International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 04, April-2020

Evaluation of Bioclimatic Principles in Design of office Building in Hot-Dry Climate Region of Nigeria

Abdullahi Yusuf [1]
Lecturer- Department of Architectural Technology,
Hassan Usman Katsina Polytechnic, Katsina State,
Katsina, Nigeria.

***Abstract*:- This study evaluates bioclimatic principles application in the design of office buildings in hot-dry Climate region of Nigeria, using university senate buildings. Purposive sampling technique was adopted for the study whereby, three university senate building where selected from Dutse, Keffi and Zaria. data were collected primarily from field survey using interview and checklist. Other secondary data were collected from the institution of study. Data collected were analysed using a five point Likert scale rating with weighted values ranging from 0 to 4 or absent to very high respectively, where mean weight values of variables were derived. Result shows a low rating of 1.33 which entails that the design of office buildings in hot-dry region of Nigeria does not fully take into cognizance the application of bioclimatic principles. Building envelop and orientation, Renewable energy source, sun shading devices, indoor air and natural cooling elements were therefore recommended in developing any office building within the hot-dry climatic region.**

Keywords—Architecture; bioclamatic principles; design; hot-dry climate; office building.

I. INTRODUCTION

Regions of hot-dry climate such as Nigeria, Niger, Egypt, Syria, Malaysia, Saudi Arabia, and United Arab Emirates, with temperature of between 20° - 35° Celsius [1] are usually characterised by very high radiation levels, ambient temperature and relatively low humidity [2] making buildings in these regions constantly exposed to solar radiation. Indoor and outdoor air temperatures are the dominant climatic factors affecting thermal comfort in the hot-dry climate [3]. The afternoon period in the area is noted for discomfort due to intense solar radiation leading to high air temperatures that affects buildings and dictates levels of indoor comfort to a high degree [3].

Energy consumption in office buildings is higher compared to the energy consumption in other building types [4], moreover, energy in office buildings is mainly consumed for heating, cooling, lighting and operating office equipment purposes [5]. Despite the effort by researchers to integrate bioclimatic principles into building design, there is still minimal consideration of these energy efficient approaches especially during design stages of offices, in which the main design solutions are identified. Most buildings around hot-dry climates in Nigeria are designed for just the designing sake with not much attention paid to its orientation or proper climatology check [6]. However, for a comfortable indoor environment to be achieved, the microclimate analysis of the locality in which design is taking place should be carried out (Ajibola, 2001). It is therefore important to evaluate bioclimatic principles application in existing buildings in hot-dry regions using office buildings as case studies in view of proffering adequate measures that will ensure user comfort, satisfaction and well-ebing. This study however evaluates bioclimatic principles application in the design of university senate buildings in in hot-dry Climate region of Nigeria.

II. LITERATURE REVIEW

A. Concept of Bioclimatic Architecture

The tenets of Architecture have always held the objective of climatic comfort which has been inherent from its origin, that protects man from the exterior environment and in this case, bioclimatic architecture attempts to achieve human thermal comfort in interacting with the exterior climate [7]. The term bioclimatic was used for the first time by Victor Olgyay in 1963, where he developed a bioclimatic chart, which relates climatic data to thermal comfort limits [8]. Bioclimatic Architecture however existed since prehistoric times when people have been naturally trying to exploit in the best way local microclimate, positioning, winds, humidity, underground streams, tellurian currents, electromagnetic fields and a good choice of materials to create a building cheaper, more pleasant and above all healthier at the same time [7]. According to [1] the protection from adverse conditions of the outdoor environment, as well as the conservation of environmental variables favouring comfort, can be achieved through two alternative mechanisms: the use of bioclimatic design resources or the mechanical plant to provide artificial conditioning. However, climatic protection and taking advantage of the favourable conditions not only implies the search for comfort and well-being, but also the reduction of the demand for fossil and non-renewable energy, as well as the better use of renewable energies from natural sources such as sun and wind.

Since the Industrial Revolution, comfort in modern architecture has been relegated to the use of devices that continuously consume energy and have an ecological footprint [9]. Thus, interaction between shape and energy was set aside and a shift was made to an indifferent architecture based on intensive energy consumption technologies [10]. The environmental damage produced by buildings in the 1980s became highly significant, which gave rise to the concept of

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 04, April-2020

sustainability [11]. After directing the global consciousness towards sustainability, there has been a return to the values of architecture where bioclimatic principles are considered again [12]. The focus of the bioclimatic approach is the consciousness of the importance to conserve energy and environmental resources with sensitivity to ecological and regional concept [13]. And since a driving purpose of architecture is human comfort and well-being, climate design ought to be considered by the architect [14].

B. Principles of Bioclimatic Architecture

Bioclimatic principles basically comprise three directions: energy, human health/wellbeing and sustainability [11]. To apply bioclimatic architecture, it is necessary to consider the various climate levels of the building's location, including the general climate, the mesoclimate and the climate near the building defined by the nearby elements or microclimate [11]. The design process should result in design strategies using bioclimatic principles that incorporate natural ventilation, day lighting, passive heating and passive cooling [15].

[16] identified bioclimatic principles as Building envelope and orientation, energy source, sun shading devices, indoor air quality, heating and cooling and the landscape. [17] outlined building shape, orientation, landscape and shading, building fabric, ventilation, glazing and windows, insulation and space. [18] described the bioclimatic principles as building design, building envelope, shading, natural ventilation, passive heating and cooling. Also, [19] identified four variables of bioclimatic architecture principles as sun shading devices, passive cooling system, thermal mass strategies and ventilation strategies.

From the above identified principles the study employs the set as described by [15] and [16]. The Principles were formulated as relate to the micro climate of a region to provide both thermal and visual comfort for occupants with renewable energy (solar) as a means of generating electricity and geothermal system for heating and cooling among other parameters as an efficient system of eco-friendly design.

i. Building Envelope and Orientation

Building Envelope principle ensures indoor and outdoor materials that are durable, resistant to vandalism, easy to maintain, and affordable. By definition, the envelope's purpose is to provide protection from external elements, which, in building construction, means protection from moisture, air, and temperature ingress and egress [20]. The design of the envelope of a building is a major task of the architect and involves a number of considerations including strength and stability, control of air flow, rain water, fire, aesthetics and cost, with some opposing others in their requirements [21].

Building envelope components have three important characteristics that affect their thermal performance: their U-factor or thermal resistance; their thermal mass or ability to store heat, measured as heat capacity (HC); and their exterior surface condition/finish (for example, are they light in colour to reflect the sun or dark to absorb solar heat?). As described in Figure 1 below, the U-factor is the rate of steady-state heat flow. It is the amount of heat in British thermal units (Btu) that flows each hour through 1 ft2 of surface area when there is a 1°F temperature difference between the inside and outside air. Heat flow can be in either direction, as heat will flow from the warmer side to the cooler side. R-values are also used to describe steady-state heat flow but in a slightly different way. Where U-factor takes account of the overall construction assembly, the R-value is a material property, like density, specific heat, and conductance. A larger R-value has greater thermal resistance, or more insulating potential, than a smaller R-value. (Of course, the opposite is true with U-factors—the lower the better).

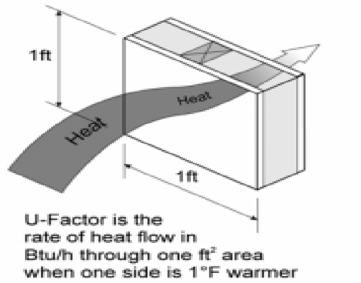

Figure 1: concept of U- Factor.
Source: [22]

Orientation refers to both the position of the building on site and the arrangement of the rooms within it, [23]. Understanding the daily and seasonal movements of the sun and especially the wind assists in orientating a building for optimal efficiency and comfort. In the tropics, a building should be oriented so that the majority of walls and windows can easily be shaded from direct sun, while allowing maximum airflow and input of natural light [24]. Main openings should face north and south so as to reduce the building's cooling load. If the site doesn't align with the with that of the sun, or if there are important views to the East and West, other building elements like service core and sun-shading can insulate the buildings [25]. As described in Figure 2 below, North-South orientation is recommended for buildings in the hot-dry zone of Nigeria. Since the sun-path across this zone is East-West, this orientation reduces the amount of solar radiation which external walls are exposed to [26].

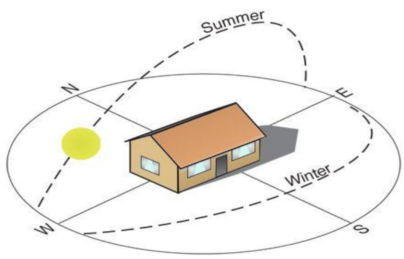

Figure 2. Sun path and Building Orientation.
Source: www.nachi.org

ii. Energy Source

Basically, there are two sources of energy supply that occur naturally, these are: Renewable sources and Non – Renewable Sources. Renewable energy is energy that is derived from natural processes that are replenished constantly. Unlike fossil fuel, renewable energy does not pollute the environment because it is a part of nature. Renewable sources as most often used solar, wind, water (hydropower), biomass and geothermal energy. The potential to generate energy from renewable sources is largely dependent on the availability of these natural resources [27].

Non – Renewable Sources are of two processes, that is, by photosynthesis and fossilation of plants and animal life and the process of formation of the earth itself. The first process gave rise to source in form of the following: coal, oil (petroleum), and natural gas. The second gave rise to the following sources in form of fuel for nuclear energy, that is, uranium. According to [28], in order to minimise energy consumption effects to the environment, Renewable Energy Sources such as photovoltaic systems (on roofs, facades or shades), biomass energy, geothermal energy and solar energy for hot water (for heating and everyday use) should be installed in our buildings.

iii. Sun Shading Device

According to [29] Solar shading devices such as overhangs, awnings and blinds should be designed in an effective way in order to allow solar radiation to reach the building in winter and block it in summer. A variety of movable and permanent shadings can be utilized. Shading of a building refers not only to shading of its windows, but to the walls, this will do much to reduce the total heat that enters the building and therefore, reduce the heat that later emits into the building. Some devices used include canopies, louvers, awnings, and external sun shading devices. According to [30], it is important to note that wall shadings are only necessary under extreme conditions. However, operable shading offers a vital device throughout the year.

iv. Passive Design

The basic idea of passive design is to allow in daylight, heat and airflow only when they are most beneficial, and to exclude them when they are not. This includes the storage of ambient energies where possible, for distribution later when there may be greater need. The full range of passive techniques are: the correct orientation of the building, appropriate amounts of fenestration and shading, an efficient envelope, maximum use of day lighting and the appropriate level of thermal mass, as well as the use of renewable resources in preference to non-renewable [31]. The major passive design techniques include: orientation, glazing, thermal mass, insulation, ventilation, and zoning of internal space [31].

v. Indoor Air Quality

According to [27] Natural ventilation is a good strategy for achieving acceptable indoor air quality. A poor environment can result in occupants suffering from sick building syndromes such as allergic reactions, respiratory problems, eye irritation, sinusitis, bronchitis and even pneumonia. The source of indoor pollutants may vary depending on the types of building and the occupants. Typical contaminants include: microbial contaminants, gases (carbon monoxide, radon, volatile organic compounds), particulates, chemical substances, i.e. solvents, and environmental tobacco smoke. By promoting good air exchanges between internal and external spaces, the concentration of contaminants may be diluted and removed.

vi. Heating and Cooling

According to [32], cooling strategy is a response to the need for summer comfort: shading from solar radiation and heat gain, minimising internal heat sources, dissipating excess heat and cooling down naturally. In hot-dry climate, the bioclimatic measures to maximise cooling during the summer period and allow heat gain during the winter include the use of evaporative cooling, trombe walls, water walls, water features (e.g. fountains), wind catchers and proper use of green features among others.

i. Landscape

There are many aspects that should be considered during the design of the outdoor environment including radiation, heat, emissivity, glare, and dust control. However, the most important considerations are; Solar Radiation Control, Wind Control and Evaporation Control. In order to address those climatic considerations landscape designers and planners use all available design elements and landscape treatments including vegetation, water and hardscape [33]. The strategic positioning of landscape features such as trees, hedges and rockery can modify radiation penetration and cool air temperatures adjacent to the building envelope by providing shade, redirecting breezes and aiding in natural ventilation. Larger trees can reduce the external wall temperatures minimize sun exposure to windows and openings, greatly aiding in the optimization of thermal performance.

i. Thermal Mass

Both heat capacity and conductivity give rise to what is known as the thermal mass effect. In large heavyweight materials, it can take a significant amount of energy to heat up their surface. This is because much of the energy is actually absorbed deeper into the material, being distributed over a larger volume.

C. Designing for Bioclimatic Comfort in Hot-Dry Climate

Climates around the globe vary greatly, ranging from the polar extreme to tropical climates. The climate is primarily influenced by the sun heating up the land and water bodies. At the regional level, the climate is influenced by altitude, topography, wind patterns and ocean currents, the relation of land to water bodies, the geomorphology, and by the vegetation pattern [34]. Hot-dry climates are usually found between 15° and 30° north and south of the equator and are characterized with large daily and annual temperature swings and marked seasonal variations, predominantly clear skies, intense solar radiation, scarce rainfall and very limited vegetation [1]. Such region requires solar protection in summer, construction with substantial thermal inertia, controlled window sizes and protection from hot-dry and dusty winds. Buildings in the hot-dry climate need patios, central courtyard to shade the building in the daytime and allow heat to be released at night [35].

III. METHODOLOGY

Three study areas were adopted for this study using: climatic zone of the building, scope of the building, the function of the building, and application of bioclimatic strategies on the building as criteria. The study areas include: Federal University Dutse (FUD) Senate Building, Nassarawa state University, Keffi (NSUK) Senate Building, and Ahmadu Bello University Zaria (ABU) Senate Building. Data required for this study include variables such as: building envelop and orientation, energy source, sun shading device, passive design,

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 04, April-2020

indoor air quality, heating and cooling, landscape and thermal mass with details on Table 1.

TABLE 1: STUDY VARIABLES

S/N	*Major variable*	*Sub variables*
1	Building envelop and orientation	Using materials that reduce heat gain and loss
		East-West Orientation
		Provision of water Bodies
2	Energy Source	Photovoltaic panels
		Wind energy.
3	Sun Shading Device	Windows overhang
		Operable shading Device
		Recesses
		Internal Shading
4	Passive Design	Natural Ventilation (size and type and position of windows)
		Ceiling height
		Natural lighting
		Use of Court Yard
		Zoning of internal spaces
5	Indoor Air Quality	Avoidance of stale air build up
		use of ventilation control system
		Avoiding noise, avoiding air pollutants
		visual amenity
		Green elements in the interior
6	Heating And Cooling	Green roof
		evaporative cooling
7	Landscape	Effective use of vegetation
		reflective roof
		Water bodies
		Vertical landscape
8	Thermal mass	Use of materials with good thermal mass e.g. clay bricks, concrete tiles etc.

Purposive sampling technique was adopted for the study whereby, data were collected primarily from field survey using interview, checklist, photographs, sketches and notes. Other secondary data were collected from the institution of study. Data collected were analysed using a five point Likert scale rating with weighted values ranging from 0 to 4 where: 0= Absent, 1 = Low, 2 = Moderate, 3 = High, 4 = Very High. The mean weight value (MWV) was then calculated by finding the averages the weighted values of sub variables.

IV. RESULTS

A. Case Study 1 (Federal University Dutse Senate Building)

Federal University Dutse Senate Building is located within the university main campus along Ibrahim Aliyu Way, Dutse, Jigawa state between latitudes 11.00°N to 13.00°N and longitudes 8.00°E to 10.15°E, and is among the dominant structures to be seen at the entrance from the main gate of the university.

Plate I. FUD Senate Building
Source: Field work

As presented in Plate I FUD senate building shape is proper to the climatic region, has adequate provision of parking lots court yard is designed to promote ventilation and lighting, proper control of thermal mass which all favours bioclimatic principles. On the other hand, the building is observed to have improper building orientation, improper location of windows (West and East), in adequate window shading and improper use of passive design strategies.

TABLE 2: APPLICATION OF BIOCLIMATIC ARCHITECTURE PRINCIPLES IN FEDERAL UNIVERSITY DUTSE SENATE BUILDING

S/N	*Major variable*	*Mean Weight Value (MWV)*
1	Building envelop and orientation	1.00
2	Energy Source	0.00
3	Sun Shading Device	0.75
4	Passive Design	2.40
5	Indoor Air Quality	2.00
6	Heating And Cooling	0.50
7	Landscape	0.50
8	Thermal Mass	3.00
9	Total Mean Weight Value (TMWV)	1.30

Results presented in Table 2 shows that: Building envelop and orientation MWV scored 1 which is low. This is because, the building has smooth surfaces but no element of insulation, has longer axis facing West and East which is inappropriate and has no water bodies. Energy Source MWV scored 0 because there is no photovoltaic panel nor wind turbine for renewable energy. Sun shading device scored 0.75 which is low, as it has few windows overhang but no operable shading devices. In the case of passive design, the MWV is 2.4 which is moderate because there are large windows for ventilation but lacks vegetative aid and improper window types, has standard building height of 3.0m; there is use of court yards, clear glazing and Some relevant spaces are arranged. For indoor air quality, the MWV is 2 which is also moderate as, the courtyard is used for avoidance of stale air build up but it is not large, however, there is no use of ventilation control system, proper zoning was used for avoiding noise, air pollutants are avoided, clear glass is used as visual amenity, natural lighting are provided but there is presence of glare and reflection but there are no green elements in the interior. For heating and cooling, MWV is 0.5 which is low because, green features were used and presence of large interlocking but there is no green roof. In the case of landscaping which also scored 0.5 MWV, soft and hard landscape were used but inadequate at the exterior, there are no reflective roof, water bodies nor vertical landscape. Thermal mass scored 3 MWV which is high because concrete and hollow blocks were used but no double glazing. The Total Mean Weight Value (TMWV) of Application of Bioclimatic Architecture Principles in Federal University Dutse Senate Building is 1.3 which is low which shows that, bioclimatic architecture principles have been weakly applied on this building.

B. Case Study 2 (Nassarawa State University, Keffi Senate Building)

Nassarawa State University, Keffi (NSUK) is located along Abuja Akwanga Road Keffi, Nassarawa state at latitude 7° 45' to 9° 25' N and longitude 7° to 9° 37' E and the building

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 04, April-2020

is situated in the centre of the University to be accessible by other buildings within the campus.

Plate II. NSUK Senate Building
Source: Field work

NSUK senate building presented in Plate II is in a location within the university, effective design with court yard for proper natural ventilation, natural lighting and minimising of heat gain, Spaces and offices are clearly defined and easily accessible, proper building orientation with the longer faces facing North and South, adequate provision of escape routes, proper building shape. However, the building has inadequate provision of windows shading, inadequate space allocation, insufficient landscaping and undefined parking spaces.

TABLE 3: APPLICATION OF BIOCLIMATIC ARCHITECTURE PRINCIPLES IN NASSARAWA STATE UNIVERSITY, KEFFI SENATE BUILDING

S/N	*Major variable*	*Mean Weight Value (MWV)*
1	Building envelop and orientation	2.30
2	Energy Source	0.00
3	Sun Shading Device	0.0
4	Passive Design	2.60
5	Indoor Air Quality	1.20
6	Heating And Cooling	0.00
7	Landscape	0.75
8	Thermal Mass	2.00
9	Total Mean Weight Value (TMWV)	1.10

Results presented in Table 3 shows that: Building envelop and orientation MWV scored 2.3 which is moderate because, the building has light colours with smooth surfaces but no insulation, has longer axis facing North and South which is appropriate but has no water bodies. Energy Source MWV scored 0 because there is no renewable energy. Sun shading device scored 0 which is absent. In the case of passive design, the MWV is 2.6 which is high because there are large windows for ventilation but lacks vegetative aid and improper window types, has standard building height of 3.0m; there is use of court yards, Spaces organised but lacks flexibility. For indoor air quality, the MWV is 1.2 which is low as, there is no use of ventilation control system although the courtyard is used for avoidance of stale air build up, air pollutants are avoided, clear glass is used as visual amenity but there are no green elements in the interior. For heating and cooling, MWV is 0 absent. In the case of landscaping which scored 0.75 MWV, soft and hard landscape were used but inadequate at the exterior, there is Use of coloured aluminium roof, but no water bodies nor vertical landscape. Thermal mass scored 2 MWV which is high because concrete and hollow blocks were used but no double glazing. The Total Mean Weight Value (TMWV) of Application of Bioclimatic Architecture Principles in Nassarawa State University, Keffi Senate Building is 1.3 which is low.

C. Case Study 3 (Ahmadu Bello University Senate Building)

Ahmadu Bello University (ABU) is located in Zaria Kaduna State at latitude 11° 5' 7.9476" N and longitude 7° 43' 11.8020" E, and the building is located in the Eastern part of the central area of the main campus (Samaru) of the University.

Plate III. NSUK Senate Building
Source: Field work

ABU senate building presented in Plate III speaks authority as its size and domination of the surrounding structures. Spaces and offices are clearly defined and easily accessible, has effective design as use of atrium results proper natural ventilation, natural lighting and minimising of heat gain and has proper location within the university. On the other hand, the stair cases provided for vertical transportation and to serve as escape lacks proper lighting and are hiding, some functions are beings interrupted by free standing columns, has undefined parking spaces and improper building shape.

TABLE 4: APPLICATION OF BIOCLIMATIC ARCHITECTURE PRINCIPLES IN AHMADU BELLO UNIVERSITY SENATE BUILDING

S/N	*Major variable*	*Mean Weight Value (MWV)*
1	Building envelop and orientation	1.24
2	Energy Source	0.00
3	Sun Shading Device	1.50
4	Passive Design	3.00
5	Indoor Air Quality	1.50
6	Heating And Cooling	1.50
7	Landscape	1.00
8	Thermal Mass	3.00
9	Total Mean Weight Value (TMWV)	1.59

Results presented in Table 4 shows that: Building envelop and orientation MWV scored 1.24 which is low because, the building has light colours with smooth surfaces but no insulation, building is square in shape which orientation is not determined and has no water bodies. Energy Source MWV scored 0 because there is no renewable energy. Sun shading device scored 1.5 which is moderate as Egg crate shading used for overhang, and recess. In the case of passive design, the MWV is 3 which is high because there are large windows for ventilation but lacks vegetative aid and improper window types, atrium was used, the building is square in shape, has standard building height of 3.0m; there is use of court yards, Spaces organised but lacks flexibility. For indoor air quality, the MWV is 1.5 which is moderate as, there is no use of ventilation control system although there are flexible mountings, absorbent surfaces, but absence of insulation, microbial contaminants are avoided, clear glass are used and natural lighting provided. For heating and cooling, MWV is 1.5 as there is no green roof but green features were used and

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 04, April-2020

presence of large interlocking. In the case of landscaping which scored 1.5 MWV which is moerate, soft and hard landscape were used but inadequate at the exterior, there is Use of coloured aluminium roof, but no water bodies nor vertical landscape. Thermal mass scored 3 MWV which is high because concrete and hollow blocks were used but no double glazing. The Total Mean Weight Value (TMWV) of Application of Bioclimatic Architecture Principles in Ahmadu Bello University Senate Building is approximately 1.6 which is Moderate.

D. Evaluation Of Bioclimatic Principles Application in Design of Office Building in the Study Area

TABLE 6: EVALUATION OF BIOCLIMATIC PRINCIPLES IN DESIGN OF OFFICE BUILDING IN THE STUDY AREA

S/N	Major variable	Mean Weight Value (MWV)			
		FUD	***NSUK***	***ABU***	***MWV***
1	Building envelop and orientation	1.00	2.30	1.24	1.51
2	Energy Source	0.00	0.00	0.00	0.00
3	Sun Shading Device	0.75	0.0	1.50	0.75
4	Passive Design	2.40	2.60	3.00	2.67
5	Indoor Air Quality	2.00	1.20	1.50	1.57
6	Heating And Cooling	0.50	0.00	1.50	0.67
7	Landscape	0.50	0.75	1.00	0.75
8	Thermal Mass	3.00	2.00	3.00	2.67
9	**Total Mean Weight Value (TMWV)**	**1.30**	**1.10**	**1.59**	**1.33**

In evaluating bioclimatic principles in design of office building in the study area the total mean weight value of the variables was derived and the result shows that: building envelope and orientation scored 1.51 which is moderate, energy source scored 0.00 which signifies absent of renewable energy source, Sun Shading Device scored 0.75 which is low, Passive Design scored 2.67 which is high, Indoor Air Quality scored 1.57 which is moderate, Heating And Cooling scored 0.67 which is low, Landscape scored 0.75 which is also low and thermal mass score 2.67 which is high.

Light colours with smooth surfaces are used on the facilities studied. the major building material used were Concrete and Hollow blocks but with single glazing. Despite the abundance of solar radiation and wind energy around the facilities studied, none of them apply the use of these renewable energy sources; the major energy supply is from the university main but with provision of smaller generators as the power backup for the buildings. Operable shading devices were not used in all cases studied. Recesses have been used to greatest degree in ABU Senate Building where egg crate shading is used in form of recess. In case of FUD, recesses were applied to relatively fair degree while the device was not properly applied on the NSUK. No internal shading was applied on the entire facilities studied.

Passive design deals with natural ventilation, natural lighting, Ceiling height, use of court yard, and Zoning of internal spaces. Of all the three facilities studied, court yard was used to aid natural ventilation and lighting. This and the use of large windows play an important role in obtaining cool interior and relatively a satisfactory ambience for the facilities. The interior spaces were properly zoned as this enhances work flow and allows good circulation/transportation route within the buildings. Natural ventilation is a good strategy for achieving acceptable indoor air quality. With the presence of the court yard within the facilities this promotes good air exchanges between internal and external spaces. Though, there has not been an evidence of air polluting elements the concentration of contaminants may be diluted and removed also stale air build up was avoided. Clear glazing was used in all the facilities studied and however, no Green elements were used within the interiors of the facilities. There was presence of hedges, trees, Green areas but paved areas around NSUK and ABU Senate Buildings. Green roof was not used in any of the facilities but the presence of the court yard helps in controlling the summer heat. Water body and evaporative cooling technique like floor cooling and fountain were not used on any of the facilities studied.

In terms of effective use of vegetation and hard/interwoven landscape all the facilities were landscaped. However, there has been excessive use of hard landscape which does not match the climatic zone. Masquerades tree were used around the ABU and NSUK Senate Buildings, this aids shading and helps to control the micro climate but care must be taken in selecting the type of trees for landscaping along the Southern part of buildings in hot climates as Deciduous trees and shrubs provide summer shade yet allow winter access. The best locations for deciduous trees are on the south and southwest side of the building. An evidence of poor demarcation of parking lots was obvious at the Nassarawa facility. Also, no element of vertical landscape was used on the three buildings. Use of materials with good thermal mass is the major concern in bioclimatic design strategies, concrete and sand Crete block is the major envelop cladding materials used on all the facilities studied.

V. CONCLUSION

In conclusion, the evaluation of bioclimatic principles application in design of office building hot-dry climate region of Nigeria using Federal University Dutse (FUD) Senate Building, Nassarawa state University, Keffi (NSUK) Senate Building, and Ahmadu Bello University Zaria (ABU) Senate Building as case studies shows a low rating. This entails that the design of office buildings in hot-dry region of Nigeria does not fully take into cognizance the application of bioclimatic principles in their design and development. Architecture objective should holds comfort to protects man from the exterior environment with high esteem to achieve human thermal comfort in interacting with the exterior climate.

It is therefore recommended that building envelop and orientation should be considered in developing any office building in the hot-dry climatic region. Renewable energy source especially solar energy should be harnessed for power generation to limit the use of non-renewable ones such as generators. sun shading devices like overhangs, awnings and blinds should be used. Indoor air quality is paramount as such; proper ventilation must be considered in designing office buildings in this region. Also, natural cooling elements such as trees should be used for landscaping to achieve the objectives of cooling and also aesthetics.

REFERENCES

[1] Evans, J. M. (2007). The Comfort Triangles: A New Tool for Bioclimatic Design. Published PhD. thesis. Retrieved on November 12, 2015 from http://www.darenet.nl.

[2] Malgwi, M, E, & Sagada. L. M. (2014) An Evaluation of thermal comfort conditions in an urban entertainment centre in hot-dry climate of Nigeria. International Journal of Energy and Environmental Research (IJEER) Vol.2, No.1, pp.55-74, March 2014

[3] Adunola A., O. (2104) Evaluation of urban residential thermal comfort in relation to indoor and outdoor air temperatures in Ibadan, Nigeria. Building and Environment 75 (2014) 190e205

[4] Batagarawa, A. (2013) Assessing the thermal performance of phase change materials in composite hot humid/hot dry climates. An examination of office buildings in Abuja, Nigeria. Unpublished PhD Thesis submitted to School Of Architecture, Planning And Landscape, Newcastle University.

[5] Santamouris, M. & Dascalaki, E. (2002) 'Passive retrofitting of office buildings to improve their energy performance and indoor environment: The office project', building and environment, 37(6), pp. 575-578.

[6] Adeda,O.F., Ayuba, P., Oyetola S., & Buhari, A. (3013). Bioclimatic Design Principle a Solution to Thermal Discomfort in Minna Residences, Niger State Nigeria, Journal of Environment and Earth Science, 3(12), 45-52. https://iiste.org/Journals/index.php/JEES/article/view/8871/9144

[7] Manzano-Agugliaro, F. Montoya, F. G. Sabio-Ortega A. and García-Cruz, A. (2016). Review of bioclimatic architecture strategies for achieving thermal comfort, Applied Energy, 183(C), 938-957. https://econpapers.repec.org/scripts/redir.pf?u=http%3A%2F%2Fwww.sciencedirect.com%2Fscience%2Farticle%2Fpii%2FS1364032115003652;h=repec:eee:rensus:v:49:y:2015:i:c:p:736-755

[8] Maciel, A. A. (2007). Bioclimatic Integration into the Architectural Design. Published Phd. Thesis. University of Nottingham, United Kingdom.

[9] Ganem, C. Esteves A. & Coch, H. (2006). Traditional climate-adapted typologies as a base for a new contemporary architectural approach, 6-8.

[10] Coch, H (1998). Bioclimatic in vernacular architecture. University Politechnicia de Catalunya

[11] Metallinou V.A (2006). Ecological propriety and architecture, Eco-Architecture: Harmonisation between Architecture and Nature, 15-22. https://www.witpress.com/Secure/elibrary/papers/ARC06/ARC06002FU1.pdf

[12] Levy, G. (2009). Interactive Architecture: Creating Opportunities for our Future, Architecture Senior Theses. 87. https://surface.syr.edu/architecture_theses/87

[13] Musa, S.H. (2012). Sustainable Architectural Education- Global Challenges and The Nigerian System_Sylvanus, African Scholars Journal of Contemporary Education Research, 6, 64-91.

[14] Ogunsote, O. O. (1991). Introduction to Building Climatology. A basic course for Architecture Students. Zaria: Ahmadu Bello University Press Ltd

[15] Sakar A. (2010). A methodology for energy-efficient shelter design with bioclimatic design tools, The IUP Journal of Architecture (2), 7-23.

[16] Folaranmi A. O., Philip A., Stephen O., & Buhari A. (2013) Bioclimatic Design Principle a Solution to Thermal Discomfort in Minna Residences, Niger State Nigeria

[17] Mahmoud, M., Ahmad, H.H. Ali, S.O., Ali K. A. & Nady M.A. (2015). The Impact of Passive Design Factors on House Energy Efficiency for New Cities in Egypt, Conference: World Academy of Science, Engineering and Technology Environmental and Ecological Engineering, 2(5).

[18] Dadia D., Parekh H., Loftness V., Aziz A., & Cochran E. (2014) Bio-Climatic Design Enclosure Guidelines for 5 Climate Zones in India, Thesis for the Master of Sustainable Design program in the School of Architecture at Carnegie Mellon University.

[19] Gutiérrez, T. & Romero M.R. & Sotelo, C. (2014). Thermal Energy Impact of Bioclimatic Techniques Applied to Low-income Housing in a Hot Dry Climate. Energy Procedia. 57. 10.1016/j.egypro.2014.10.163.

[20] Howell, G., (2008). Integrated design process. Riverdale NetZero Home.Info-times organization, 2013. Worsening electricity crisis in Egypt. http://www.infotimes.org/topic/view

[21] Bala S.E. (2014). An Evaluation of Sustainable Design Strategies to Enhance Energy Efficiency in Conference Centres, MSc. Architecture Thesis, Ahmadu Bello University, Zaria. http://kubanni.abu.edu.ng/jspui/bitstream/123456789/6366/1/AN%20EVALUATION%20OF%20SUSTAINABLE%20DESIGN%20STRATEGIES%20TO%20ENHANCE%20ENERGY%20EFFICIENCY%20IN%20CONFERENCE%20CENTRES..pdf

[22] Lstiburek J. W. (2000). Towards Understanding Prediction of Airflow in Buildings, PhD. Disertation in Architecture, University of Toronto. https://www.buildingscience.com/sites/default/files/000_complete_thesis.pdf

[23] Cairns Regional Council (2011). Sustainable Tropical Building Design Guidelines for Commercial Buildings, https://www.cairns.qld.gov.au/__data/assets/pdf_file/0003/45642/BuildingDesign.pdf

[24] Wambui, K. R. (2014). Integrated Bioclimatic Design – Principles of High Rise Buildings in Warm Humid Climate, a thesis submitted to University of Nairobi, College of Architecture and Engineering, School of built environment, Department of architecture and Building Science.

[25] Yeang, K., (1996). The Skyscraper Bioclimatically Considered, London Academy.

[26] Gbadeyan, J.A., Idowu, A.S., Ogunsola, A.W., Agboola, O.O., & PO Olanrewaju (2011). Heat and mass transfer for Soret and Dufour's effect on mixed convection boundary layer flow over a stretching vertical surface in a porous medium filled with a viscoelastic, Global Journal of Science Frontier Research 11 (8)

[27] Keung J. (2010) Building Planning and Massing, The Centre for Sustainable Buildings and Construction, Building and Construction Authority. Singapore.

[28] Macharia, P. & Thuranira, E. & Ngángá, L. & Lugadiru, Jesse & Wakori, S. (2012). Perceptions and adaptation to climate change and variability by immigrant farmers in semi-arid regions of Kenya. Afr. Crop Science Journal, 20. 287-296.

[29] Bahrami, S. (2008). Energy efficient buildings in warm climates of the Middle East: Experience in Iran and Israel. Published M. Sc. Thesis, School of Environmental Management and Policy. Sweden: IIIEE. Retrieved October 4, 2016 from http://lup.lub.lu.se/student-papers/record/1481091/file/1481092

[30] Hernández, V. & Hellín, P. & Fenoll, J. & Garrido, I. & Cava, J. & Flores, Pilar. (2015). Impact of Shading on Tomato Yield and Quality Cultivated with Different N Doses Under High Temperature Climate. Procedia Environmental Sciences. 29. 197-198. 10.1016/j.proenv.2015.07.259.

[31] Jiyoung E.E, & Sun K. Lee, & Jaehan Lim (2015). Passive design techniques applied to green buildings as an aesthetic and spatial design concept. Journal of Green Building. 10. 79-109. 10.3992/jgb.10.2.79.

[32] Somfy Group, (2009). Bioclimatic Facade. Published paper. Retrieved on October 8, 2016 from www.somfyarchitecture.com.

[33] Attia S., & Duchhart I. Bioclimatic landscape design n extremely hot and arid climates. In: PLEA 2011—architecture and sustainable development, conference proceedings of the 27th international conference on passive and low energy architecture; 2011. p. 459–64. http://www.scopus.com/inward/record.url?eid=2-84864120840 &partner ID=40 & md5= eaa6a 485415bdc414efa3af21854b247

[34] Isah, D. A. (2014) Application of Bioclimatic Architecture Principles in the Design of Hotel at Katsina Nigeria. MSc thesis submitted to Department Architecture, Ahmadu Bello University, Zaria.

[35] Xiaodong Xu, Fenlan Luo,Wei Wang, Tianzhen Hon, & Xiuzhang Fu. (2018). Performance-Based Evaluation of Courtyard Design in China's Cold-Winter Hot-Summer Climate Regions, Sustainability, 10 (3950) 2-19. doi:10.3390/su10113950