# Effects of Energy Efficient Architectural Design Features on Users' Thermal Comfort in a Typical Private Nigerian University

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## Abstract

The effects of energy efficient architectural building design Features on the users' thermal comfort in public building spaces have become critical concerns on the built environment in Nigeria. This study therefore relied on the collection of data from respondents that receive their lectures from three (3) selected auditorium buildings in Ajayi Crowther University Oyo State Nigeria. The methodology engaged quantitative techniques by the administration of questionnaire (with 40 questions). The study assessed the: (i) existing energy efficiency design features in the auditorium buildings, (ii) application of the energy efficiency design features in the auditorium buildings and (iii) critical success factors that influence the application of the energy efficiency building design features in the auditorium buildings. The results revealed Ten (10) energy efficiency architectural design features applied in the three (3) auditoria with the respondents mostly agreed on the availability of sun shading devices and the use of operable windows. In terms of the application of the architectural building design features in the selected auditoriums, the respondents mostly agreed on the application of raked sitting arrangements ranked 1st, LED (light emitting diode) lighting ranked 2nd, solar shading devices ranked 3rd and green roof as the least (10th) agreed upon respectively. More so, the critical success factors that determine application of architectural building design features in the auditorium buildings, the respondents mostly agreed on the willingness of the school to finance the purchase and installation of these design features (3.50) and the organisation of enlightenment seminars by the school authorities (3.31). This study concluded that improvements in the application of architectural design features that enhance users' thermal comfort levels can be made inclusive and other more effective energy efficient measures could also be integrated to improve the thermal comfort experiences of the users of the auditorium buildings in the school environment. This study suggested further studies on other smart technologies that can simulate the effects of energy efficiency-tropical design features that can enhance users' thermal comfort satisfaction.

**Keywords**: Architectural, Auditorium, Comfort, Design, Energy, Efficient, Features, Thermal

## 1. Introduction

The energy efficiency of architectural building design features has had adverse effects on the users'thermal Comfort in public building spaces. In most climates in the tropics around the built environments of the world, building construction and design contributes to 30 percent of the adverse consumption patterns which are responsible for the release of large amounts of carbon emissions in the environment thereby harming the environment. Again, the recent challenges of climate change calls for a reevaluation of how we build and arrange spatial functional relationships in the design and construction of buildings. Therefore, there is the need to now design buildings not only to suit human needs but to also enhance the climatic demands of our tropical environments.

In the last decade, due to climate change, the global mean temperature increase went from $0.1^{O}$ to $2.8^{O}$and is predicted to increase (Rahmstorf & Coumou 2011) and with this huge increase in global temperatures, our internal environments are also being affected as the external climate has a great effect on the internal environment. This made the indoor mean temperature differs from place to place. However, the internal environment can be controlled in order to achieve a sensible level of comfort in the tropical environment. Also, the American Society of Heating Refrigerating and Air Conditioning Engineers, thermal comfort is

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referred to as the condition of the mind which expresses satisfaction or dissatisfaction with the thermal environment (ASHRAE 2017). Thermal comfort can be said to have been achieved when at least 80 percent of the occupants of a building are comfortable (HSE 2016). Therefore, thermal comfort which has varied implications on the occupants comfort levels within a space does not connote measurements in degrees or numbers but involves other factors that are quite complex when achieving comfortability within spaces. Therefore accessing thermal comfort can be based both on physical environmental factors as well as personal physiological factors (Neto, Bianchi, Wurtz, and Delinchant 2016). Environmental factors such as temperature and humidity play a big role in the indoor thermal environment of a space while personal factors such as body metabolism, clothing insulation and weight play a role on how humans perceive a space.

It is believed that a lack of comfort levels within spaces can have huge health consequences within a given environment and also affects the occupants' functional activities within the spaces or working environments also. As a direct consequence and implication of these lack of comfort levels in academic buildings is the effects attributable on the user's health, productivity and psychology of the users of the academic spaces thereby affecting their optimum learning abilities. A pleasant and accommodating learning environment can encourage active learning, which may finally improve learners' conceptual understanding, therefore, thermal discomfort in overheated or undercooled learning spaces can be connected to physical stress (thermal stress), which may be the cause of illnesses and subpar performance in pupils (Lau, Zhang & Tao, 2019). Tertiary institutions like universities have auditoriums as their principal spaces for the acquisition of knowledge and these are constituted mainly of large functional areas where the students receive their lectures. In addition, these spaces usually accommodate large numbers of individuals and for effective and proper understanding and assimilation of these requisite knowledge, these large functional spaces should be comfortable in terms of their thermal occupancy and volume.

Building design features play a big part in thermal comfort as they control the internal environmental factors of a space. The temperature, humidity or air pressure of a particular space can be controlled through certain features implemented in the building design. Architectural building design features are certain elements and characteristics that are incorporated into building design to create a safe and functional structure. These building design features that promote thermal comfort in buildings can be divided into two categories: passive and active design strategies. Passive design strategies are building design features that rely on the natural elements of the environment to regulate indoor temperature, such as insulation, shading and orientation while active design strategies, on the other hand, are building design features that rely on mechanical systems, such as air conditioning, to regulate indoor temperature (Asadi, Omidvar & Ganjehkaviri2016). However due to the general changes in the climatic condition and Nigeria being a tropical region, experiencing an even high temperature that is predicted to get even hotter and more humid with predicted mean temperature of 24 to 30 degrees over time according to (Joshua, Kandar, Aminu & Opeyemi 2012). The world is leaning towards more energy efficient designs and also embarking on designs that allow for less carbon emissions. Energy efficient building design features aim at reducing energy consumption, minimizing environmental impact, and promoting sustainable practices. However, Energy efficiency is not highly considered in Nigeria both in residential and commercial sectors hence people end up using more energy than they should actually consume just to get a thermally comfortable environment (Rashad, Khordehgah, Żabnieńska-Góra, Ahmad & Jouhara 2021). Therefore, the current research looks to suggest energy efficient building design features that can be incorporated into the design process that would reduce dependence on mechanical means. When buildings are not properly designed, we often make up for it with more usage of air conditioning and other lighting fixtures which tend to allow for heavy energy consumption patterns thereby reducing building efficiency and then in turn affecting the natural environment. Hence, the need to implement these design features in the beginning of design. These features include passive features such as double-skin facade, proper building orientation, fenestrations, climatic adaptive building shells, size and types of openings, use of operable windows and sun shading devices. Active design features include HVAC systems, use of solar panels and energy efficient landscaping. Building materials selections also play a huge role in the thermal comfort of a space. Also, it is noteworthy that any increase resulting from heat transfer due to the materials used in the construction process makes it imperative for designers to take a critical look when designing auditorium buildings (Asaju, Alagbe & Adetona 2023). This is because students learning experience is usually developed here since they spend a large proportion of their time within the user's space. Materials of construction in the form of the type of envelope system used becomes a barrier separating the both the indoor environment and the outdoor environment thereby enhancing the comfort level within the desired space. As a result, specifying the right type of envelope system is important in maintaining a comfortable indoor environment thereby reducing the dependence on mechanical ventilation systems within the desired spaces thereby enhancing the sustainability of the building structure. Thermal mass and the height of seating arrangement are also investigated which according to (Ricciardi, Ziletti & Buratti2016) suggest that air distribution at different heights in auditoriums differ.

Not only does an energy efficient building feature reduce the effects on other buildings around it and the environment as a whole, it also reduces the amount of money spent on power supply and even fuel which will be a big advantage for the university and even Nigeria as a whole. *In the face of vehement lack of electricity power supply and extreme rise in fuel prices (recent subsidy removal saga), costs of maintaining higher education facilities, staff and student wellbeing or welfare have been on a skyrocketing level. Presently, as at the time of this investigation, Nigeria as a country is at a critical challenging state.* Currently, most studies in this sphere were done in the developed countries of the world where Nigeria depended for economic survival. The energy problem in Nigeria therefore would need local-amicable solutions, climate-specific with little or no external interventions. Therefore, this evaluated the building features that can be integrated into the design process of tropical (i.e auditorium) buildings in order to create a thermally comfortable environment for students to learn and teachers to teach well with little or no external need for power supply or the use of heavy mechanical or electrical systems (i.e for the cooling and heating of these spaces-HVAC).

# 2. Literature Review

## 2.1Thermal Comfort and Its Design Measures

There are energy efficient building design features that enhance the building occupants comfort levels within the building space and these are associated with certain environmental factors influencing the space and the building occupant's perception levels resulting from their personal physiological factors. Therefore, thermal comfort is evaluated by comparing environmental factors and subjective human responses to these factors. In a study to find the relationship between a space and personal variables by (Chan, Chau & Leung, 2017), the study shows that climatic factors have an equal effect on the perception of thermal comfort just as psychological adaption (personal variables), environmental factors; temperature: temperature is one of the main factors affecting thermal comfort because not only does general external temperature in different climates affect the indoor thermal experience, the internal body temperature also has to be at a balance to be able to perceive the thermal environment rightly. On the other hand, air movement is another important factor, as it has to do with how air flows through the space that is the speed and the direction. Either by natural ventilation or with fans as adequate air movement enhances comfortability by removing excess heat and transfer of heat from the body through convection. Humidity refers to the amount of moisture or water vapor present in the air. Naturally, the human body cools through evaporation and perspiration. However, when there is high humidity, it leaves even more moisture on the skin and reduces the body's ability to cool naturally. The humidity should not be too low as well as it can cause dryness on the skin. Therefore, it is advised that relative humidity for thermal comfort should be around 40 to 60 percent.

## 2.2Architectural Building Design Features

Architectural Building design features are characteristics, parts, or components of a building that contributes to the overall appeal of the building in terms of aesthetics, thermal environment, functionality, stability and sustainability of the building. These features can be adjusted to achieve various purposes for instance, in a study of building features in relation to seismic forces it was advised to consider proportion in building plan layout that the buildings must be in the right proportion, i.e., if a building is too long or too tall it is more prone to seismic forces (Madeh, Ayineh, Moezzi & Yazdi 2009).

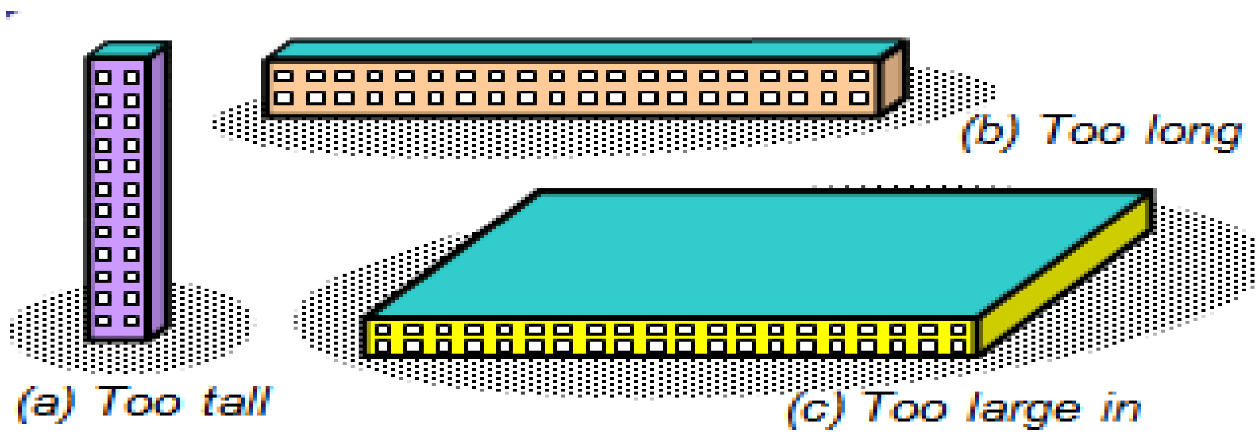


***Plate 1:*** *Architectural Building Design Features*

***Source****: The Constructor*

Building design features are to be incorporated during the primary planning stage of the design because often time they are added to correct what has already been done wrong in the design phase. These features These features can include elements such as the building's layout, orientation, materials, insulation, windows, natural lighting, shading devices, renewable energy systems, water efficiency measures, green spaces, and overall architectural design. Incorporating these design features is essential for promoting energy efficiency.

## 2.3Energy Efficient Building Design Features

Over the past few years, building owners, designers, contractors, and facility managers have placed significant emphasis on prioritizing the integration of energy-efficient and environmentally sustainable design elements in both new and existing buildings. It involves the study of the energy-related effects and relationships of various building elements, encompassing factors such as the building's placement, structure (including walls, windows, doors, and roof), heating, ventilation, and air conditioning (HVAC) system, lighting, controls, and equipment. How all these factors are combined and designed plays a big role in controlling the general internal environment of the space (Kim, Stumpf & Kim 2011). Energy efficient building design features show that a building can achieve maximum satisfaction without reliance on heavy electrical and mechanical use which also has less harmful effects on the environment and less carbon emission which goes in line with the goals of world climate change policies such as the Paris agreement whose main goal is to limit global warming to 1.5°C and for green houses gases to decline by 43% by 2023 as well as other policies with the general goal of reducing climate change.

## 2.4 Energy Efficient Building Design Features Affecting Thermal Comfort

The incorporation of energy-efficient building design elements has a notable influence on the thermal comfort experienced inside buildings. These features are specifically designed to create pleasant indoor environments while simultaneously reducing energy consumption. The U.S. Department of Energy (DOE) asserts that integrating energy-efficient design strategies can effectively enhance building performance, leading to enhanced thermal comfort and decreased energy consumption which further leads to less carbon emission or emission of greenhouse gases. Some of these energy efficient building design features that affect thermal comfort are:

### 2.4.1 Adaptive Building Facades

In a study conducted in Lagos by (Sholanke & Ademo 2022), the results demonstrated thus suggesting placing emphasis at the design stages of construction on thermal comfort levels of building occupants while using and specifying energy efficiency measures. As a direct result and consequence on the thermal comfort levels of building occupants associated with the specification of energy efficiency design measures was the application of energy efficient adaptive facades which not only improves the buildings energy efficiency and energy consumption levels within the building structure due to their innate abilities to change their behavior in real-time according to indoor-outdoor parameters by means of materials, components, and systems.

***Plate 2:*** *Adaptive Building Facades*
***Source****: Next Tech Construction*

### 2.4.2 Space Conditioning and HVAC Systems

Another strategy towards achieving thermal comfort in buildings is the application of energy efficient space conditioning systems. A conditioned space would be a space with a cooling or heating system installed, and ASHRAE 90.1 defines the minimum cooling or heating capacity that the system must have to be considered conditioned. These cooling and heating systems have to reach a certain level of efficiency according to ASHRAE standards for it to be considered adequate. Therefore, the heating and cooling of a place can be conditioned according to the need of the space or even the region it is located, as much colder regions might want to increase their indoor temperature through heating and hotter regions might want to decrease their indoor temperature through cooling.

***Plate 3:*** *Adaptive Building Facades*
***Source****: donnellymech.com*

### 2.4.3 Building Envelope Material

In their study on building envelope systems, (Yüksek & Karadayi 2017) also asserted that building envelopes which revealed that while specifying a buildings external covering otherwise referred to as the envelope system, attention should be placed on this deliverable because they constitute a major construction cost during the construction process. In addition, it should be noted that the envelope system specified normally forms a shield between the buildings internal enevironment and its external surroundings while also maintaining the building's interior conditioned internal spaces which therefore allows for transmissions of thermal energy to the buildings surrounding environment. According to (Mirrahimi, Mohammed & Haw 2017), the indoor thermal environment of a building depends on the types of building energy efficient building envelope materials specified thereby reducing an overdependence on mechanical systems of heat, ventilation and air-conditioning systems usage for enhancements in thermal comfort levels and occupants well-being and increase in occupants productivity levels. Other added advantages as a direct fall out of these advantages derivable from adequate specifications are reductions in life-cycle costings thereby enhancing energy savings derivable. The authors further suggest the adoption of passive design strategies in hot-humid tropical regions of the built environment. In addition, (Bano & Kamal 2016) in their study conclude that materials specified for building construction projects should be selected in accordance with the specific climatic conditions perculiar to a particular environment since the external walls and glazing types of high-rise buildings contribute to adverse heat gains within the buildings constructed. It is further suggested that specified materials of construction should be energy efficient and it is also advisable that emphasis on construction materials should be placed on locally sourced materials that have the tendency of achieving reduced levels of carbon emissions into the built environment. In a study by (Maimagani, Majid & Chung 2023) to evaluate the use of compressed earth bricks as building envelope systems, the authors indicated that embracing these applied bricks not only achieve sustainable design while constructing educational buildings in north western Nigeria helps in achieving teaching and learning activities within them while also boosting the comprehension levels of the students. Other advantages arising from the use of these compressed earth bricks are the creation of conducive internal environments and improved comfort levels for the building occupants for effective assimilation of their studies

### 2.4.4 Daylighting Strategies

It is a widely known fact according to (De Kay & Brown 2014) that effectively using natural daylighting as a source of transmitting light into the building's interior spaces enhances reductions in mechanical ventilating systems within the buildings space for cooling and heating purposes. Therefore, specifying adequate glazing materials and openings achieves the desired purpose which are further influence by application of effective shading devices. These approaches aid in reducing solar heat gains while also reducing cooling loads. In their study on the advantages of passive cooling strategies, (Gupta and Tiwari 2016) suggest passive cooling strategies as a way of limiting the passage of heat into or out of a building space while also requiring little or no mechanical energy on the part of the building owner. Therefore, it is true to state that passive energy efficiency strategies, in general, aid in the achievement of an energy-efficient architectural design.

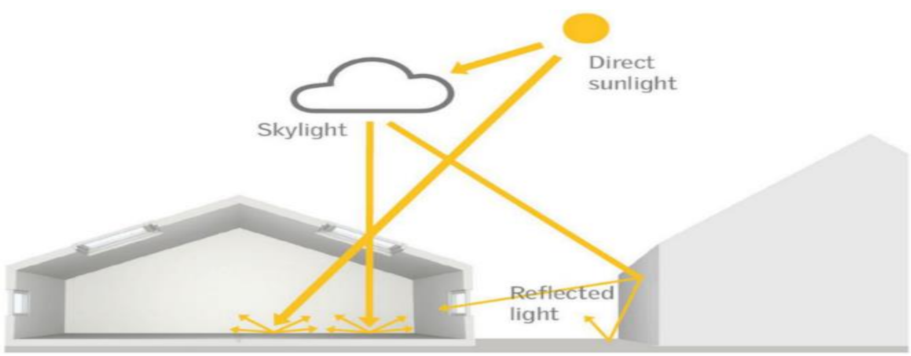


***Plate 4:*** *Daylighting Strategies*
***Source****: Donnellymech.com*

### 2.4.5 Building Orientation

A few Authors (Adebisi, Olagunju, Akande & Akanmu 2019) have shown in their research that the orientation of a building is also significant in improving the thermal comfort of buildings. Building orientation refers to the placement of a building on the construction site in reference to the solar path and wind patterns. Some general rules are: (i) South-facing windows, as much as possible allow direct sunlight in windows at window and shade during summer periods. (ii) Buildings main façade should be oriented towards the sun's path. This maximizes the potential for natural daylighting, solar heat gain during colder months, and shading during hotter months, (iii) Openings should be concentrated around the southwest to take advantage of the cool south west monsoon wind, and (iv) In places with warmer climates, it is advised positioning the long side of the building in an east west direction to minimize direct heat gain during the hottest parts of the day.

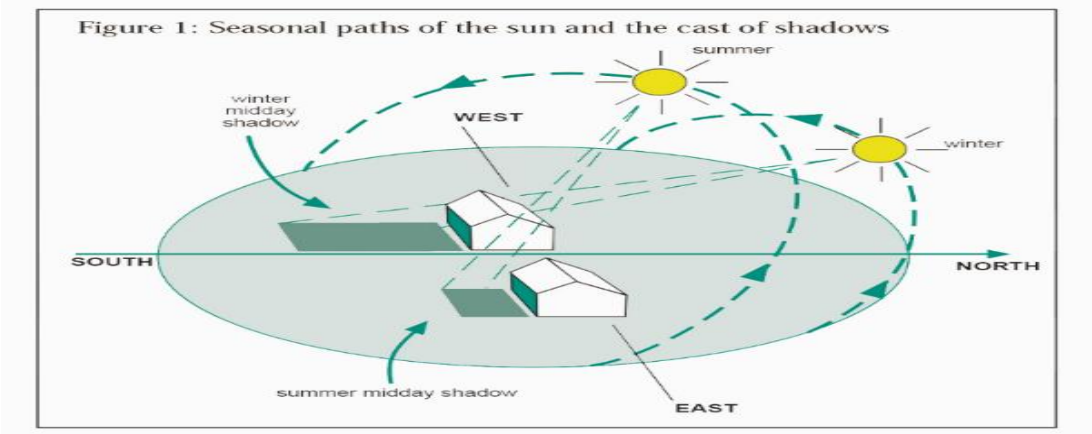


***Plate 5:*** *Building Orientation*
***Source****: Donnellymech.com*

### 2.4.6 Green Areas

In an experimental study which (Saifi, Belatrache & Dadamoussa 2023) discussed extensively, there are advantages gained in using greenery for building components used as walling and roofing systems regarding thermal comfort levels within the buildings spaces while also reducing the buildings temperature levels during dry climatic periods. A lack of green spaces and cool sinks means that dry regions within the built environment will experience greater temperatures. The study further highlighted that green design strategies enhance satisfaction levels while also gaining advantages in studies on thermal comfort and architectural design practices in the long run. In addition, (Ebadati & Ehyae, 2020) analyzed the effects of utilizing a green roof with continuous irrigation of vegetation in place of an asphalt roof in a two-story residential building for three different climates of Iran. It was discovered that the reduction of yearly electricity consumption for space cooling and heating for the three cities of Bandar Abbas, Tehran, & Tabriz is 23.0%, 16.3%, and 12.5%, respectively.

***Plate 5:*** *Green Areas* ***Plate 6:*** *Green Walls*
***Source****: Sponzillli.com****Source****: Sponzillli.com*

# 3. Methodology

The study investigated three (3) different lecture theaters in Ajayi Crowther University, Oyo State, Nigeria, they were: (i) the Law Faculty (Alakija Hall) of the University of 750 Capacity (used for General studies classes, seminars, matriculation ceremony and convocation),(ii) Olaniran Olajire Auditorium (Performing arts auditorium) of 230 seater capacity (used by the performing arts students for their performances and examinations); and (iii) Faculty of Natural Sciences Lecture Auditorium of 300 seaters' capacity. The methodology engaged a cross-sectional sectional survey of the relationship between building design features and thermal comfort of the users. It employed quantitative and qualitative research techniques while the sampling method was purposive. A structured survey questionnaire was administered to collect quantitative data from the respondents. In the course of the surveys, a total of 100 hard copies of the questionnaire were administered to the users of the selected auditorium buildings. However, 83 copies of the questionnaires representing 83% of the total number of questionnaires administered to the users of the auditorium buildings were collected and analysed. The data analysis was both quantitative (primary data- by descriptive) and qualitative (secondary data-textual analysis). The software package used in the quantitative analysis was Statistical Product and Service Solution (SPSS). The respondents were chosen using the purposive sampling methods. The study population (N=83) considered acceptable for this study was eighty-three. In addition, the sample size was three (3) lecture theatres using a purposive sampling method.

# 4. Discussions

## 4.1 Auditorium Buildings and Characteristics of Respondents

The results of the analyses presented in Table 4.1 revealed the respondents' demographic characteristics, specified energy efficient building components used in the construction of the Auditorium Buildings, Application of Energy Efficiency Design Features in the Auditorium Buildings and Critical Success Factors of Application of the selected features in the selected auditorium buildings within the study area. The descriptive analysis reveals the personal profiles of the 83 respondents in the auditorium buildings that participated in the survey of the three (3) selected auditorium buildings investigated in this research (Table 4.1).

**Table 4.1** Names of Auditorium Buildings and Characteristics of Respondents

| Characteristics | Categories | Frequency n=83 | Percentage 100% |
|---|---|---|---|
| Name of Auditorium Building | Alakija auditorium | 29 | 34.9 |
| | Faculty of Natural Sciences Auditorium | 31 | 37.3 |
| | Professor Olaniran Olajire Auditorium | 23 | 27.7 |
| Gender | Male | 39 | 47 |
| | Female | 44 | 53.0 |
| Age of Respondent | 16-20 | 40 | 48.2 |
| | 21-25 | 42 | 50.6 |
| | 26-30 | 1 | 1.2 |
| Status in the institution | Undergraduate | 77 | 92.8 |
| | Graduate | 6 | 7.2 |
| Years in the university | 1-2 years | 24 | 28.9 |
| | 3-4 years | 52 | 62.7 |
| | 5-7 | 5 | 6.0 |
| | 7 and above | 2 | 2.4 |
| Level in the Institution | 100 Level | 14 | 16.9 |

| | | | |
|---|---|---|---|
| | 200 Level | 14 | 16.9 |
| | 300 Level | 15 | 18.1 |
| | 400 Level | 36 | 43.4 |
| | 500 Level | 2 | 2.4 |
| | M.Sc | 1 | 1.2 |
| | Others | 1 | 1.2 |
| Age of Institutiton | Below 5 years | 1 | 1.2 |
| | 5-10 years | 1 | 1.2 |
| | 11-16 years | 68 | 81.9 |
| | 17-22 years | 12 | 14.5 |
| | Above 22 years | 1 | 1.2 |
| Stay | Yes | 77 | 92.8 |
| | No | 6 | 7.2 |

Table 4.1 shows a summary of basic information on the auditorium buildings investigated. The Table 4.1 specifically shows the names of the auditorium buildings that were studied which are the Alakija Auditorium Building, Professor Olaniran Olajire Auditorium Building and the Faculty of Natural Sciences Auditorium Building all domiciled within Ajayi Crowther University Campus.

The results in Table 4.1 further shows that a majority (53.00%) of the respondents sampled were female, while the minority (47.00%) were male. In addition, most (50.60%) of the respondents were between 21 years and 25 years old and around (92.80%) of the respondents were undergraduates. It also showed that around (62.7%) of the respondents had spent between 3 to 4 years in the University (Table 4.1). Furthermore, a majority (43.40%) of the respondents were in 400 Level within the Institution while (81.90%) of the respondents believed that the University had been in existence for between 11 to 16 years. Whereas the highest number (92.80%) of the respondents sampled agree that they stayed within the campus accommodation. (Table 4.1). These results generally indicate that the respondents who participated in the research were mainly middle-aged male and female students and are therefore considered well qualified to provide valid data for this research.

## 4.2 Existing Energy Efficiency Design Features in the Auditorium Buildings

This section presents the results on the existing Energy Efficiency Design Features in the selected auditorium buildings. Table 4.2 shows the results of the descriptive analysis of the 10 selected Energy Efficiency Design Features in the selected auditorium buildings as documented by the 83 respondents sampled in the survey. The results show that in terms of ranking, the respondents are mostly agreed on the availability of sun shading devices the use of operable windows since these have mean scores of (3.43) and (3.24) respectively followed by Adaptive building facades and  air conditioning systems with mean scores of (3.23) and (3.22) respectively Table 4.2.In line with these results is also the evidence that around 51.80%, 48.10%, 49.40% and 48.20% of the respondents mostly agree that there are the availability of sun shading device, use of operable windows, adaptive building facades and air conditioning systems in the auditorium buildings as shown in Table 4.2.

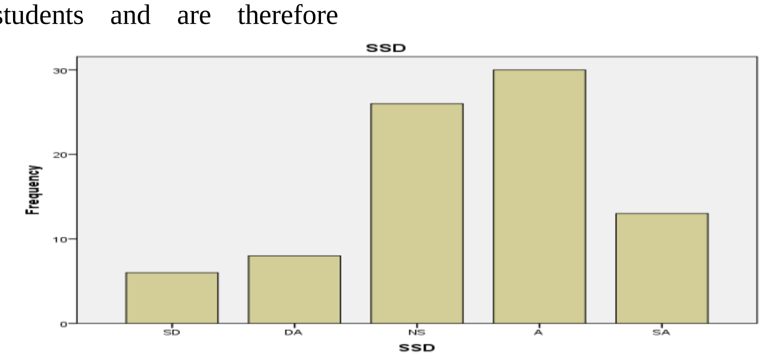


**Fig 4.1:** Sun shading devices bar chart

In Table 4.2, the respondents agreed more on the availability of energy efficiency features. Therefore, sun (solar) shading device was ranked 1st, then, the use of operable windows 2nd, and adaptive building facades ranked 3rd.However, the respondents were found to agree least on the availability of bright colours, raked sitting arrangements, use of solar panels and green roofs. This informed the low mean values of 3.10, 3.01, 3.01 and 2.12 respectively, as shown in Table 4.2.

**Table 4.2:** Descriptive Statistics of Different Energy Efficiency Design Features in the Auditorium Buildings

| | **Energy Efficiency Design Features** | **Level of Agreement of Availability of Different Energy Efficiency Design Features in the Auditorium Buildings** | | | | | Mean | Std Deviation | Ranking |
|---|---|---|---|---|---|---|---|---|---|
| | | Strongly Disagree (1) n(%) | Disagree (2) n(%) | Not Sure (3) n(%) | Agree (4) n(%) | Strongly Agree (5) n(%) | | | |
| 1 | Green Roofs | 30(36.10) | 26(31.30) | 17(20.40) | 7(8.40) | 3(3.60) | 2.121 | 1.109 | 10th |
| 2 | Raked Sitting Arrangements | 6(7.20) | 23(27.70) | 21(25.30) | 24(28.90) | 9(10.80) | 3.084 | 1.139 | 8th |
| 3 | Use of Operable Windows | 6(7.20) | 17(20.50) | 20(24.10) | 31(37.30) | 9(10.80) | 3.241 | 1.122 | 2nd |
| 4 | LED Lighting | 10(12.00) | 15(18.10) | 18(21.70) | 37(44.60) | 3(3.60) | 3.096 | 1.122 | 6th |
| 5 | Use of Solar Panels | 13(15.70) | 17(20.50) | 22(26.50) | 12(14.50) | 19(22.90) | 3.084 | 1.381 | 9th |
| 6 | Air Conditioning Systems | 9(10.80) | 16(19.30) | 18(21.70) | 28(33.70) | 12(14.50) | 3.217 | 1.230 | 4th |
| 7 | Sun Shading Devices | 6(7.20) | 8(9.60) | 26(31.30) | 30(36.10) | 13(15.70) | 3.434 | 1.095 | 1st |
| 8 | Adaptive Building Facades | 8(9.60) | 13(15.70) | 21(25.30) | 34(41.00) | 7(8.40) | 3.229 | 1.119 | 3rd |
| 9 | Tinted Window Glazing | 10(12.00) | 15(18.10) | 23(27.70) | 23(27.70) | 12(14.50) | 3.145 | 1.231 | 5th |
| 10 | Bright Colours | 10(12.00) | 16(19.30) | 22(26.50) | 26(31.30) | 9(10.80) | 3.096 | 1.196 | 7th |

## 4.3 Application of Energy Efficiency Design Features in the Auditorium Buildings

This section presents the results on the application of energy efficiency design features in the selected auditorium buildings. Table 4.3 showed the application of the Ten (10) energy efficiency design features in the selected auditorium buildings as documented by the (n=83) respondents. The results showed that in terms of application of energy efficiency features, the respondents mostly agreed on the application of raked sitting arrangements and LED lighting with the mean scores of (3.45) and (3.28) respectively. More so, these were followed by availability of sun shading devices and bright colours with mean scores of (3.32) and (3.26) respectively.

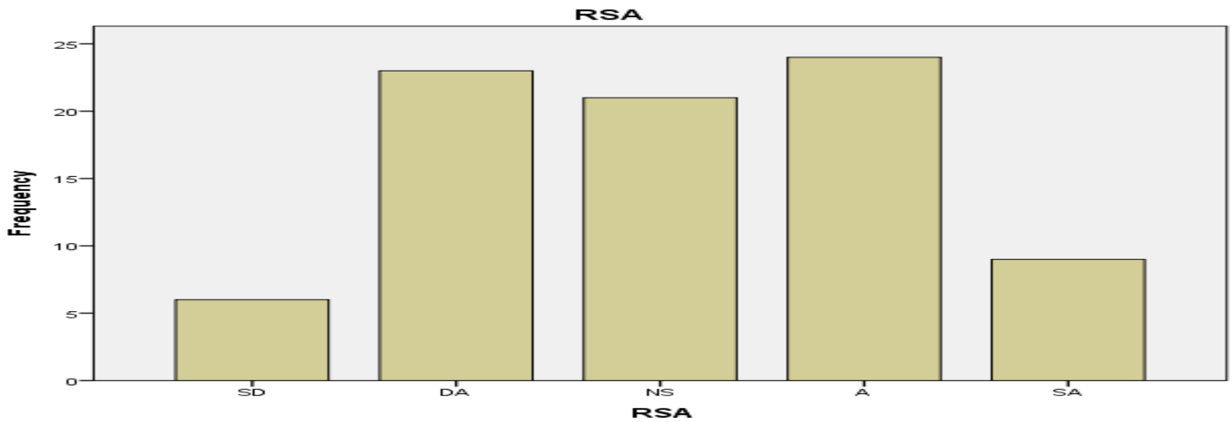


**Fig 4.2:** Raked seating arrangement bar chart

Also, the respondents mostly agree that there was application of raked sitting arrangements, LED lighting, sun shading devices and bright colours in the (1st, 2nd, 3rd and 4th respectively) auditorium buildings.

**Table 4.3:** General Descriptive Statistics of Applications of Different Energy Efficiency

**Design Features in the Auditorium Buildings**

| | **Energy Efficiency Design Features** | **Level of Agreement of Application of Different Energy Efficiency Design Features in the Auditorium Buildings** | | | | | | Mean | Std Deviation | Ranking |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Very Inadequate (1) n(%) | Inadequate (2) n(%) | Not Sure (3) n(%) | Adequate (4) n(%) | Very Adequate (5) n(%) | Error | | | |
| 1 | Green Roofs | 36(43.40) | 21(25.30) | 13(15.70) | 8(9.60) | 5(6.00) | | 2.096 | 1.236 | 10th |
| 2 | Raked Sitting Arrangements | 4(4.80) | 23(27.70) | 22(26.50) | 26(31.30) | 7(8.40) | 1(1.20) | 3.470 | 3.448 | 1st |
| 3 | Use of Operable Windows | 9(10.80) | 17(20.50) | 21(25.30) | 25(30.10) | 11(13.30) | | 3.145 | 1.211 | 6th |
| 4 | LED Lighting | 5(6.00) | 14(16.90) | 23(27.70) | 35(42.20) | 6(7.20) | | 3.277 | 1.028 | 2nd |
| 5 | Use of Solar Panels | 13(15.70) | 15(18.10) | 19(22.90) | 21(25.30) | 15(18.10) | | 3.121 | 1.338 | 7th |
| 6 | Air Conditioning Systems | 10(12.00) | 18(21.70) | 15(18.0) | 29(34.90) | 11(13.30) | | 3.157 | 1.254 | 5th |
| 7 | Sun Shading Devices | 7(8.40) | 10(12.00) | 31(37.30) | 27(32.50) | 8(9.60) | | 3.229 | 1.063 | 3rd |
| 8 | Adaptive Building Facades | 15(18.10) | 10(12.00) | 26(31.30) | 25(30.10) | 7(8.40) | | 2.989 | 1.225 | 9th |
| 9 | Tinted Window Glazing | 12(14.50) | 14(16.90) | 21(25.30) | 25(30.10) | 11(13.30) | | 3.108 | 1.259 | 8th |
| 10 | Bright Colours | 9(10.80) | 12(14.50) | 25(30.10) | 29(34.90) | 8(9.60) | | 3.181 | 1.139 | 4th |

However, the respondents were found to least agree on the application of solar panels, tinted window glazing, adaptive building facades and green roofs. This informed the low mean values of 3.12, 3.11, 2.99 and 2.10 respectively, as shown in Table 4.3. These results indicate that the respondents who were involved in the study listed in Table 4.3 agreed more on the application of application of raked sitting arrangements, LED lighting, sun shading devices and bright colours in the auditorium buildings.

**Table 4.4:** Statistical Test of Applications of Different Energy Efficiency Design Features in the Selected Auditorium Buildings

| S/No | Existing Energy Efficiency Design Features | Auditorium Buildings | | | Chi Square ($X^2$) | Asymp Sig |
|---|---|---|---|---|---|---|
| | | Alakija Auditorium | Professor Olaniran Auditorium | Faculty of Natural Sciences Auditorium | | |
| 1 | Green Roofs | 5 | 5 | 5 | 11.680 | .166 |
| 2 | Raked Sitting Arrangements | 11 | 10 | 12 | 7.971 | .632 |
| 3 | Use of Operable Windows | 13 | 9 | 14 | 5.047 | .753 |
| 4 | LED Lighting | 17 | 13 | 11 | 6.496 | .592 |
| 5 | Use of Solar Panels | 13 | 12 | 11 | 5.769 | .673 |
| 6 | Air Conditioning Systems | 13 | 13 | 14 | 2.885 | .941 |
| 7 | Sun Shading Devices | 15 | 9 | 11 | 8.640 | .374 |
| 8 | Adaptive Building Facades | 11 | 11 | 10 | 6.290 | .615 |
| 9 | Tinted Window Glazing | 16 | 11 | 9 | 13.185 | .106 |
| 10 | Bright Colours | 14 | 12 | 11 | 6.627 | .577 |

In Table 4.4, it is also evident that in terms of applications of different energy efficiency design features, raked sitting arrangements was most significant (Asymp=.632; $X^2$=7.97) with faculty of natural sciences auditorium, more significant with LED lighting in Alakija auditorium (Asymp=.592; $X^2$=6.49) and much was the sun(solar) shading devices (Asymp=.374; $X^2$=8.64) also with most applications in Alakija auditorium. The statistical tests revealed that Alakija auditorium has more energy efficiency features applications than the other two (2) auditoriums.

## 4.4 Factors That Influence Application of Energy Efficiency Building Design Features in the Auditorium Buildings

This section presents the results on the factors that influence the application of energy efficiency design features in the selected auditorium buildings. Table 4.4 shows the results of the descriptive analysis of the nine selected factors affecting the application of energy efficiency design features in the selected auditorium buildings as documented by the 83 respondents sampled in the survey. According to the results of the survey, it is shown that in terms of ranking, the respondents are mostly agreed on the willingness of the school to finance the purchase and installation and Enlightenment seminars since these have mean scores of (3.50) and (3.31) respectively.

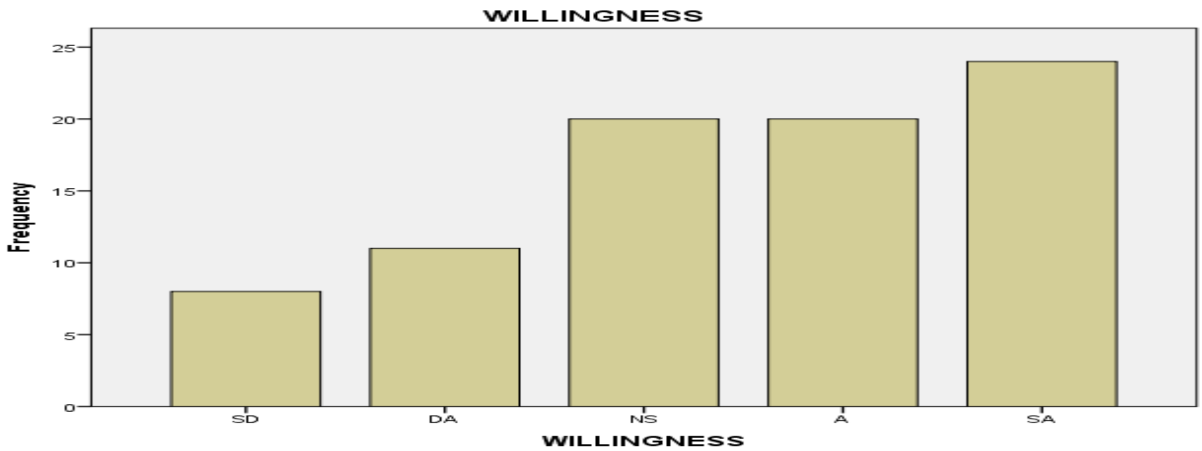


**Fig 4.3:** Willingness of the school to finance the purchase and installation bar chart

Management and leadership and appropriate policies with mean scores of (3.30) and (3.29) respectively as shown in Table 4.4 follow them. In line with these results is also the evidence that around 53.00%, 47.1%, 45.80% and 42.20% of the respondents mostly agree that there is the willingness of the school to finance the purchase and installation, enlightenment seminars, support of the management and leadership and appropriate policy measures as factors affecting the application of energy efficiency design features in the auditoriums as shown in Table 4.5

**Table 4.5:** Descriptive Statistics of Factors That Influence Application of Energy Efficiency Building Design Features in the Auditorium Buildings

| | **Factors** | **Level of Agreement of Factors Influencing the Application of Energy Efficiency Design Features in the Auditorium Buildings** | | | | | Mean | Std Deviation | Ranking |
|---|---|---|---|---|---|---|---|---|---|
| | | Strongly Disagree (1) n(%) | Disagree (2) n(%) | Not Sure (3) n(%) | Agree (4) n(%) | Strongly Agree (5) n(%) | | | |
| 1 | Knowledge | 25(30.1) | 15(18.1) | 18(21.7) | 17(20.5) | 8(9.60) | 2.615 | 1.360 | 9$^{th}$ |
| 2 | Attitude and Belief | 4(4.80) | 15(18.10) | 31(37.30) | 20(24.10) | 13(15.70) | 3.277 | 1.086 | 5$^{th}$ |
| 3 | Training Programs | 7(8.40) | 12(14.50) | 28(33.70) | 25(30.10) | 11(13.30) | 3.253 | 1.124 | 6$^{th}$ |
| 4 | Enlightenment Seminars | 7(8.40) | 14(16.90) | 23(27.70) | 24(28.90) | 15(18.10) | 3.313 | 1.199 | 2$^{nd}$ |
| 5 | Appropriate Policies | 7(8.40) | 9(10.80) | 32(38.60) | 23(27.70) | 12(14.50) | 3.289 | 1.110 | 4$^{th}$ |
| 6 | Availability of Energy Efficient features | 15(18.10) | 11(13.30) | 21(25.30) | 28(33.70) | 8(9.60) | 3.036 | 1.263 | 8$^{th}$ |
| 7 | Cost | 11(13.30) | 8(9.60) | 29(34.90) | 23(27.70) | 12(14.50) | 3.205 | 1.207 | 7$^{th}$ |
| 8 | Management and Leadership | 5(6.00) | 19(22.90) | 21(25.30) | 22(26.50) | 16(19.30) | 3.301 | 1.197 | 3$^{rd}$ |
| 9 | Willingness of the School | 8(9.60) | 11(13.30) | 20(24.10) | 20(24.10) | 24(28.90) | 3.494 | 1.301 | 1$^{st}$ |

However, the respondents were found to least agree on the cost, availability, and knowledge of energy efficiency design features as factors influencing their application in the auditoriums. This informed the low mean values of 3.21, 3.04 and 2.62 respectively. These results indicated that the respondents who were involved in the study listed in Table 4.5 agreed more on the willingness of the school (ranked 1st), enlightenment seminars (ranked 2$^{nd}$), the management and leadership support (ranked 3$^{rd}$) and appropriate policies (ranked 4$^{th}$) as factors influencing the application of energy efficiency design features in the auditoriums.

## 4.5 Application of Energy Efficiency Design Features on Thermal Comfort in the Auditoriums

Based on the results of the survey, it was discovered that the majority of the respondents agreed most on the normal level (m=2.89; 37.30%) of thermal comfort in the auditorium, more on the cold comfort level (m=2.87; 15.70%) and the least agreed that they felt hot (tending to discomfort spectrum levels; m=2.86; 37.40%) in the auditoriums.

**Table 4.6:** Descriptive Statistics of How the Application of Energy Efficient Feature Affect the Level of Thermal Comfort in the Auditorium Buildings

| | **Influence on Thermal Comfort** | **Level of Agreement of Extent of Fire Safety Design Measures in the Auditorium Buildings** | | | | | | Mean | Std Deviation | Ranking |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Strongly Disagree (1) n(%) | Disagree (2) n(%) | Not Sure (3) n(%) | Agree (4) n(%) | Strongly Agree (5) n(%) | Error | | | |
| 1 | Hot | 21(25.30) | 18(21.70) | 13(15.70) | 14(16.90) | 17(20.50) | | 2.855 | 1.491 | 3rd |
| 2 | Cold | 12(14.50) | 32(38.60) | 25(30.10) | 11(13.30) | 2(2.40) | 1(1.20) | 2.868 | 3.488 | 2nd |
| 3 | Normal | 12(14.5) | 22(26.50) | 18(21.70) | 25(30.10) | 6(7.20) | | 2.892 | 1.200 | 1st |

From Table 4.6, the results revealed various existing energy efficiency building design features in the selected auditorium buildings: availability of sun shading devices had the highest mean score (m=3.43), next was the use of operable windows (m=3.24) and the least in adaptive building facades (m=3.23). It was further found from the results of the data analysis that regarding the application of energy efficient building design features in the selected auditorium buildings, raked sitting arrangements had the highest mean score of 3.47 with LED lighting and sun-shading devices were second and third with mean scores of 3.28 and 3.23 respectively.

For factors that influence the application of energy efficient building features design in the auditorium buildings, the willingness of the school to finance the purchase and installation with mean score of 3.50 was the highest factor determinant in the study of the selected auditorium buildings in Ajayi Crowther University, followed by enlightenment seminars and support of the management and leadership. They had respective means score of 3.32 and 3.30.

Regarding how the application of energy efficient building design features affect the level of thermal comfort in the auditorium buildings, the result of the survey shows that normal temperature was experience the most with a mean value of 2.90, cold temperature mean value of 2.87 and the hot temperature with a mean value of 2.86.

# 5. Conclusion

The findings from this study revealed the urgent need to enable and facilitate the application of energy efficient design features in the three(s) selected buildings (auditorium). It established that, there exist some of these energy efficient building design features in the selected auditoria. But because of high level energy efficiency required in the tropics; however, improvements can be made on these buildings with other effective energy efficient strategies to improve the thermal comfort experience of the users. This study recommended that University leadership vis-à-vis management organs need to work in synergy with Building professionals (Architects, Engineers, Quantity Surveyors, Energy experts, and other stakeholders in sustainable development goal sector) should pay more attention to the adequate applications of energy efficient building design features in building construction (i.e auditorium ) of higher institutional buildings by making relevant findings about these features and their thermal comfort levels effects as occasion demands. There is also urgent need for higher education sector to revisit the sustainable development goals and carve a niche in the area of environment wellness or wellbeing for individual schools and their campus macroclimate and microclimate.

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