IMPORTANCE OF USING PASSIVE DESIGN PRINCIPLES IN ARCHITECTURAL BUILDING DESIGN

Efe, Igben

Department of Architecture,
Rivers State University, Npkolu, Oruworukwo Port Harcourt,
Email: nowhereblue@yahoo.com

ABSTRACT

Proper integration of all passive strategies as it regards sustainability will be a giant stride to optimizing energy usage in building with absolute mechanical dependant. Passive Design regards the particular way to construct a building using the natural movement of heat and air, passive solar gain and cooling in order to maintain a good internal comfort. usage of passive strategies in the building sector enhances sustainability measures predominantly through mitigating building's negative environmental impacts besides optimizing its energy performance. Building a passive home takes careful planning, which includes the introduction of five Basic principles: Orientation, Overhangs and shadings, Insulation, Double or triple glazing, Thermal mass, Through the use of passive solutions it is possible to mitigate, or at least reduce, the use of mechanical systems and the energy demand by a measurable percentage as well as the CO2 emissions. The aim of this paper is to avoid solar radiation, promote ventilation from the prevailing wind and ensure daylight into the building. This journal however demonstrates the importance of an alternative usage of energy in buildings as it regards the sustainable building through careful analysis of related journals, articles, and books. The study is useful for various resource persons involved in construction activities who wishes to imbibe all strategies for the achieving an eco-friendly building.

Keywords: *Energy Efficiency, Passive Design, Passive Strategies, Sustainable building*

Obsolescence is commonly regarded as the beginning of the end-of-life phase of buildings. Sources about the life cycle of buildings show a variety of terms. The building and development trade commonly refers to the development cycle, consisting of the development phase, including the design and the construction phase, and the usage phase, consisting of the actual use and the reuse or end-of-life phase (de Jonge and Arkesteijn, 2008). Sources regarding the life span, building pathology and mortality of buildings more often refer to the physical life or real life, being the period of physical existence, including the usage and end-of-life phase. This is in line with most national building stock statistics that in general only state withdrawal from the residential stock, in some countries subdivided by withdrawal by demolition and/or disaster, merging with other buildings and loss of function (Dol and Haffner, 2010). Obsolescence is commonly regarded as the beginning of the end-of-life phase of buildings. Sources about the life cycle of buildings show a variety of terms. The building and development trade commonly refers to the development cycle, consisting of the development phase, including the design and the construction phase, and the usage phase, consisting of the actual use and the reuse or end-of-life phase (de Jonge and Arkesteijn, 2008). Sources regarding the life span, building pathology and mortality of buildings more often refer to the physical life or real life, being the period of physical existence, including the usage and end-of-life phase. This is in line with most national building stock statistics that in general only state withdrawal from the residential stock, in some countries subdivided by withdrawal by demolition and/or disaster, merging with other buildings and loss of function (Dol and Haffner, 2010)

Obsolescence is commonly regarded as the beginning of the end-of-life phase of buildings. Sources about the life cycle of buildings show a variety of terms. The building and development trade commonly refers to the development cycle, consisting of the development phase, including the design and the construction phase, and the usage phase, consisting of the actual use and the reuse or end-of-life phase (de Jonge and Arkesteijn, 2008). Sources regarding the life span, building pathology and mortality of buildings more often refer to the physical life or real life, being the period of physical existence, including the usage and end-of-life phase. This is in line with most national building stock statistics that in general only state withdrawal from the residential stock, in some countries subdivided by withdrawal by demolition and/or disaster, merging with other buildings and loss of function (Dol and Haffner, 201)

INTRODUCTION

It is widely known and observed that a building that is not based on sustainable conception is always in separation from the natural environment and this has lead to functional isolation of such building. This negation of environmental factors and their influences on the building has lead to building solely depending on mechanical means as it only means of survival. Arup (2016), improving energy efficiency requires a different approach to the design and operation of buildings. It starts from the design methodology and goes through to the implementation of regulatory frameworks to allow and enforce *energy efficiency* (EE) targets. Education, dissemination and validation of the achievements of EE buildings could be provided by *energy efficiency* and sustainability certification schemes in conjunction with the Green Building Council of Nigeria (GBCN) and other relevant bodies. The resulting buildings will not only benefit from reduced energy consumption but will also provide a more comfortable internal environment for occupants, reduce the negative environmental impact, and be more economically sustainable and resilient. Operational energy in any building has mostly in recent time's dependant on artificial means. This in-turn negates nature and has caused certain indoor poor air which makes occupants encounter discomfort in the absence of power.
Operational energy that is dependent on natural means through the proper usage and consideration of all natural and environmental factor is of cause the best bet for enhancing the indoor air quality and thereafter provide a comfortable and sustainable environment for the occupants and also increase the life cycle of the building

Mohammad, (2012) gave an overview of the passive cooling techniques in building has it that Building energy use produces 33% of all annual carbon dioxide emissions, significantly contributing to the climate changes brought about by the accumulation of this heat-trapping gas.

He also has it that in the process of passive cooling a passive solar design involves the use of natural processes for heating or cooling to achieve balanced interior conditions. The flow of energy in passive design is by natural means: radiation, conduction, or convection without using any electrical device. Maintaining a comfortable environment within a building in a hot climate relies on reducing the rate of heat gains into the building and encouraging the removal of excess heat from the building. To prevent heat from entering into the building or to remove once it has entered is the underlying principle for accomplishing cooling in passive cooling concepts. This depends on two conditions: the availability of a heat sink, which is at a lower temperature than indoor air, and the promotion of heat transfer towards the sink. Environmental heat sinks are:
Outdoor air (heat transfer mainly by convection through openings)

- Water (heat transfer by evaporation inside and / or outside the building envelope)
- The (night) sky (heat transfer by long wave radiation through the roof and/or other surface adjacent to a building
- Ground (heat transfer by conduction through the building envelope)

Passive Architecture

That Passive Architecture is a climate responsive building that provides comfortable indoor conditions, without relying on mechanical cooling or artificial lighting. In hot and humid tropics, the aim of Passive Architecture is to avoid solar radiation, promote ventilation from the prevailing wind and ensure daylight into the building. The maximum impact can be achieved by strategizing the building elements such as orientation, form, opening and sun shading devices to achieve the said goals. Passive Architecture is not a new idea. Local traditional houses in the tropics have exemplified Passive Architecture by means of raised floor, low thermal mass envelope and raised/jacked roof to facilitate ventilation.

(Olgyay, 1963, Hyde, 2000). Says that generous openings like windows, doors and ventilation outlets are deliberately positioned to encourage natural ventilation. Traditional house also put emphasis in encouraging daylight as much as possible into its rooms. Nonetheless, the openings are well shaded, thus reducing heat gain.
This is done through varying principles Strategies. Among which are:

Solar Shading

Among all other solar passive cooling techniques, solar shading is relevant to thermal cooling of buildings especially in a developing country owing to their cost effectiveness and easy to implement. Rural India and developing countries in Middle-east region has witnessed a steep rise masonry houses with RCC roofs. However, the availability of electric power in the villages especially during summer is limited. These RCC roofs tend to make the indoor temperature very high around 41°C: This is due to high roof top temperature of around 65°C in arid regions. Solar shading with locally available materials like terracotta tiles, hay, inverted earthen pots, date palm branches etc. can reduce this temperature significantly.

Shading with tree reduces ambient temperature near outer wall by 2°C to 2.5°C. On an average a depression of six degree centigrade in room temperature has been observed when solar shading techniques are adopted. Kumar,
Garg and Kaushik (2005), evaluated the performance of solar passive cooling techniques such as solar shading, insulation of building components and air exchange rate. In their study, they found that a decrease in the indoor temperature by about 2.5°C to 4.5°C is noticed for solar shading. Results modified with insulation and controlled air exchange rate showed a further decrease of 4.4°C to 6.8°C in room temperature.

In the use of passive cooling, certain principle are adhered to these principles are also point of emphasis in this paper. Below are some of the consideration.

- **Building Orientation**

The appropriate placement of building with respect to solar path and taking full advantage of it positive effect is a passive strategy to adopt. Room placement and on a given site should be carefully determined and placed according to the activities or functions.

- **Window Specifications**

Double-glazing is now almost a requirement, because of recent changes to the energy efficiency requirements. A window's thermal property is made up of a combination of its glazing performance and its frame performance. Thermally broken aluminium was selected for the framing. Although alternative framing materials perform better thermally, other considerations – such as cost, maintenance and structural rigidity – dictated the decision. The wider (12 mm) spacing between insulated glazing units was chosen for its better thermal performance. A low-E (emissivity) coating was applied to the outside surface of the inner pane to further reduce the transfer of radiant heat.

- **Shading By Trees And Vegetation**

Proper Landscaping can be one of the important factors for energy conservation and improving passiveness in buildings. Vegetation and trees in particular, very effectively shade and reduce heat gain. Trees can be used with advantage to shade roof, walls and windows. Shading and evapotranspiration (the process by which a plant actively release water vapor) from trees can reduce surrounding air temperatures as much as 5°C. Different types of plants (trees, shrubs, vines) can be selected on the basis of their growth habit (tall, low, dense, light permeable) to provide the desired degree of shading for various window orientations and situations Roman (2008).

1. 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. When these trees drop their leaves in the winter, sunlight can reach inside to heat the interiors. Deciduous trees also form a strong buffering effect on

the environment and building thus maintaining a cooling effect or mitigating the effect of of a harsh climatic condition
2. Trees with heavy foliage are very effective in obstructing the sun's rays and casting a dense shadow. Dense shade is cooler than filtered sunlight. High branching canopy trees can be used to shade the roof, walls and windows.
3. Evergreen trees on the south and west sides afford the best protection from the setting summer sun and cold winter winds.
4. Vertical shading is best for east and west walls and windows in summer, to protect from intense sun at low angles, e.g. screening by dense shrubs, trees, deciduous vines supported on a frame, shrubs used in combination with trees.
5. Shading and insulation for walls can be provided by plants that adhere to the wall, such as English ivy, or by plants supported by the wall, such as jasmine.

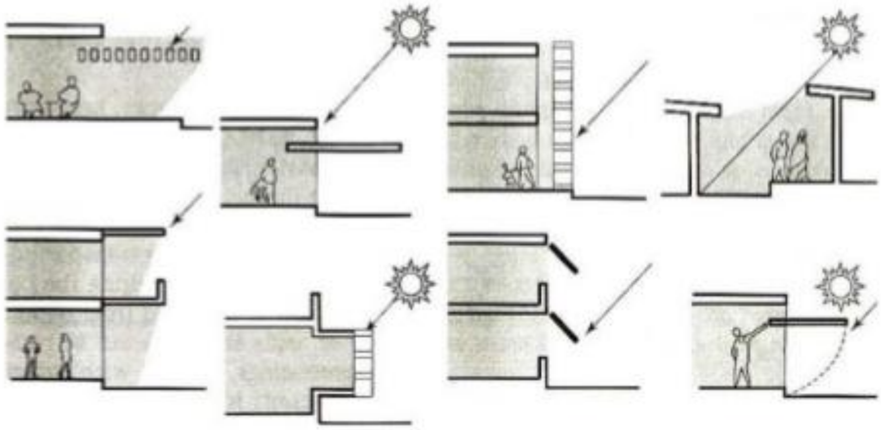
6. Horizontal shading is best for south-facing windows, e.g. deciduous vines (which lose foliage in the winter) such as ornamental grape or wisteria can be grown over a pergola for summer shading.

Glazing Types

Glazing plays an important role in building energy management due to their influences on allowing the solar radiations to pass through the inner spaces. Lee JW et al. [25] opined that, windows are responsible for 20-40% wasted energy in the building. Window is an indispensable part of building configuration, which has an influential impacts on the overall building energy performance. The energy performance of a window depends on its thermal transmittance, the glazing solar transmittance, and the air leakage due to the frame and installation airtightness. Among all these parameters, glazing system can be considered as a major determinant in energy performance.

Shading By Overhangs, Louvers and Awnings Etc.

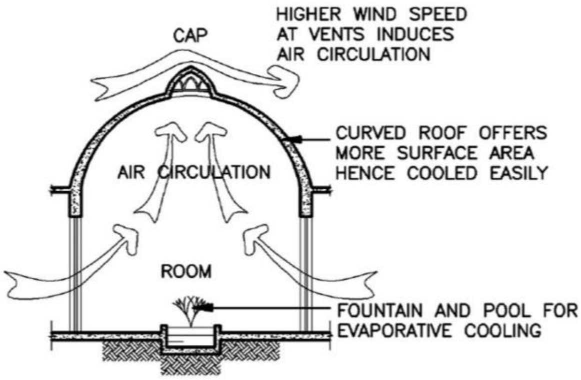
Well-designed sun control and either shading devices, as parts of a building or separately placed from a building facade, can dramatically reduce building peak heat gain, cooling requirements, and improve the natural lighting quality of building interiors. The design of effective shading devices will depend on the solar orientation of a particular building facade. For example, simple fixed overhangs are very effective at shading south-facing windows in the summer when sun angles are high. However, the same horizontal device is ineffective at blocking low afternoon sun from entering west facing windows during peak heat gain periods in the summer. Fig. 1 shows the different types of shading devices.



Types of Shading Devices
SOURCE: Acta Technica Napocensis: Civil Engineering & Architecture Vol. 55, No. 1 (2012)

Air Vents

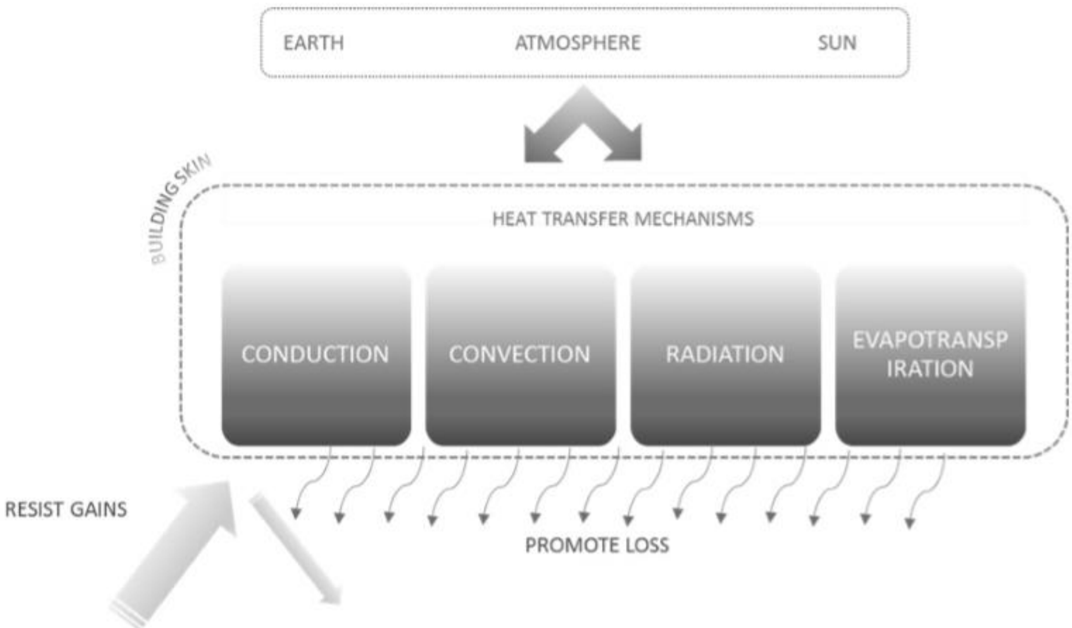
Curved roofs and air vents are used in combination for passive cooling of air in hot and dry climates, where dusty winds make wind towers impracticable. Suited for single units, they work well in hot, dry, warm, and humid climates. A hole in the apex of the domed or cylindrical roof with the protective cap over the vent directs the wind across it, The opening at the top provides ventilation and provides an escape path for hot air collected at top. Arrangements may be made to draw air from the coolest part of the structure as replacement, to set up a continuous circulation and cool the living spaces. The system works on the principle of cooling by induced ventilation, caused by pressure differences.



Induced ventilation through curved roof and air vents
SOURCE: Acta Technica Napocensis: Civil Engineering & Architecture Vol. 55, No. 1 (2012)

- **Evaporative Cooling**

Evaporative cooling is a passive cooling technique in which outdoor air is cooled by evaporating water before it is introduced in the building. Its physical principle lies in the fact that the heat of air is used to evaporate water, thus cooling the air, which in turn cools the living space in the building. However passive evaporative cooling can also be indirect. The roof can be cooled with a pond, wetted pads or spray, and the ceiling transformed into a cooling element that cools the space below by convection and radiation without raising the indoor humidity.



Design for cooling: basic strategies, site selection & orientation

Building Form & Geometry

The building form dictates the effectiveness of natural daylight and natural ventilation through a building. Features such as courtyards and buffer zones are described.

Desiccant Cooling

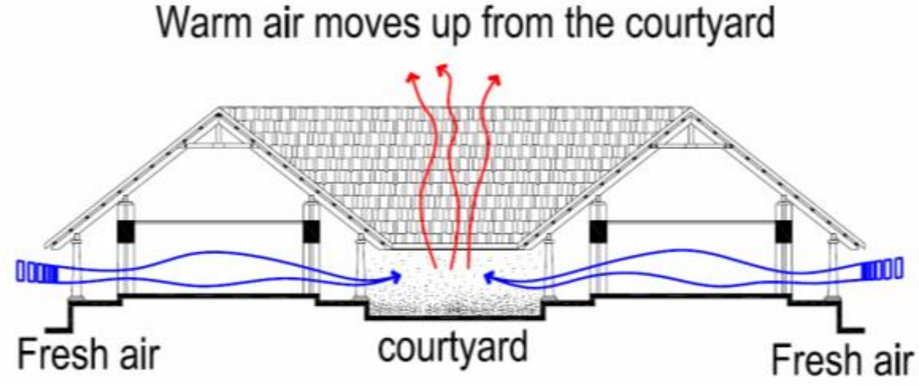
In the Nigerian region especially in the southern part, Desiccant cooling is effective because it is a warm and humid climates that predominates. Natural cooling of human body through sweating does not occur in highly humid conditions. Therefore, a person's tolerance to high temperature is reduced and it becomes desirable to decrease the humidity level. In the desiccant cooling method, desiccant salts or mechanical dehumidifiers are used to reduce humidity in the atmosphere. Materials having high affinity for water are used for dehumidification. They can be solid like silica gel, alumina gel and activated alumina, or liquids like triethylene glycol. Air from the outside enters the unit containing desiccants and is dried adiabatically before entering the living space. The desiccants are regenerated by solar energy. Sometimes, desiccant cooling is employed in conjunction with evaporative cooling, which adjusts the temperature of air to the required comfort level.

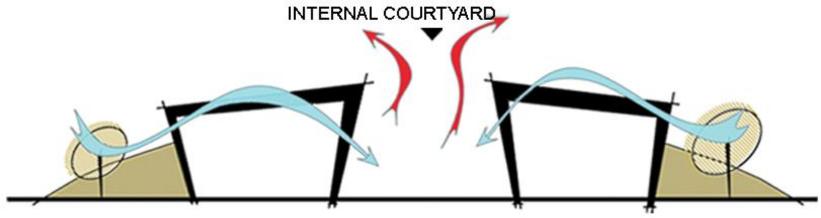
Ventilation

Proper ventilation is one of the important ways of promoting passive homes. Various rules of thumb exist to help with the design of naturally ventilated spaces.

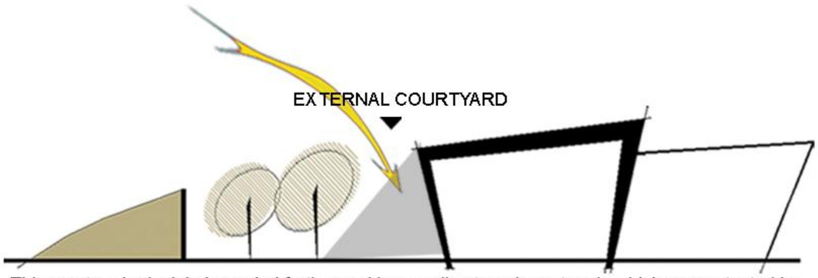
Single sided openings are the simplest form of ventilation, but are only viable for room depths around 6m or 2.5 times the ceiling height. Cross ventilation is more effective since the wind pressure will help force air through the building. In this case, room depths of around 12m or more are possible (five times the ceiling height). More complex natural ventilation schemes are possible involving atria, light wells etc. Atria must be designed with caution in Nigeria, since any roof lights will result in high solar gains into the building.

The Use of Courtyard





Courtyard spaces allow in cooler air thereby creating cooler spaces within. (A principle of traditional indian design for hot climates)



This courtyard principle is carried further making small external courtyards which are protected by earth berms externally.

The important of courtyard is of great important when it is conceptually used and is indeed a sustainable.
A courtyard is an architectural design element commonly applied in tropical buildings for its social, environmental and therapeutic potentials (Reymolds, 2002)

It provides fresh air, improves oxygen supply and dilute odours. It is important that the internal spaces in public buildings are well ventilated through the natural means that is, the use or incorporation of courtyards into the building form to reduce energy use in buildings which is a critical component of meeting carbon reduction commitments (Lutzenhiser, 1993). Hot climatic regions likes Nigeria experiences hot and harsh weathers which result in high temperature, this has lead to high need for indoor cooling using mechanical means which are not just expensive but require frequent maintenance and skilled workmanship, all of these practices has lead to high cost of building construction and maintenance. The high desire for comfort and cooling of the inner spaces within a building, it has resulted in high reliance on artificial cooling devices and machines in public buildings, because of this there is high energy consumption in buildings, and has contributed to climate change, a key factor of eliminate change

Energy Savings Benefit

The consequent effect of Passive Architecture is "savings" in the operational energy, termed as Energy Savings Benefit. This could be made tangible by comparing the energy consumption in buildings of similar type. For the purpose of this study, a house been chosen as a sample of a building. Theoretically, a house designed for maximum daylight needs less artificial lighting, hence uses less commercially supplied energy when compared to another that has no consideration for day lighting (Baker & Steemers, 2000).

In this instance, the Energy Savings Benefit claimed by the former occurs when it does not need to use artificial lighting (Fig. 4). Similarly, a house with good natural ventilation would require less mechanical cooling as compared to the one with poor ventilation. Nonetheless, such comparison is only valid when it is made on a leveled platform, whereby the two houses must be of the same locality and size. In addition, the behavior of the occupants in both houses has to be the same.

CONCLUSION

Integrating buildings and the environment is the best way of achieving a sustainable design. Therefore in achieving this, imbibing the strategies of Passive Design Principles is sure way of achieving the later. The artificial system, which is recently adopted and in turn has incurred a high standard of living on building owners, will drastically be mitigated. The importance of this system should be thought of at the conceptual stage of the every architectural piece.

RECOMMENDATION

Careful consideration of the importance of adopting passiveness in design will greatly enhance every design indoor comfort. It can also cause the life cycle of a building to withstand most atmospheric condition therefore making the building sustainable. The service life of buildings and their maintenance culture can also be minimized when these parameters are carefully considered and implemented. Negligence to the consideration of these principles will cause a deray in design

Therefore this study is considered best for consideration and implementation.

REFERENCES

Aina A.G. (2010), Energy Efficient Buildings Using Solar Energy as an Alternative Energy Source. Unpublished B.Sc Dissertation submitted to the Department of Architecture, Covenant University Ota.

Amole B. (2005), Logical Argumentation and the Case-study Method, Architectural Research Techniques and Analysis by Amole B., Amole D., Arayela

Auliciems, A. & Szokolay, S. V. (1997). *Thermal comfort - PLEA notes no. 3*. Australia: The University of Queensland.

Auliciems, A. & Szokolay, S. V. (1997). *Thermal comfort - PLEA notes no. 3*. Australia: The University of Queensland.

Baker, N. & Steemers, K. (2000). *Energy and environment in architecture – a technical design guide*, London: E&FN Spon Press.

Buchanan, P. (2005). *Ten shades of green: architecture and the natural world*. New York: The Architectural League.

Arup. (2014). City Resilience Framework. Rockefeller Foundation.

Chartered Institute of Building Services Engineers (CIBSE) Code for Interior Lighting, (1994).

Federal Government of Nigeria. (2015). Energy Efficiency Policy.

Federal Government of Nigeria. (2015). National Energy Action Plan.

G.S. Brager, R. d. (2001). Climate, Comfort & Natural Ventilaton: A new adaptive comfort standard for ASHRAE Standard 55. Berkeley: University of California, Berkeley.

Hyde, R. A. (2000). *Climatic responsive design: a study of buildings in moderate and hot humid climate*. London: E&FN Spon Press.

Majoros, A. (1998). *Daylighting: PLEA notes no. 4*. Brisbane: PLEA International/University of Queensland Arch Dept.

Mustapa, S. I. & Yusop, M. Y. (2007). Mitigating the adverse impact of climate change through sustainable use of energy. *Energy Smart*, Issue 0021. Kuala Lumpur: Pusat Tenaga Negara.

Olgyay, V. (1963). *Design with climate: Bioclimatic approach to architectural regionalism*, New Jersey: Princeton University Press.

Sh. Ahmad, S. (2004). *A study on thermal comfort and energy performance of urban multistorey residential buildings in Malaysia*. Unpublished Ph.D, The University of Queensland, Brisbane.

Smith, P. F. (2005). *Architecture in a climate of change: a guide to sustainable design* (2nd ed.). Oxford; Boston: Elsevier/Architectural Press.

Szokolay, S. V. (2006). Proceedings from the International Symposium on Sustainable Energy & Environment (ISEESEE): *Passive Climate Control in Warm-humid Region*, Kuala Lumpur.

Reference to this paper should be made as follows: Efe, Ighen (2019). Importance of using Passive Design Principles in Architectural Building Design. . *J. of Environmental Science and Resources Management* Vol. 11, No. 3, Pp. 100-114