010). Although the impact of climate change may well prove irreversible according to many authorities, the risks to society may be reduced by accepting adaptation and mitigation strategies (McMichael, 2003 Sing, 2012). This can be deduced from the views expressed by intergovernmental Panel on Climate Change (Climate Change 2007) which urged world leaders to act immediately by reducing greenhouse gas (GHG) emissions.

Having a clear understanding of how the surroundings of higher education buildings perform will enhance the economic, social, environmental, and operational performance of the Nigeria higher institution of learning (Akadiri, Chinyo, & Olomolaiye, 2012). As such. this research seeks to increase the understanding of the energy performance of higher education buildings and surroundings by planning and developing a decision support framework to better facilitate the energy assessment of educational buildings.

An important benefit also applies when the focus is placed on buildings used for higher education because these enhancements can play a major role, not only as described above, but also when the buildings are used as an instructive tool to educate and teach students, staff, and the broader community about sustainability (Rohwedder, 2004).

According to Rohwedder (2004) properly designed educational buildings can showcase economic, water and energy savings, reductions in GHG and social responsibility by employing this to demonstrate to students that educators care about their future well-being. Acceptable and comfortable indoor conditions are essential to improve the health, performance, and learning of university students, and staff (Corgnati et al., 2007; Sharaidin et al., 2012). However, most of the existing higher education buildings in Nigeria today are generally designed at a time when the sustainability and comfort of the occupants were not the priority, thus, the design naturally leaves a lot of room for inefficient operation with resultant frequency of failure to provide acceptable thermal comfort for the occupants throughout the year (Machar, 2017). Furthermore, universities typically operate a diverse collection of buildings with wide-ranging performance issues that affect them to different degrees, which is why a general approach is likely to be required when assessing the extent to which university building can be made more sustainable and comfortable (Okolie, 2011). In essence, considering the building as a whole component when an upgrade of the already exiting educational buildings is to be undertaken in form of retrofitting, there is a need of an established framework to guide the process of a decision making which is complex.

The acceptance of energy efficiency technologies and systems has been identified as one of the most cost-effective ways of reducing GHG emissions (Energy White Paper Task Force, 2004), as well as providing energy security, and economic, climate and social benefits (Steuwer, Rosenow, & Jahn, 2019). In many European countries, Asia and Austrialia, retrofitting existing commercial buildings during the next decade is seen to save about 1.4 billion a year (Climate Works Australia, 2010), reduce building emissions by 30% and generate 27,000 jobs (Langdon, 2009).

Research established that, to decrease energy consumption in buildings, design professionals need to come up with design that consume less energy. Energy performance has emerged as an important concept that must be inculcated in design process due to high consumption of building sector (Petersen & Svendsen, 2010). Such smart buildings significantly decrease building energy consumption, operational cost and lower Green House Gas emission. From 40% - 60% compared to the conventional new buildings. Good building envelope design as argued by Latha, Darshana, & Venugopal (2015) can yield good result in lowering heating and cooling load in buildings. Passive design technique as asserted by Gustafsson (2017) as the best sustainable strategy to energy demand in buildings. Previous studies (Yuichiro, Cook, & Simos, 1991; Givoni, 1994) have proposed passive and low energy as the most efficient way of reducing buildings energy consumption. This paper proposes a framework for design of an energy efficient higher education building in Bauchi Nigeria using passive design techniques and application.

1.1. Statement of the problem

Izael & Edward (2011) found that insufficient consideration has been accorded to the poor design and energy performance of Institutional buildings. Educational institutions are amongst the major consumers of energy in any country most of which is utilized within buildings for lighting, cooling, heating and other services. A thorough critique of the building system is necessary to reduce energy wastage in such buildings through adoption of sustainable design strategies in Lecture spaces in Bauchi. This is essential in other to reduce energy consumption in the daily running of these buildings.

As it was asserted by Oyedepo et al., (2015) unlike major economic sectors (industrial, commercial, transportation), very few campus energy potential studies had been carried out in recent past in Nigeria. In his study, Unwachukwu (2010) assert there is an absence in potential identification of energy conservation measures, achievement of thermal comfort in lecture halls through a holistic approach of the design and composition of the building fabric. When this is implemented on campus, it can improve the indoor environmental air quality thereby making the energy usage more efficient and less expensive. The need to link this important gap is of immense benefit to research in higher education buildings in Nigeria and the global demand for energy efficiency.

1.2. Aim and objectives of the study

The aim of this paper is to investigate the energy efficiency in Higher Education buildings in Bauchi Nigeria with a view to provide a sustainable conceptual framework for adaptation in Nigeria. In other to achieve this aim, the objectives will be;

i. To identify passive building design strategies to improve and reduce energy consumption in Higher Education buildings.
ii. To identify sustainable shading strategies for retrofits in the façade of existing Higher education buildings in Bauchi Nigeria.

1.3. Hypotheses

Null and alternative hypotheses were formulated to guide the study and these hypotheses will be tested at a 0.05 level of significance.

Null Hypothesis:

H_0: A design framework to assess energy efficiency of higher education building in Bauchi Nigeria would not be an effective tool in the creation of sustainable buildings.

Alternative Hypothesis:

H_1: A design framework to assess energy efficiency of higher education building in Bauchi Nigeria would be an effective tool in the creation of sustainable buildings.

2. Literature Review

A building is a physical structure whose fundamental purpose is to provide shelter for some activity that could not be carried out as effectively, if at all in the natural environment. Such activities may involve people, a mix of people and machines. All such activities require some degree of protection from external elements and may require a specific range of environmental conditions and a specific set of service facilities if they are to be carried out successfully (Izael & Edward, 2011). Institutional buildings like Universities are therefore required to provide a conducive environment for the conduct of educational services such as delivery of lectures to students, computer laboratories, libraries for study, and offices for lecturers, etc. All these require a thermally and visually comfortable environment. Sustainable building design have similar definitions which according to the U.S. Green Building Council defines it as a building's total economic and environmental impact and performance, from material extraction and product manufacture to product transportation, building design and construction, operations and maintenance, and building reuse or disposal (USGBC, 2013).

Energy is very important in the daily activities of humans and every human endeavour require the use of energy and similarly, no country can develop without efficient energy use (United Nation Environmental Programme [UNEP], 2009). Access to ample energy is the dividing line between the poor countries and the rich countries (Karekez, McDade, Boardman & Kimani, 2012). This explains why the developed countries of the world have and consume more energy than the developing and underdeveloped countries. As such, there is need for energy efficiency; in residential homes, agricultural settings, industries, educational and other commercial buildings (Ochedi & Taki, 2016)

Energy efficiency measures are meant to reduce the amount of energy consumed while maintaining or improving the quality of services provided in the building. According to the United Nations Industrial Development Organization, (2015) amongst the benefits likely to arise from energy efficiency investments in buildings are:

i. Reducing energy use for space heating and/or cooling and water heating;
ii. Reduced electricity use for lighting, office machinery and domestic type appliances;
iii. Lower maintenance requirements;
iv. Improved comfort;
v. Healthy indoor and outdoor air quality;
vi. Enhanced property value.

2.1. Energy use in building

There is insufficiency of reliable data on energy consumption in buildings, partly due to poor metering of mains electricity and also due to the fact that most buildings also generate electricity using petrol and diesel generators which complicates assessments in Nigeria (Ochedi et. Al., 2016). In late 2014, it has been estimated that 55% of Nigerian electricity users are not metered (Energy Commission of Nigeria, 2008). This is accepted as a major barrier to energy efficiency, and efforts are underway to ensure appropriate meters are installed. Energy use in building is one of the most noteworthy means of energy consumption and greenhouse gas emissions, thereby creating negative impact on the environment. Energy use can be linked with the emission of greenhouse gasses which is responsible for global warming and consequently climate change. Pérez-Lombard, Ortiz & Pout (2008) reported that there has been a steady increase in the global energy consumption of buildings which steadily emit greenhouse gasses; this has reached figures between 20% and 40% from both residential and other public buildings in developed countries.

Cooling and heating energy have been recognised as the most leading source of energy use in building which is also referred to as operational energy Adegbie (2016). Buildings are responsible for a considerable proportion of global energy use Ashden, (2014) and UNEP (2009) acknowledged that building sector consumes up to 40% of global annual energy and contributes up to 30% of annual greenhouse gas emissions. Cooling loads accounts for approximately 40% of the electricity consumed in the building, while lighting and powering of appliances accounted for 12% & 48% respectively (Batagarawa, 2013). Adoption of energy efficiency strategies in buildings will drastically reduce energy demand and consumption.

2.2. The need for low energy building

Adapting buildings to low-energy is one of the ways to make it energy efficient. Ashdeen (2014) stated that low-energy buildings use a mixture of passive and active systems to deliver a comfortable environment with lowered energy use and related greenhouse gas emissions. Low-energy buildings have decreased energy demands and without deterioration of the indoor climate condition. Low-energy designs in buildings is the inventive use of the basic form and enclosure of a building to save energy while enhancing occupants' comfort as stated by the U.S Federal Energy Management Programme (2001).

Low-energy building design combines energy conservation strategies and energy-efficient technologies which result in absolute reduction in the use of fossil- fuel based power. Further, building operational energy cost can be saved from low-energy buildings. This savings can be achieved through integrated design solutions. A low-energy building has fabric energy efficiency that is effective in minimizing the energy needed for cooling and space heating (Adegbie, 2016). Low-energy design strategies make use of the building fabric or envelope such as wall, windows, floors and roofs through appropriate design, materials and construction methods to minimise buildings energy consumption, enhance environmental performance and the economy (Adegbie, 2016). It is essential to consider low-energy principles at the inception of a building design because it has been recognised as the cheapest way to cut greenhouse gas emissions (UNEP, 2009). Low-energy buildings should consume significantly less energy than the level specified in the building regulation and the key objective of such buildings is energy-efficient design in which minimal energy is consumed throughout the building life cycle (Ashdeen, 2014)

2.3. Retrofits potential for energy reduction in Nigerian higher education buildings

In Nigeria, there seems to be an overall lack of awareness about the direct link between building design and technologies, and their impact on energy efficiency in the state-of-the-art building design. Traditional building materials and concepts responding to local climatic conditions are usually considered unprogressive, while modern materials and building designs from abroad are preferred, leading to designs that consume a large amount of energy, especially for cooling and lighting (Ley, Gaines & Ghatikar, 2015).

There are a series of well-tested and advanced strategies available that would suit the climate which can include the adoption of phase change materials, activation of thermal mass, retrofitting existing buildings, and these measures are not well established, as there is no local precedent available (Geissler, Österreicher & Macharm, 2018). The acceptance of energy efficiency retrofits for existing buildings has been identified as the most cost-effective solution available for reducing energy consumption in buildings (Energy White Paper Task Force, 2004).

3. Research Methodology

This study employed the use of measurements, case studies, and questionnaires to investigate the perception of a population on a prevailing phenomenon. A total of a hundred (100) questionnaires issued to Architects and students within the study area. To minimise the impact of time, finance and human resources, the study is limited to selected higher educational buildings in Bauchi, usually referred to as Bauchi State to distinguish it from the city of Bauchi. One amongst the selected buildings in Abubakar Tafawa Balewa University and The Federal Polytechnic Bauchi was chosen for this study. 90% of distributed questionnaire were received and analysed for this study. It is purely based on aggregation of facts observed from stated opinions since the possibility of experimentation would not be feasible. The questionnaire was divided into sections and questions were asked and the expected responses were either “Yes” or “No”. The other section anticipated response which were measured on a five-point scale format which ranged from “Highly Significant”, “Significant”, “Slightly Significant”, “Insignificant”, and “Highly Insignificant”. The scale was assigned numerical values of 5, 4, 3, 2, and 1 respectively from positive expression to negative opinion. T-Test was adopted for analysis of the subjective responses to determine the difference and level of significance between the variables under study. Amongst the items considered in the survey questionnaire were existing issues in higher educational energy demand and use; these include thermal comfort, building energy use, components of the building fabric, sustainable design consideration, institutional appliances as well as retrofitting existing buildings.

4. Presentattion and Discussion of Results

This study focuses on energy efficiency in buildings as a tool to harness energy conservation hence questions were asked broadly on energy performance of buildings and also the social consciousness of the user's perception of the building components towards efficient usage of energy.

4.1. Gender distribution

It was recorded from returned questionnaires of architects that 87.5% were male while 12.5% were females while the student respondents 80.5% were male while 19.5% were females that the distribution.

4.2. Age range of the respondents

The sample for this study was relatively matured in age with almost 62.5% between 40-60 Years. This observation suggests that respondents experience and maturity will give a certain degree of reliability to the study since their huge expertise will supply benchmark for the framework. They youngest respondents that make up 32.5% are between the ages of 35-40 years are also relevant as their age classification lend a good degree of credibility. Purposive sampling in the distribution of the questionnaires for students in context was drawn from 400 level and above. The sample had almost 58.5% between 25-29 Years. This observation suggest that respondents age group and level of study will ensure a certain degree of reliability also to the study since their knowledge gained from 100 level will supply a yard stick for the framework.

4.3. Design approach

Building design is an exceptional means of decreasing energy demand and consumption by buildings. Furthermore, sensible building design will aid thermal comfort and people's wellbeing. Numerous studies substantiated this position (Heiselberg, 2002; Allard & Ghiaus, 2012; Gratia & De Herde, 2007). GIZ (2015), stated that the Nigerian building sector is categorized by the post-modern buildings of the 1990's and the sprawling new Nigerian architecture that is taking shape due to the introduction of new building materials mainly imported from Asia. The concept of energy efficient bioclimatic architecture adapted to the site as used in traditional architecture seems to have lost its usage as many of the design in the urban areas are not a resolution of the climate and environmental conditions but by designs from abroad.

Respondents in the survey as shown Table 1 and 2 in study area indicate that from existing buildings the design approach adopted, building materials and construction techniques used are not appropriate for the microclimate and contribute to thermal discomfort. To realize the benefits of building design with regard to energy, comfort and other factors, building design should be based on the site microclimate. Conversely, the data from professionals and the observational survey showed that most of the buildings in the study area were designed without considering the microclimate. Building morphology and envelopes do not reflect the features that will stabilize the environmental factors.

Challenges with the design of buildings, use of building materials that are not responsive to the microclimate and lack of awareness on energy efficient buildings are predominant.

Meanwhile poor design can contribute greatly to energy consumption and thermal discomfort in buildings. Designers need to be sensible in their design of buildings bearing in mind the microclimate and other relevant factors. This will make life better for building users.

Table 1: Energy Conservation Measures

	Yes	**No**
Energy need	19 (47.5%)	21 (52.5%)
Energy consumption	13 (32.5%)	27 (67.5%)
Thermal comfort	18 (45%)	22 (55%)

Source: Authors Survey (2021)

Table 2: Design approach to higher educational buildings

	Highly Insignificant	Insignificant	Slightly Significant	Significant	Highly Significant	**Mean**	**Remark**
Functional spaces	3	3	15	14	3	**3.29**	**S**
Building elements (substructure and superstructure)	0	3	8	16	11	**3.92**	**S**

Source: Authors Survey (2021)

Key: 1.00 - 3.00 = Insignificant (I)
3.01 - 5.00 = Significant (S)

4.4. Retrofitting

There are energy efficiency codes and guides suitable to new buildings than existing buildings. Existing buildings have limited measures for enhancing thermal comfort and energy consumption of building occupants within. Building retrofit has been identified as one of the effective ways of improving comfort in existing buildings and reducing the energy usage, thereby adapting to the changing climate (Porritt, Cropper, Shao, & Goodier, 2012)

Survey results in Table 3 from which particularly addresses objective which all respondents agree that retrofitting the facades of existing higher education building in Bauchi Nigeria to enhance their shading ability is a solution to achieving better cooling and thereby enhancing thermal comfort in existing lecture and other training spaces. In the aspect of static and dynamic facades for shading lecture spaces, 92% believe that the deployment of dynamic shading devices on the building envelope will perform better to static shading device. Nonetheless the static shading devices which also help in achieving thermal comfort is mostly absent in 80 % of the buildings. A lot of technology and studies need to be carried out in the aspect of dynamic shading device in this part of the world before adopting its use which is deemed better because of the varying and harsh weather condition in Bauchi, Nigeria.

Table 3: Facade Classification best suites Bauchi Nigeria climate

	Highly Insignificant	Insignificant	Slightly Significant	Significant	Highly Significant	**Mean**	**Remark**
Static façade	0	10	8	9	8	**3.43**	**S**
Dynamic façade	0	0	4	6	28	**4.63**	**S**

Source: Authors Survey (2021)
Key: 1.00 - 3.00 = Insignificant (I)
3.01 - 5.00 = Significant (S)

Analysis of a Design Framework for higher education building in Bauchi Nigeria:

Hypotheses considered for this study test the effect the provision of framework as design guide for higher education buildings in Bauchi Nigeria.

Null Hypothesis:

H_0: A design framework to assess energy efficiency of higher education building in Bauchi Nigeria would not be an effective tool in the creation of sustainable buildings.

Alternative Hypothesis:

H_1: A design framework to assess energy efficiency of higher education building in Bauchi Nigeria would be an effective tool in the creation of sustainable buildings.

The T test is a type of inferential statistics used to determine whether there is a difference between the means of two groups which are most at times related with certain features. It is one of the many test used for hypothesis testing. Having the t as the calculated t-statistics from the data. The df gives the degree of difference between the Means of the two observed population. The t-test used the responses gotten from the architects with a total of 40 architects from the study area and their response was used to test these hypotheses and the results are presented on Table 4.

From the T-test Table 4, the p-value (Sig (2-tailed)) has a value of 0.000. Since the p-value (0.000) is less than the level of significance (0.05), we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1) to conclude that a design guide for higher education building in Bauchi Nigeria would be an effective tool in the creation of sustainable buildings.

Table 4: T-Test

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Do you think a design guide for higher education building in Bauchi Nigeria would be an effective tool in the creation of sustainable buildings?	20.113	39	.000	3.450	3.10	3.80

Source: Authors Survey (2021)

Time, finance, available space and human resources always place constraints on any research project, forcing adjustments between coverage and level of detail. During the survey of existing higher educational buildings, the indoor air temperature and humidity of one of the five buildings selected in the study area was measured to support the understanding on thermal comfort condition in indoor spaces and presented for the purposes of analysis in this study. Table 5 shows the indoor temperature and humidity measured during the survey. Amongst information in Table 5 include the date and time measurement and the presence or absence of mechanical cooling device used in the buildings. “Yes (Y)” or “No (N)” were recorded as symbols to indicate whether windows were opened during the time of measurement or not. Similar approach was adopted to indicate whether mechanical ventilation was in use during the measurement or not.

Table 5: 500 Capacity Lecture Hall, Federal Polytechnic Bauchi

Date	Time	Average Indoor Temperature (°C)	Average Humidity (%)	Window opened during Measurement (Y/N)	Mechanical Ventilation in Use or Not during Measurement (Y/N)	Type of Mechanical Ventilation
3/1/2020-27/1/2020	13.10/16.40	35.5	23	Y	Y	FAN/AC
1/2/2020-26/1/2020	9.20/16.00	35	21	Y	Y	FAN/AC
3/2020-27/3/2020	10.10/15.30	37.8	19	Y	Y	FAN/AC
2/4/2020-25/4/2020	9.00/16.30	40	19	Y	Y	FAN/AC
4/5/2020-28/4/2020	10.20/15.20	36	17	Y	Y	FAN/AC
1/5/2020-29/5/2020	9.00/16.30	35	39	Y	Y	FAN/AC
2/6/2020-30/6/2020	10.05/17.20	35	51	Y	Y	FAN/AC
2/7/2020-30/7/2020	9.30/16.10	31.5	61	Y	N	FAN/AC
4/8/2020-29/8/2020	9.20/16.10	30.5	75	Y	N	FAN/AC
20-29/9/2020	9.10/14.10	29.5	70	Y	Y	FAN/AC
1/10/2020-28/10/2020	9.50/17.05	33	63	Y	Y	FAN/AC
2/11/2020-30/11/2020	08.40/15.40	33.5	30	Y	Y	FAN/AC
2/12/2020-30/12/2020	08.20/16.35	33	28	Y	Y	FAN/AC

Source: Authors Survey (2020)

The result of survey shows also that most of the respondents were slightly comfortable only during the morning hours of lecture periods even though the indoor temperatures were 28^{0}C-30^{0}C.

The Temperature Humidity Index according to Windchill Metrology (2010) in the United States is the combination of temperature and humidity that is a measure of the degree of discomfort experienced by an individual usually in warm weather. The index is essentially an effective temperature based on air temperature and humidity. It equals 15 plus 0.4 times the sum of simultaneous readings of the dry and wet bulb temperatures. Based on the measurement so far in the study area the dry bulb temperature is 95^{o}F (35^{o}C) and wet bulb is 50^{o}F (10^{o}C).

The discomfort index is hence calculated as 15 + 0.4(145) = 73^{o}F

Most humans are comfortable when the index is less than 71^{o}F. It is recommended that even if the discomfort sensation is not obvious, adequate protection measures should be taken. Hence there is an urgent need to seek cooler internal environment by sensible and passive design methods to cool the lecture spaces. All buildings surveyed rely on ceiling fan and AC for cooling. Notwithstanding the use of ACs and fans, indoor temperatures measured in all buildings during the survey were still high ranging from about 30 - 42^{0}C. This is due to obvious air leakages from open windows which is not supposed to function with open fenestration. User occupant sensitisation is key even with the best design consideration followed in generating these lecture spaces. There is need for a policy framework that will guide the operationalisation of these lecture spaces

Figure 1: 500 Capacity Lecture Hall, Federal Polytechnic Bauchi
Source: Authors 2021

The lowest temperature occurred in September at 29^0C while the highest indoor temperature recorded was in the month of April at 40.5^0C. The mean indoor temperature for the building was 40.20^0C which is slightly above the average highest temperature during the hot (dry) season of about 40.10^0C (Machar, 2017). Survey results examining variables affecting thermal comfort as seen earlier in the discussion show that building occupants are not always comfortable in their buildings without mechanical cooling systems. Hence, building occupants depended largely on mechanical cooling systems which is Ceiling Fans and Air conditioning systems. It is also worthy to note that effort through achieving a good energy performing building which will ensure comfort for the occupant and reduce energy consumption which is also a scarce resource in Nigeria as a whole cannot be overemphasized as these mechanical systems are prone to breakdown and most of the time vandalism hence the need for a passive approach to designing of these facilities.

Observational Survey:

The observational survey of the existing buildings was carried out bearing in mind the following; building elements and landscaping which is to ascertain what is required in design, material specification and the approach to the construction of higher educational buildings in Bauchi Nigeria in order to provide data for the production of the proposed framework. The building elements observed were the floor, external wall, windows, ceiling and roof.

The result of the survey of the building in terms of landscaping, window types, floor materials seems to point to the need for massive advocacy for proper landscaping around buildings, as this is relevant to achieving thermal comfort and increasing the energy performance of higher educational buildings. Appropriate window sizes and ceiling materials deployed in this building will also go a long way in achieving a good energy performing building. Most professionals in the built environment and architects in the study area supported this view.

Findings:

From the analysis so far, the lowest annual average operative temperature for case study is 29.5^{0}C. The study of the selected buildings exposed that there are no substantial differences between them in terms of thermal comfort. The annual operative temperature for the case studies shown above affirms this. The measurement of climatic data established the level of thermal discomfort in buildings leading to overdependence on mechanical cooling systems, especially ceiling fans and Air Conditioners. The mean indoor temperature for the building was 35.90^{0}C. The results of the analysis of case studies have confirmed thermal discomfort in buildings, the need to improve comfort level in Higher Educational buildings and reduce energy demand due to too much reliance on mechanical cooling systems. There were no thoughtful decisions during design on building orientation based on passive design strategies. Consequently, this research investigation confirms the assertions above on the low level of knowledge and information in Nigeria.

By implication this proposes that the built environment professionals are not likely to apply the most appropriate features for the production of sustainable buildings. A key basis of buildings' orientation by design professionals were based on the availability of space within the department of interest were building will be constructed and major access road to the facility as most buildings were designed to face the major access road. Solar radiation has been observed to be an important parameter in determining the cooling load in a building. All the buildings depend on mechanical cooling systems for thermal comfort. The study also shows that building retrofits can be conducted not just for reducing energy consumption by HVAC and lighting systems but to improve thermal comfort within buildings and can be done affordably to benefit institutional buildings whom are not so much a revenue generating agency hence the need for low cost intervention for maintenance of its structures. All higher educational buildings in the study area lack adequate landscaping to enhance cooling of interior spaces which will allow the building to perform better in term of energy consumption for cooling. This brings to fore a massive necessity for proper landscaping around buildings to aid thermal comfort. The observation of the building envelope calls for improvement in design, material selection and construction approach to improve energy consumption and downsize energy demand. Some areas of concern include choice of paint finish, choice of roofing materials, geometry of roofing structure to aid hot air exit from buildings, window and glazing type, shading devices and other wall finishes

Passive cooling in buildings is another means of making our buildings sustainable. It can be said to be removal/restriction of heat from/to the building environment by using the natural process of rejecting heat in the ambient atmosphere by convection, evaporation, and radiation or the adjacent earth by conduction and convection which is cheaper to execute. Cool outdoor air properly harnessed through conscious design efforts, can be effective in cooling buildings in the tropics with little need for mechanical cooling. Cooling through convection by surrounding air, which serves as a heat sink has been used to achieve comfort condition indoors in hot humid locations. Architects and planners should endeavour to apply passive design strategies at the design stage, to increase building performance and encourage sustainability in new construction. Self-regulating policies by the government, to include sustainable building retrofit option for adaptation in existing buildings to the changing climate conditions. Natural ventilation requires a driving force, and sufficient number of window openings to produce air flow (Harvey, 2008). Wind is the driving force for passive cooling. Hence, the building orientation should take advantage of the prevailing winds to achieve cooling.

Solar shading is a significant approach in developing countries because it is cost effective and easy to implement (Kamal, 2011). Shading of buildings and outdoor spaces can lower temperatures during hot periods, improves comfort and save energy by blocking up to 90% of the heat generated by direct sun from heating the surface of buildings. Shading devices such as overhangs on roofs and windows, awnings, louvers shutters, pergolas, proper length of shading all devices which can be part of the building or placed close to the building, can serve as efficient means of achieving passive cooling. A proper site analysis will aid the placement of shading devices to minimise heat gain and storage.

5. Conclusion

This study investigated the use of sustainable design in reducing the total energy consumption in higher educational buildings in Bauchi Nigeria. It was discovered that most buildings pervading the built environment lack the basic facilities to make them self-sufficient in the conservation of energy for heating/cooling/lighting/ventilation which was ascertained from response gotten from the questionnaires. Building retrofits can be conducted as seen not just for reducing energy consumption by HVAC and lighting systems but to improve thermal comfort within lecture spaces and can be done in a low cost form to the government who are the major owners of these institutions. There are two important ways we can approach the efficient use of energy, the first one is the technological approach while the second is the behavioural approach which can only be achieved by having adequate information on best practices in conserving energy in running of buildings. There is urgent need for policy makers to invest into energy awareness creation on energy efficient buildings stating the importance in terms of environmental, economic and social factors

Architects and planners should ensure they apply passive design strategies at the design stage, to improve building performance and promote sustainability in new construction. Independent policies should be added to the Building Code for Nigeria by the government, to include building retrofit as an option for adapting existing buildings to the changing climate. Significant development has been made in the area of Energy Balancing of buildings using the principles of Building Physics which will serve as a guide to draft policy in future energy regulations documents.

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