Global Scientific JOURNALS
GSJ: Volume 10, Issue 6, June 2022, Online: ISSN 2320-9186
www.globalscientificjournal.com

Bioclimatic Design Strategies in Resorts in Warm Humid Tropical Climate, Rivers State, Nigeria

Tamunomieibi, Ibikoroma [1], Tonye Dagogo Pepple [2]

[1,2] Rivers State University, School of Environmental Sciences, Department of Architecture.
Ibitamsly@gmail.com

April 10, 2022.

Abstract

Humans energy and health depend to a large measure on the changes that occur within the environment due to the climate, which change is repeatedly one of the major problems humans face in recent times within the habitat from global carbon emissions into the ecosystem which the built environment is responsible for about thirty-nine percent. Bioclimatic architecture concerns itself with Climate (or impression of climate) is a primary contextual generator in bioclimatic architecture, and the goal is to create benign settings with minimum energy use. It takes into account climate and environmental conditions to help achieve indoor comfort especially in a resort facility. With proper planning, development and management, tourist products can be used as tools for conserving and protecting the natural environment. This paper seeks to outline and adopt strategies of bioclimatic design in resort buildings in hot humid tropical climates to solve afore mentioned problems of climate change. Through a resourceful literature review and examination of existing case studies, concepts of bioclimatic design were explored including natural ventilation and lighting, solar protection, passive cooling techniques amongst others. The whole idea developed in the concepts of bioclimatic design is to identify considerations that allow the application of natural strategies, smart designs, sustainable elements, regenerative design principles and effective efficient use of energy to make the environment less harmful.

Keywords: *Bioclimatic design strategies, energy efficiency, resort facility, warm humid climate.*

1. INTRODUCTION

Climate change is reportedly one of the major problems humans face in recent times within the habitat which has both direct and indirect implications on his health, lifestyle and need for safety. Human activities within the habitat through industrialization have readily and considerably negatively impacted climate change through the emission of greenhouse gases (GHG) and carbon dioxide; which by their physical and chemical properties accumulates and are re-emitted into the atmosphere from the built environment. Greenhouse gases, and carbon dioxide – being the major gas released into the atmosphere by human activities in the built environment has increased global temperatures drastically.

Bioclimatic architecture combines the goals of sustainability, environmental consciousness, green, natural, and organic methods to develop a design solution based on these criteria, as well as the site's qualities, neighborhood context, and local microclimate and topography. (Al-musa'ed, 2011).

Climate (or impression of climate) is a primary contextual generator in bioclimatic architecture, and the goal is to create benign settings with minimum energy use. To help achieve thermal comfort in buildings, it considers climate and environmental variables. It focuses on design and architectural aspects, as well as a reduction in the utilization of mechanical systems, which are more commonly thought of as support systems.

Hospitality facilities account for about 5% of global carbon emissions. Resorts are part of the hospitality and tourism sector, which is highly climate sensitive. It is considered one of the main contributors to GHG emissions (Gössling, 2013).

In Nigeria, buildings have experienced unfavorable thermal comfort. Most buildings are poorly designed in respect to the environment, necessitating a significant amount of energy for cooling during climatic extremes (Akande, 2010). This has increased the overall energy consumption with a negative impact on the environment. According to the Energy Commission of Nigeria, the amount of energy consumed within hospitality facilities accounts for about 20% of the total energy consumed in the country.

Most beach resorts in Nigeria in a bid to provide relaxation, recreation and accommodation for guests have increased energy use and failed to create a symbiotic relationship between humans, the building and biological and climatic conditions of the environment. According to Maciel (2007), resorts can be designed to meet guests' need for thermal and visual comfort at a reduced level of energy consumption using bioclimatic solutions as an alternative to the environmental and energy problems.

The solutions to high energy demand can be achieved by enhancing the use of natural day lighting, adoption of passive cooling techniques, micro-climate improvement or adjustment of environmental conditions by the best use of the sun, prevailing wind, the ambient temperature and humidity. (Axarli and Teli.,2008).

In fact, Al-musa'ed (2011) stated that Architecture can be used to harness these natural resources by designing with climate that is through; the use of the appropriate architectural forms, appropriate orientation, good material selection, and efficient use of the site resources.

2. BIOCLIMATIC DESIGN

It is required to use a design method and approach that responds to the impact of climate and the characteristics of the building type in order to select and incorporate appropriate bioclimatic responses in architectural design. The complexities and characteristics of various building types, as well as the conventional design technique informs the bioclimatic design sequence. According to Maciel (2007), the simple and complex building types are specified for the investigation of thermal performance of architectural projects and the application of bioclimatic design principles.

1. **Simple Buildings:** In cooler areas, these have limited internal thermal gains, natural lighting and ventilation, and modest heating systems. For most months of the year, the average indoor temperature in these structures is similar to or slightly higher than the average outdoor temperature, with the option of employing solar radiation as a supplementary heating source. The majority of schools and residences fall into this group of structures. Traditional texts on bioclimatic design have focused on these scenarios, where using bioclimatic design resources to accomplish natural conditioning can frequently provide a high level of comfort or reduce the need for artificial heating and cooling.

2. **Complex Buildings**: With significant internal gains from inhabitants and equipment, as well as deep plan buildings that require artificial ventilation and lighting in the interior spaces This sort of structure includes large offices, hospitals, and shopping malls. These qualities can also be found in large auditoriums and movie complexes. Indoor temperatures may increase above typical outdoor

temperatures in this circumstance, necessitating artificial cooling as well as artificial lighting and ventilation. Bioclimatic design resources may not be adequate to obviate the requirement for artificial conditioning in these complex buildings, but they are nevertheless crucial to minimize conventional energy demand.

2.1 Bioclimatic Design Process.

According to Szokolay, (2002). scientific thinking must pervade the early stages of design to prevent architecture from reverting to being merely a kind of art with no objective classification or qualification. The bioclimatic design process, in contrast to the normal design sequence, is said to follow the stages as listed in the following points:

1. Before commencing with the design development, the architect investigates the site's environmental conditions, particularly the climate data.

2. The conditions of comfort for the activities carried out in the building are then established.

3. In each hour of the day and season of the year, a comparison of the existing conditions established in Stage 1 and the required conditions selected in Stage 2 reveals the design needs for protection from adverse impacts and the preservation of favorable aspects.

4. The bioclimatic design resources are determined by the needs for protection and conservation, as well as an analysis of current conditions and needs.

5. From the beginning, these design materials are analyzed and integrated into project development.

6. Designers and consultants determine the degree of natural conditioning, then assess the project and the level of comfort that may be achieved with natural conditioning by inserting bioclimatic design features into the architecture.

7. Only after the passive natural conditioning methods have been performed can the requirement for artificial conditioning be assessed and the artificial conditioning system's residual capacity evaluated.

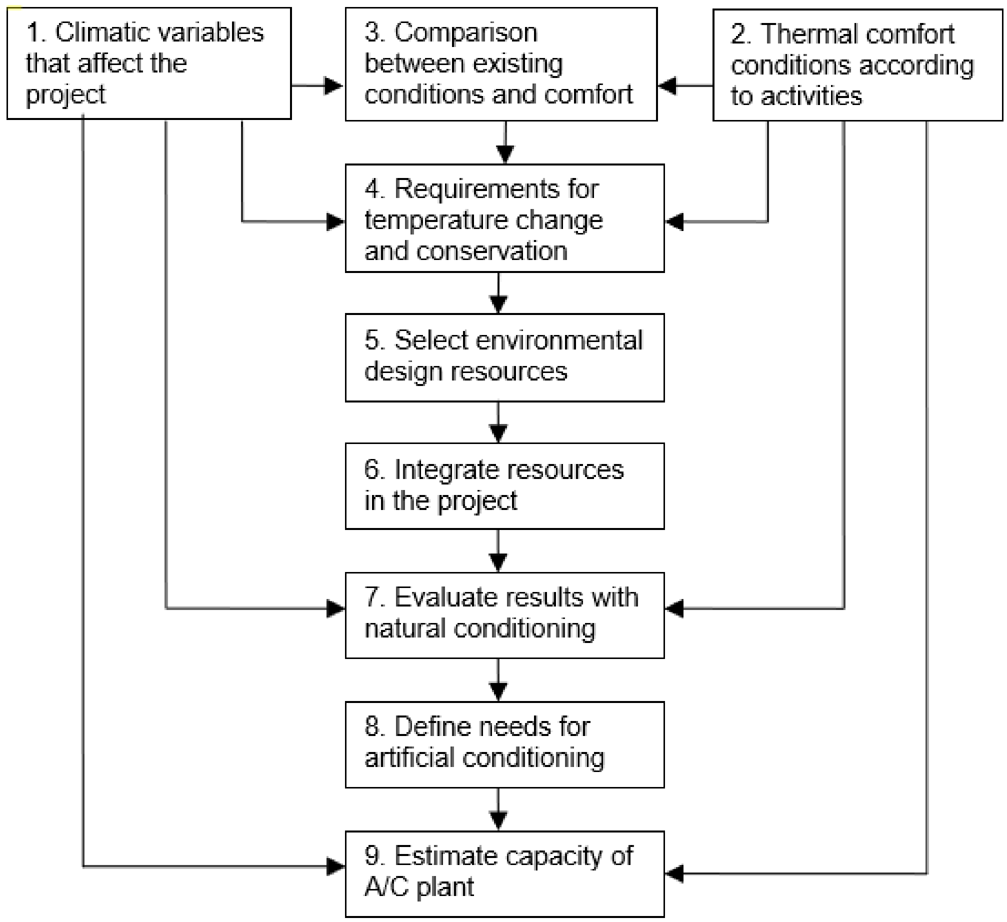

Figure 2.2: Stages of Bioclimatic Design, Testing, Evaluation, and Feedback

Source: Evans, (2007)

2.2 Comfort Zone and the Bioclimatic Chart

The shelter is the most important tool for meeting comfort criteria. It alters the natural environment to get it closer to livable circumstances. It should absorb or repel ambient components depending on whether they contribute to human's comfort in a positive or negative way. (Olgyay, 1963). The Comfort Zone is a set of environmental parameters in which the body feels at ease. The interaction of air temperature, humidity, radiation, and air movement are the major climatic factors that define comfort.

Physiological factors, such as the sort of activity being performed, the type of clothes worn, and geographic location, all play a role in determining comfort, since people in colder climates can tolerate lower temperatures than people in warmer climes. Gender, age, and the external climate are other relative factors that affect comfort. The effects of the climatic aspects are combined into a single graphic that depicts the interaction between the climatic elements, with the comfort zone in the center.

The ordinate of the bioclimatic chart is the dry-bulb temperature, and the abscissa represents the relative humidity. The lines above the comfort zone represent the effect of air flow on extending the comfort zone's top boundary. The lower lines below the comfort zone represent different levels of radiation.

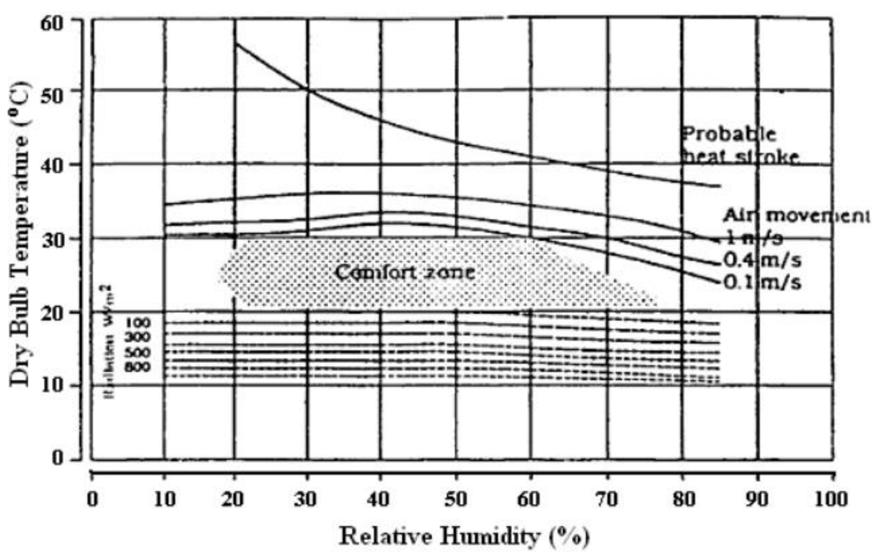

Figure 2.3: Olgyay's Bioclimatic Chart

Source: Olgyay, (1963)

3. Vernacular Architecture of Rivers State, Nigeria

Nigeria has five distinct climate zones: hot-dry, temperate-dry, hot-humid climate, temperate-humid climate, temperate-dry with cool temperature, and temperate-dry with cool climate. (Dorcas, 2020)

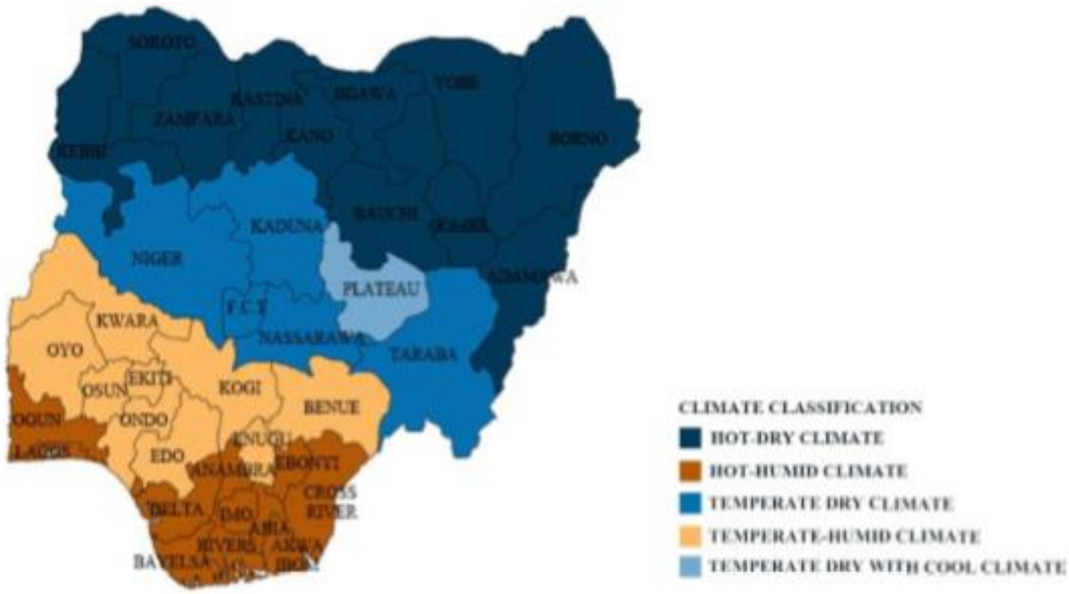

Figure 2.4: Climate Classification of Nigeria

Source: Dorcas, (2020)

Each climate zone has distinct characteristics, as does the region's vernacular architecture, which differs in terms of urban layout, building plan, material, roof type, opening size, and other elements. It is critical to examine the vernacular architecture of the area where the building is located in order to maximize the benefits of climate design and reduce the use of mechanical temperature control equipment in the interior spaces of the structure.

The Hot-Humid Climate, often known as the tropical rainforest climate or the equatorial monsoon, is found in Rivers State, Nigeria. The South Atlantic Ocean monsoons, which are brought into the country by the air mass of the maritime tropical (MT), a warm wet sea with seasonal surface wind, influence the climate. Because of the warmth and high humidity, it has a strong inclination to rise and create a lot of rain, which is caused by water vapor condensation in the fast rising air.

High temperatures and a narrow temperature range characterize the temperature. Throughout the year, the temperature remains nearly consistent. The hottest month in some locations is 28℃, while the coldest month is 26 ℃ (Nwalusi, 2013).

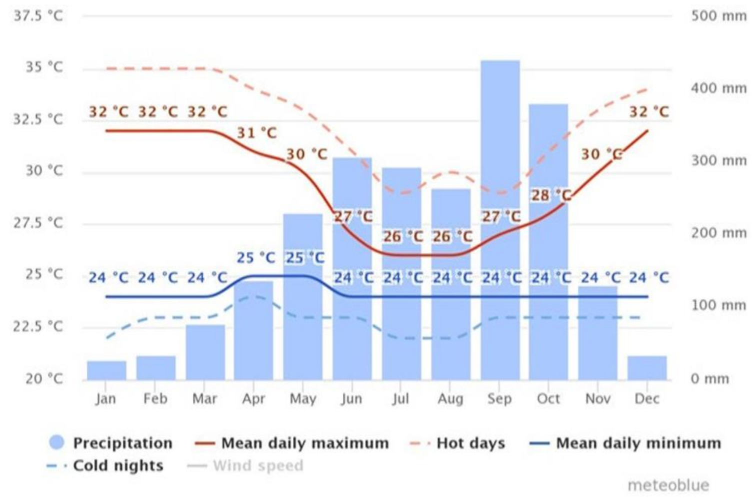

Figure : Precipitation and Temperature Chart per Month

Source: Meteoblue (2020)

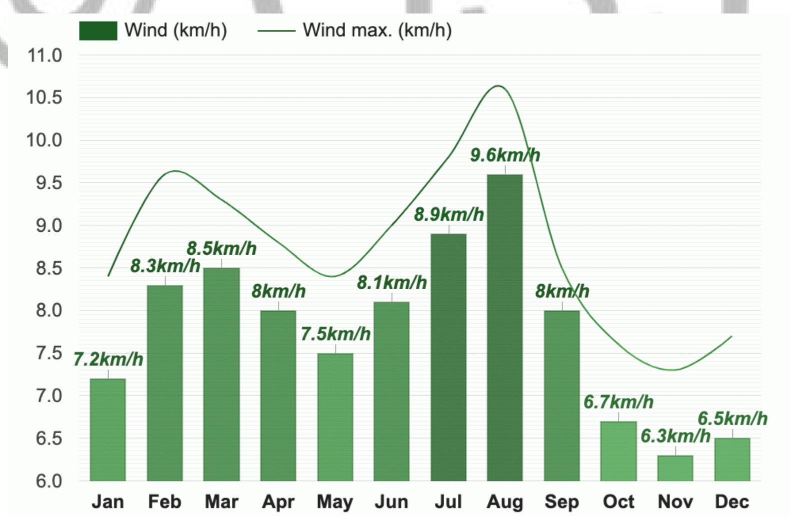

Figure 4.37: Wind Chart Showing Average Monthly Wind Speed in Rivers State

Source: Meteoblue (2020)

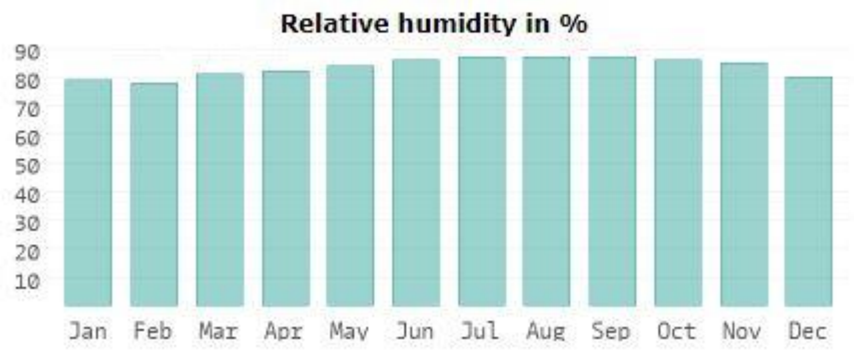

Figure: Relative Humidity Chart

Source: Meteoblue (2020)

Throughout the year, there is a lot of humidity, which causes delayed evaporation and a lot of rain. The humidity level in the area ranges from 70% to 90%. The rainfall is heavy and short-lived, with storms occurring often. There is a lot of vegetation in the area. Mangrove swamps and freshwater swamps are the predominant vegetation types in this area. Because of the extreme humidity, the settlement pattern is open and extensive. (Auwalu, 2019). Because of the amount of rain, rectangle and hipped roofs are the most common. Roofs are light to reduce heat storage from radiation and to allow air circulation and flow in and out of the structure to cool it. Long, narrow forms are used in the buildings, with huge openings for proper ventilation and dissipation of heat and humidity from the interior spaces.

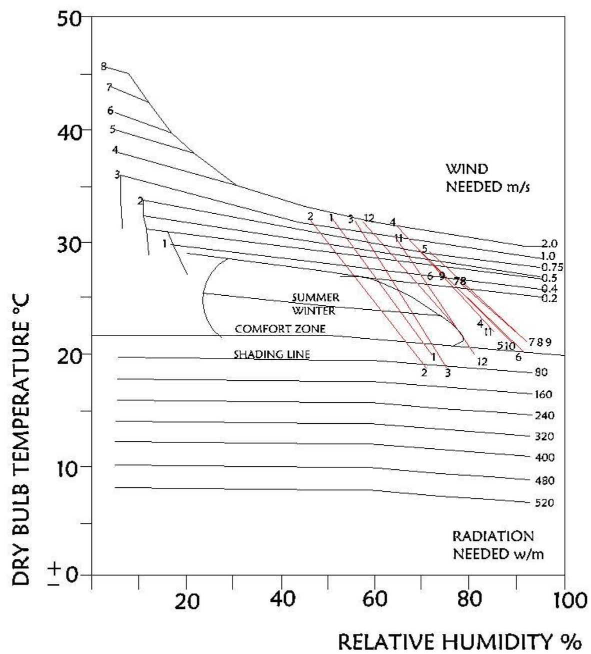

Figure 2.5: Bioclimatic Chart of Rivers State

Source: Dorcas, (2020)

4. Principles of Bioclimatic Architecture

In order to improve the thermal comfort conditions for the inhabitants, Bioclimatic Architecture imposes evolving climate responsive implantation in architecture through the employment of appropriate project techniques that take into account the climatic peculiarities of each location (Lamberts, 2006).

The energy savings have mostly been pushed by ensuring comfortable conditions for the building's occupants/users. Passive low energy techniques are persuaded for developing ecologically interactive, efficient, and contented to human comfort requirements to a large extent in spirit (Yeang, 1996). On this foundation, bioclimatic architectural principles are established to depict energy-saving measures, with applicability varying depending on the region's environmental features and building type (Maciel, 2007).

Some authors (Lamberts, 2006, Axarli & Teli, 2008), EDP Energy, 2008) have outlined different sets of principles. There are similarities and differences identified among them, according to the set of principles. They have defined a set of microclimate principles, as discussed in the next subsections.

4.1 Solar Protection

To stay in the comfort zone, bioclimatic architectural solutions try to limit heat gains from solar radiation and temperature increases. All building openings are protected, but the building envelope as a whole can be protected. Using large overhangs to protect internal spaces from solar radiation, ensures that east and west elevations have few or no low-sun windows, and that walls on these elevations are reflective and well-insulated. Others are the use of low thermal mass materials to minimize heat storage; and use shading devices to reduce solar gain. Solar protection can be achieved through natural means, such as the employment of deciduous trees, or through architectural components, such as pergolas, porches, awnings, and finally interior and external (sunblind) blinds and exterior slats. The last resource is employed as an exterior building screen in certain public buildings in hot climates.

4.2 Natural/Day Lighting

Natural lighting solutions make use of both direct and indirect light to provide appropriate comfort and even light distribution in the interior throughout the year, depending on the type of building. Daylight availability is a design concern that varies throughout the day. The contact with changing natural light is physiologically, psychologically and architecturally important. (Vitrius, 2014) The optimal utilization of natural sunshine, according to Goulding and Lewis (1997), contributes significantly to energy efficiency, visual comfort, and occupant well-being. The utilization of daylight for internal illumination can help buildings save energy while also improving visual comfort. As a result, if natural day lighting is considered during the design phase, the utilization of daylight can result in a large reduction in the amount of electricity consumed for lighting, as well as a reduction in overall energy consumption. Sources of daylight include beams diffused by the atmosphere, reflected light from surrounding surfaces - ground, water, vegetation, and other buildings. Day lighting is determined by the availability of daylight, as well as the position, size, and orientation of windows, according to Altomonte (2008). Roof lights, Atria, Glazing, Transparent Insulation, Light pipes, and Light ducts are examples of solutions that can be utilized to optimize how natural light is captured and permitted to infiltrate a building, as well as how it is diffused and focused. It is also necessary to consider light control in order to avoid visual discomfort. The following are the most crucial characteristics of an effective day-lit space:

1. Adequate and uniform light distribution in the space;
2. Color rendition and natural shadow projections; and
3. Disabling glare is avoided, and contrasting glare is minimized.

Figure 2.7: Section Showing Natural Lighting

Source: www.somfyarchitecture.com

4.3 Natural Ventilation

The supply and removal of air through an indoor space without the use of mechanical devices is what this procedure entails. It is the flow of outside air into an enclosed place due to pressure or temperature variations. This is accomplished by being either wind-driven or buoyancy-driven by a directional buoyancy force caused by a temperature difference between the interior and external space.

Maximize natural ventilation by ensuring that: north and south walls have large ventilation openings; rooms are arranged to aid cross-ventilation; plans are open and free spaces between buildings are wide;

large volumetric ventilation is provided to remove internal heat; spacing of buildings optimizes access to breezes; and elevated construction is used, where possible, to improve wind exposure in free-standing houses.

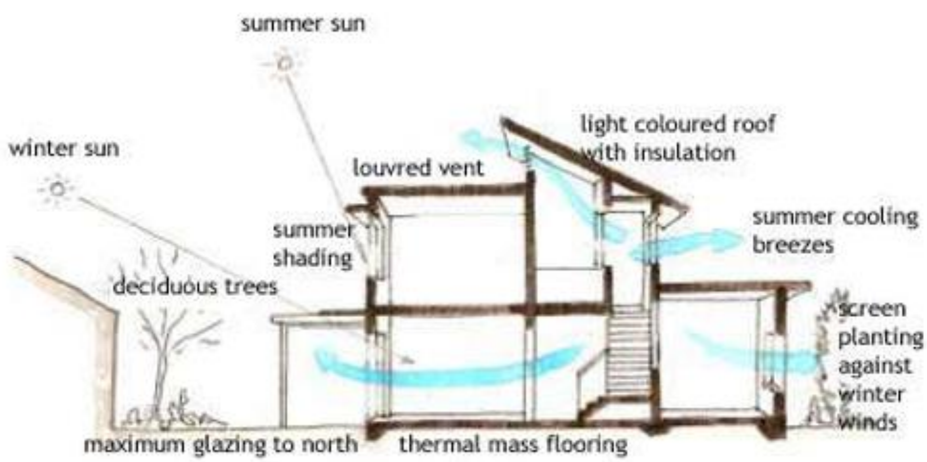

Figure 2.8: Section Showing Natural Ventilation

Source: Vilnius (2014)

4.4 Humidity Control

Humidity is moist air which contains water vapor. For comfort within the building, humidity levels should be about 35% and 60%. Condensation occurs in a structure when moist air comes into contact with a lower-temperature surface. Condensation accumulates first on the room's coolest surfaces, usually the glass of windows and doors. Condensation problems on building surfaces are determined by the amount of moisture that occurs, its duration on the surface, and if it accumulates on water-damaged surfaces. Condensation can develop in a specific area, such as the kitchen, bathroom, or laundry room, or it might be short-term during a severe cold spell. Homeowner Protection Office (HPO) (Homeowner Protection Office, 2014). Once the surfaces warm up or the moisture source is reduced, condensation moisture simply evaporates back into the air.

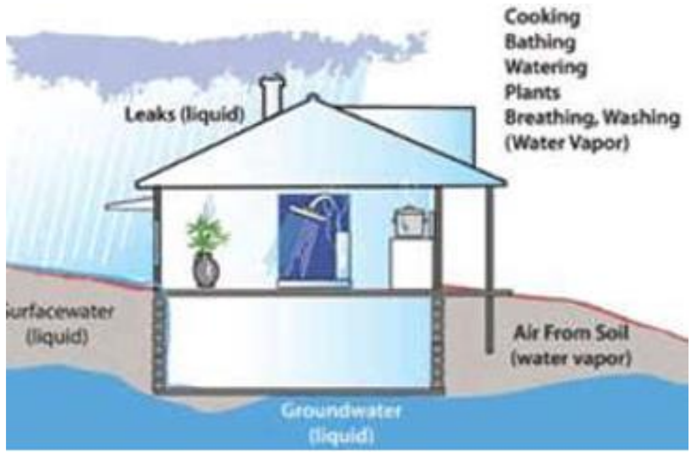

Figure 2.9: Section Showing How Humidity Enters the Building

Source: Vilnius (2014)

Some of the ways in which humidity enters the building could be from:

1. Rainwater intrusion, moisture in building materials and on the construction site, and leaks inside building systems or through the building shell are all factors to consider.
2. Infiltrated moisture from outside air. This may be from wind or HVAC systems.
3. Moisture generated internally from the activities of occupants.
4. Diffused vapor through the building envelope from differential vapor pressure.

Condensation issues can lead to drywall crumbling or soft patches, wood framing degradation or steel framing corrosion, peeling paint on walls, damage to the insulation inside the walls, and mold and mildew issues in a building.

Controlling humidity is achieved by the means of natural ventilation by opening windows for cross ventilation, the removal of moisture at source and the use of insulating materials for walls. Preventing moisture penetration underneath the floor can be achieved by covering with a vapor barrier such as polyethylene sheet.

5. Designing for Bioclimatic comfort in Hot-humid Climates

Hot-humid climates have warm temperatures all throughout the year that vary little between day and night, and present heavy precipitation and air humidity. Based on these characteristics, effective bioclimatic strategies for this climate seek to prevent heat gain, maximize heat dissipation, and protect from the rain and humidity levels. Heat gain can be optimally minimized by protecting the building from direct sun**.** This can be done by shading the windows, and by orienting openings away from facades that receive more radiation. In fact, the orientation of a building in this climate can affect energy use by 30% with the west facade being the biggest contributor to heat gain**.**

Orienting the building along the east-west axis is best to avoid the radiation of west facades and to more easily control the high sun on south and north facades. Heat dissipation can be obtained through natural ventilation, and the use of light colors and vegetation. Passive cooling through air flow may be achieved by two processes:

- Cross-ventilation, which is caused by air pressure differences and openings located in opposite facades, and,
- Stack-effect ventilation, which is caused by the buoyancy of heated air even when there is no wind pressure. The use of light colors and vegetation help to reflect the heat and prevent radiant heating. Furthermore, a combined system leveraging shading and correct sizing and placement of openings can reduce cooling energy demand by 40%.

  Keeping moisture out of the building can be achieved using sloped roofs, site work that drains the water out of the edifice, and building for low thermal mass. Elevating the construction or building on hills is an effective strategy that achieves this goal, whilst also improving indoor air circulation.

These concepts can be applied to each building system as follows:

- **Roof:** Because hot-humid climates are concentrated in low latitudes, the roof is subjected to the majority of the radiation. Therefore, a large portion of the thermal stresses occurs in this system. The roof type recommended is ventilated, insulated, watertight, light-colored to reflect sun rays, and sloped with wide overhangs or verandas to protect against the rain and minimize sky glare.

- **Walls:** The use of thin, low-thermal-mass walls prevents moisture from accumulating, making it easy to dry after precipitation events. In this climate, high thermal mass is not advantageous since the temperature variation between night and day is not significant. The use of walls is primarily for screening and wind penetration, as opposed to responding to thermal stresses.

- **Openings:** The windows need to be operable and large to improve ventilation. For cross-ventilation, larger openings should be facing up-wind. All openings, however, should be shaded. An example strategy to improve ventilation, while also blocking solar radiation, is to employ the use of louvers. Furthermore, it is not optimal to have openings on the east and west facades due to increased radiation gain and challenges to control the sun at lower angles.

- **Floor and Foundation:** The ground floor should be elevated to avoid the earth's humidity.

- **Shading Devices:** Shading devices should be located on the exterior to block direct sun before it enters the building. Horizontal slats and projections efficiently shade openings on both the south and north facades. The west and east facades may employ sun-breakers such as vegetation to prevent excessive radiation.

6. Conclusion

In view of the probable adverse impact the tourism and hospitality industry and its related products have on the environment as part of the built environment, reducing the adverse human impact on the environment becomes more critical. The general public, as well as designers and clients, are now aware of the enormous environmental implications that buildings have. Architects, on the other hand, must always strive to create a harmonious environment for building occupants. The use of architectural solutions based on these bioclimatic principles should be encouraged as natural principles that can reliably aid artificial or mechanical means of energy generation.

REFERENCES

Akande, O.K. (2010), *Passive design strategies for residential buildings in a hot dry climate in Nigeria.* Wit Trans. Ecol. Env. 2010, 128, 61–71.

Almusaed, A. (2011). *Biophilic and Bioclimatic Architecture:* Analytical Therapy for the Next Generation of Passive Sustainable Architecture. London: Springer-Verlag.

Altomonte, S. (2008). *Daylight for Energy Savings and Psycho-Physiological Well-Being in Sustainable Built Environments.* UK: University of Nottingham University. Retrieved on March 2, 2012 from http:// *journal.ccsenet.org.*

Auwalu, F.K. (2019), *Exploring the Different Vernacular Architecture in Nigeria*. Int. J. Afr. Soc. Cult. Tradit. 2019, 7, 1–12

Axarli, K. and Teli, D., (2008). *Implementation of bioclimatic principles in the design of urban open spaces:* microclimatic improvement for the cooling period of an open space adjacent to the sea. Paper presented on the PLEA 2008 – 25th Conference on Passive and Low Energy Architecture, Dublin, 22nd to 24th October 2008

Dorcas T. and Pourvahidi P., (2020) "*Bioclimatic Approach for Climate Classification of Nigeria*

Energy Commission of Nigeria, (2014). *Overview of the building energy efficiency guideline (BEEG) for Nigeria.*

Energy Design Partnership, EDP Energy (2011). *Principles of bioclimatic architecture*. Retrieved on March 9, 2012

Evans, J. M. (2007). *The Comfort Triangles: A New Tool for Bioclimatic Design*. Published PhD. thesis. Retrieved on January 12, 2012 from http://www.darenet.nl.

Lamberts, R., (2006). *Bioclimatic Buildings*: A paper presented to the Federal University of Santa Catarina.

Maciel, A. (2007), *Bioclimatic integration into the architectural design*, University of Nottingham

Nwalusi, D.; Anierobi, C.; Efobi, K.; Nwokolo, C. (2015), *Climatic Considerations in Architectural Design of Buildings inTropics*: AcasestudyforhotdryandwarmhumidclimatesinNigeria. J.Env. Manag. Saf. 2015, 6, 54–63.

Olgyay V. and Olgyay A. (1963), "Design with climate," Bioclimatic Approach to Architectural Regionalism, New Jersey, 1963.

Somfy Group, (*2009). Bioclimatic Facade.* Publised paper. Retrieved on october 8, 2012 from www.somfyarchitecture.com.

Szokolay, S. (2002), *"Putting the science back in the building."* Solar progress 23(1): 2.

Vilnius A. (2014), *Bioclimatic Principles in Architecture*: a way to better buildings. Vilnius Gediminas Technical University.

Yeang, K., (1996). T*he Skyscraper Bioclimatically Considered*, London Academy.