INTEGRATING PRINCIPLES OF PASSIVE COOLING IN THE DESIGN OF FIVE STAR HOTEL, MINNA

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TITLE PAGE

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JANUARY, 2017

DECLARATION

I hereby declare that the work in this Dissertation titled “INTEGRATING PRINCIPLES OF PASSIVE COOLING IN THE DESIGN OF FIVE STAR HOTEL, MINNA” has been carried out by me in the Department of Architecture, ABU, Zaria. The information derived from the Literature has been acknowledged in the text and a list of reference is provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

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Name of Student	Signature	Date

CERTIFICATION

This Thesis titled “INTEGRATING PRINCIPLES OF PASSIVE COOLING IN THE DESIGN OF FIVE STAR HOTEL, MINNA” by Abdullahi MOHAMMED LAWAL meets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

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ABSTRACT

The world faces the problem of energy crisis. Nigeria, not being an exception faces the same problem as its generating capacity is below 5000 megawatts. Studies have also shown that only 48% of Nigerians have access to electricity, ranking Nigeria among the lowest in the world.Generally, buildings uses approximately 40% of the total energy consumed globally and represent 33% of the annual carbon dioxide emission that causes global warming. Hotel buildings use 60% out of the 40% of the energy consumed by buildings. Considering that hotel buildings represent a large proportion of a county's energy consumption.This suggests the need for urgent and concerted action by all stakeholders in the construction industry to minimise ecological degradation on a massive scale. The research approach is quantitative in nature and adopts both primary and secondary sources of data collection. The research instruments utilized during the course of the study include; Self- administered questionnaire and Non-participant observation.Literature review utilizes the review of works done on the subject drawn from published books, articles, journals, papers and official documents of professional bodies and an energy audit was used to study the energy use patterns, principles of passive cooling and the architectural requirement of three selected hotel buildings within the composite of hot-humid/hot-dry climate of Nigeria.The research has disaggregated energy demand in hotel buildings into cooling, lighting and other appliances with cooling accounting for 57% followed by appliances with 30% and lighting 13%. The research has also established that energy consumption in hotel buildings within a composite of hot-humid/hot-dry climate of Nigeria is 157kWh/m². Computer simulation has further revealed that the average normalized cooling load for conventional material/construction is 126kWh/m² while that of optimized material/construction is 88kWh/m². Finally, the research recommends that cooling end-use in hotel designbe targeted by integrating principles of passive cooling as this will provide a substantial savings in energy consumption of up to 45%.

1 INTRODUCTION

1.1 Background of study

Over the past decades, it became possible with the advent of oil, gas and electricity to disregard completely the effect of climate in the design and construction of buildings as needs were met by mechanical aids(Guyer, 2013). Although mechanical aids were successful in controlling the internal environment, but they were dependent entirely on the use of large quantities of energy(Rowe and Piechowsky, 2007). Today, high energy costs impose restrictions on the application of these mechanical aidswhile energy sources deplete (Larson, 2006). The rapid increase of the world population, especially in the third world, reduces the amount of energy available per capita which increases the importance of energy conservation(Renewable Energy Policy Network for the 21st Century REN 21, 2013)

Sawin (2013) in the Renewables Global Status Report (RGS) stated that United Nation has been investing a huge sum of money in its sustainable energy for all initiative to achieve universal energy access for all. Achieving this objective has risen to the top of international agenda.

Today, the world population has risen to about seven billion and is geometrically increasing, according to the Renewable Energy Policy Network for the 21st century (Renewable Energy Policy Network for the 21st Century REN 21, 2013). The Energy Information Administration (EIA,) in the United States of America (USA) has predicted that in the twenty first century, there will be substantial increases in energy demand which in turn will increase carbon dioxide (CO2) emission due to numerous human activities (EIA, 2009). Similarly, Sawin(2013)has reported in the REN 21 that the current human population of seven billion has increased the generation of greenhouse gases to 400 parts per million of atmospheric Carbon dioxide (CO2) potentially

enough to trigger a warming of two degrees Celsius compared to pre-industrial levels. This increase of greenhouse gas emission is expected to occur because of numerous activities leading to economic growth in developing economies of the world (Michell, 2012).

Meeting the growing energy needs in a climate-constrained world requires a fundamental shift in how energy service is delivered and used. Energy conservation measures are central to achieving this objective (Goswami, 2007). According to Beggs, (2002) Energy conservation will help in advancing energy security, economic and social development and poverty alleviation while mitigating climate change.Similarly, Energy conservation can also increase national energy security and will help to improvenation's international balance of payment (Goswami, 2007).

According to World Watch Institute(2007), buildings uses approximately 40% of energy consumed globally and produces 33% of all annual carbon dioxide emission that causes acid rains and contributes to smog formation. Similarly, Awbi (2010),also stated that buildings are responsible for a large proportion of a country's total energy consumption and large part of it is used in ventilation, heating, cooling and cleaning of outdoor air supplied to the buildings.

United States Department of Energy (USDOE, 2008) studies, have also shown that 60% out of the 40% of energy consumed by buildings globally is used up in heating, cooling and ventilation.Geetha and Velraj (2012),stated that the increasing level of damage to the environment has created greater awareness at the international level, which resulted in the concept of green energy building in the infrastructural sector leading researchers, policy makers, environmentalists and building architects focusing on the conservation of energy and its utilization in buildings

It is the Hotel sector where energy consumption is of most concern(Nayak, 2005). According to International Energy Agency (2010), the integration of principles of passive cooling in hotel buildings is receiving a lot of attention internationally and the tourism industry is interested in improving thermal comfort and air quality through passive means so as to minimise energy consumption.

1.2 Energy Consumption in Nigeria

World Bank's data (2014), on access to electricity across countries of the world, show that only forty eight (48) percent of Nigerians had access to electricity between 2009 and 2013, ranking it among the lowest in the world.

The Energy Commission of Nigeria (2013), states that the power (about 5,000 MW) currently generated in Nigeria is inadequate and unstable, forcing a large portion of the industry, businesses and households to rely on diesel and petrol generators as primary or back-up source of electricity which is expensive and a source of greenhouse gas emission. More also, a large part of the energy generated in Nigeria is wasted due to the wasteful behavior and the use of energy intensive and inefficient technologies (Adeleke et al, 2010).

ThisDay Newspaper (2015) reported that Nigeria's Power Sector generation capacity stands at 5,500 megawatts. When this is divided by the population of 183 million (CIA world factbook, 2015), there is only 30 watts per person. The household bulbs used are rated 25w, 40w, 60w or 100w while the 2-feet fluorescent tube consumes about 20w. Thus, if all the generated electricity is used exclusively in homes with nothing for industries, business, and commercial centers, there is just enough to light one bulb for every Nigerian.

According to World Tourism Organization(World Tourism Organisation (WTO), 2012) hotel buildings have become major sources of revenue to both the governments and individuals as they represent the major energy-consuming of the buildings stock's total energy usage. The patronage and the profitability of the hotel business depend largely on comfort of the guests in the hotel, forcing owners in Nigeria to rely on diesel and petrol generators for running their hotels as primary or back-up source of electricity.

1.3 Energy Conservation in Hotel Buildings.

According to Energy Conservation Center (ECC, Japan, 2009), the first commitment period of Kyoto Protocol started in 2008, which requires hotel owners to achieve a target of reducing greenhouse gas emissions to 6% below the base year (1990) levels by 2012. Approximately 87% of the greenhouse gas is comprised of carbon dioxide (CO2) from energy consumption. The CO2 emissions have been significantly growing especially in hotel business sectors and enhancement of drastic measures has become an urgent need.

1.4 Problem Statement of the research

The world faces the problem of energy crisis. Nigeria, not being an exception faces the same problem as its generating capacity is below 5000 megawatts. Studies have also shown that only 48% of Nigerians have access to electricity, ranking Nigeria among the lowest in the world.Generally, buildings uses approximately 40% of the total energy consumed globally and represent 33% of the annual carbon dioxide emission that causes global warming. Hotel buildings use 60% out of the 40% of the energy consumed by buildings. Considering that hotel buildings represent a large proportion of a county's energy consumption.

United Nations Development Programme (UNDP) with support from Global Environment Facility (GEF) in its project to promote Energy Efficiency, in collaboration with Nigerian Energy Commission (ECN), The Federal Ministry of Environment and the National Centre for Energy Efficiency and Conservation (NCEEC) principally focuses on aspects of energy consumption in industries, agriculture and transportation with no specific reference to energy consumption in buildings. Similarly, the Nigerian National Building Code, (2009) was also evolved with the aim of setting minimum standards on buildings pre-design, design, construction and post-construction stages to ensure quality, safety and proficiency in the building industry. However, this document made no reference to energy conservation in buildings.

The rapid development and haphazard constructions taking place in most Nigerian cities, adds to the need to create awareness on energy conservation techniques in buildings with minimal impacts on the environment in tandem with the current international best practice.

More so, a large part of the energy generated in Nigeria (which is inadequate) is wasted due to the wasteful behavior and the use of energy intensive and inefficient technologies. Hotel buildings could make a far greater contribution to energy management if their performance is measured and understood to ensure continuous improvement in their energy conservation.

1.5 Aim and Objectives

This thesis is aimed at minimizing energy usage for cooling in hotel buildings through the evaluation and application of principles of passive cooling techniques.

Specific objectives of the study are as follows:

i. To identify energy consumption patterns in hotel buildings

ii. To identify the principles of passive cooling in hotel buildings

iii. To identify the architectural requirement of hotel building design

iv. To simulate the effect of passive cooling strategies on energy consumption in a proposed hotel building.

v. To integrate passive cooling strategies as means of energy conservation in the design of a five star hotel in Minna, Niger state.

1.6 Research Questions

During the course of this research, the following questions are raised to assist in the research process.

i. What are the energy consumption patterns in hotel buildings?

ii. What are the principles of passive cooling in hotel buildings?

iii. What are the architectural requirements of hotel building design?

iv. What is the effect of passive cooling strategies on energy consumption in the proposed hotel?

v. How can passive cooling strategies be used as a means of energy conservation in thefive star hotelto be situated in Minna, Niger state?

1.7 Justification

The need to evolve architecture that would respond to the changing climate of the World and the global boom of the hotel industry promoting green buildings to solve the problem of climate change. The effect of this phenomenon needs to be intercepted from different angle in order to

conserve energy.If nothing is done, greenhouse gas emissions from buildings will be more than double in the coming years.

Implementing simple and inexpensive energy conservation measures could cut hotel's bills to as much as 20% (Carbon trust, 2013). Similarly, Lighting control, optimising room and water temperatures, and raising energy awareness among staff are some of the simple energy conservation measures in hotels. Equally importantly, energy efficiency measures are likely to benefit the reputation of any hotel establishment. In addition to financial and customer service benefits, there are social and environmental advantages to reducing energy consumption, such as minimising climate change (Carbon trust, 2013).

1.8 Scope

The scope of this thesis coversprinciples of passive cooling in hotel buildings that minimizes energy usage in composite of hot-humid/hot-dry climates.An energy audit is conducted in some selected hotel buildings to ascertain the amount of energy consumed every year and a simulation is conducted using Computational Fluid Dynamic (CFD) software (Ecotect) to see the possibility of saving energy by adopting principles of passive cooling in hotel design.

1.9 Research Methods

The research approach is quantitative in nature and adopts both primary and secondary sources of data collection. The primary source employs the use of case studies of related hotel buildings while the secondary source utilizes the review of works done on the subject drawn from published books, articles, journals, papers and official documents of professional bodies. The research instruments utilized during the course of the study include:

i. Self- administered questionnaire

ii. Non-participant observation

Statistical and parametric analysis is conducted during the research. The data collected during the energy audit is analyzed using descriptive and inferential statistical analysis while the parametric analysis gives predictions made following modification of variables in the Computational Fluid Dynamic (CFD) software.

1.10 Research Development

This thesis consists of seven chapters:

Chapter One which is the Introductiongives the background of study, problem statement, aim and objectives and research questions which are intended to answer the objectives which are tailored towards achieving the aim of the research. It also covers motivation, justification and the scope of the research.

Chapter Two which is the theoretical framework looked into information for understanding passive cooling principles and energy conservation in hotel buildings.

Chapter Threefocuses on the methodology that will be employed to achieve the set objectives in the process of conducting the research.

Chapter Four presents the data collected from energy audit and simulationusing the computational fluid dynamic software (Ecotect).

Chapter Five is the findings made from the energy audit and the simulation software (Ecotect) with regard to passive cooling as a means of energy conservation and discussion of the findings with respect to other views and opinions discovered from the literature.

Chapter Six is design report of the proposed hotel. Key design requirement and how the research findings are incorporated into the design are discussed.

Chapter Sevenis the conclusion and recommendation. In this chapter, summary of findings, contribution to knowledge and areas of further research are discussed.

2 LITERATUREREVIEW.

2.1 Preamble

This Chapter forms a theoretical framework coveringprinciples ofpassive cooling and energy conservation in hotel buildings. It further covers information regarding climate and factors affecting passive cooling in a composite of hot-humid/hot-dry climate. It also looks into hotels types and their star rating classification and finally, thespatial hotel standard requirement guiding successful delivery of a three star garden hotel design is also reviewed.

2.2 Effects of Global Climate Change

The Intergovernmental Panel on Climate Change (Inter-Governmental Panel on Climate Change (IPCC), 2007) described Africa as "one of the most vulnerable continents to Climate Change and Climate variability" due to social, economic and environmental conditions that amplify susceptibility to negative impacts and contribute to low capacity to cope with and adapt to the climate hazards.

Improved Energy conservation techniques are critical response to the pressing phenomenon of climate change, economic development, and energy security facing many countries worldwide (Inter-Governmental Panel on Climate Change (IPCC), 2007). It has been observed that different regions of the world are already experiencing the impacts of this climate change as this is evident in the rise in the sea levels, change in the amount and pattern of precipitation causing droughts, changes in animal migration and life circles, Higher temperatures and more heat waves as well as expansion of subtropical deserts and melting ice bags in the polar regions as shown in Plate I (WGBC, 2013).

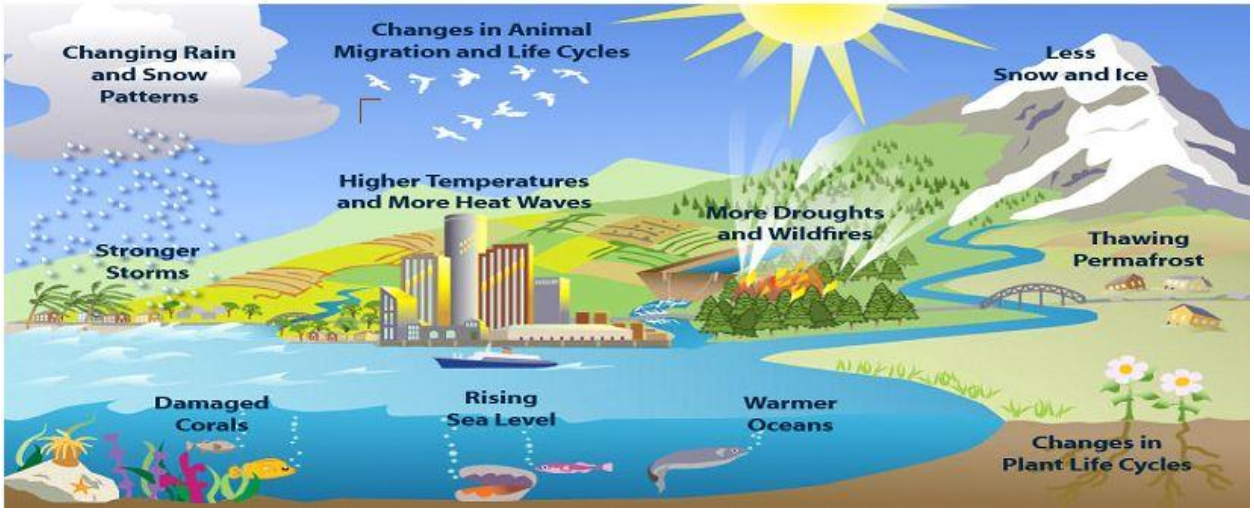


Plate I: Effects of Climate change around the World.
Source: World green building Council, (2013).

2.3 Passive Cooling

Passive cooling has been used throughout history for cooling building'sinterior in various ways (Emueze, 2013). Passive cooling refers to techniques employed in building design in order to prevent and modulate heat gains so as to achieve thermal comfort within spaces in buildings(BRANZ, 2011). Passive cooling involves the use of natural processes for heating/cooling so as to achieve balanced interior conditions by preventing heat from entering into the building or removing excess heat from the building. Passive cooling techniques helps to reduce the peak cooling load in buildings, thus, reducing the size of air conditioning equipment and the period for which it is required. Passive cooling is also an approach to building design that uses the building architecture to minimise energy consumption and improve thermal comfort.

According to Geetha (2012), passive cooling in buildings is classified into two classes namely:

i. Heat Prevention/Reduction (Reduce heat gains)

ii. Heat Dissipation (Remove internal heat gains)

2.3.1 Heat Prevention/Reduction

This is a passive cooling technique which prevents heat from the surrounding from gaining access into the building. It also involve means of reducing the surrounding heat by employing cooling measures which when the surrounding hot air gets in contact also becomes cool. Solar control is the primary design measure employed to prevent heat from entering the building. Some of the solar control measures as outlined byGeetha (2012) include:

i. **Building Orientation:** Thisinvolves placing the building on the site taking cognizance of the sun path so as to minimise surfaces exposed to solar radiation.

ii. **Shading devices:**This includes; overhangs, awnings, exterior shades, venetian blinds, curtains and drapers.

iii. **Landscaping:**This include all soft landscape such as plants, trees etc, which absorbs most of the solar radiation incident on to the building by lowering the air and surface temperatures as well as increase the relative humidity of the surrounding air thereby making the air cold.

iv. **Building insulation:**Heat naturally flows from a warmer to a cooler space; insulation provides resistance to heat flow, thereby reducing the amount of energy needed to keep a building warm in the winter and cool in the summer. Building Insulation is frequently discussed in terms of its ability to resist heat flow, or it's R-value. A variety of insulation options exist, including blanket, concrete block, insulating concrete forms, spray foam, rigid foam, and natural fibre insulation.

2.3.2 Heat Dissipation

This is a passive cooling technique which removes excess heat from the interior of a building by the use of natural heat sinks. Heat dissipation techniques deal with the disposal of the excess heat in a building to a heat sink characterized by lower temperature, like the ambient air, the water, the ground and the sky. Some of the heat dissipation measures stated by Geetha (2012) include:

i. Natural ventilation (air as heat sink)
ii. Ground cooling (earth as heat sink)
iii. Evaporative cooling (water as heat sink)

However, only Natural ventilation and Ground cooling are employed in composite of hot-humid/hot-dry climate (Geetha, 2012).

2.3.2.1 Natural ventilation

According to Allard (1998) Natural Ventilation is defined as a strategy for achieving acceptable indoor Air Quality (IAQ) based on the supply of fresh air to a space and the removal or dilution of the indoor pollution concentration. Similarly, Natural ventilation is defined by Ogwezi, (2012) as a low energy alternative that produces thermally acceptable and improved indoor air quality (IAQ) of spaces within buildings. In addition, it is also said to be a means of achieving optimum indoor air quality free of pollutants that causes irritation, discomfort or ill health in the occupants (Emueze, 2013).Natural Ventilation also plays a major role in maintaining acceptable thermal comfort by heat dissipation and removal of unwanted gases within buildings (Allard and Ghiaus, 2005). Thomson (2011),also added that the thermal behaviour of a building strongly depends on its natural ventilation and air infiltration into the building. In the same vein

Willmert(2001),stated that Natural Ventilation also helps to remove moisture from buildings to alleviate dampness.

Natural Ventilation is possible through the utilization of a natural driving force. This is achieved by basically relying on windor thermal buoyancy or both as driving forces. Taking advantage of these basic strategies promotes passive cooling in buildings. The wind driven and the thermal buoyancy can occurseparately but frequently occur at the same time (Kleiven, 2003)

2.3.3 Wind Driven Ventilation

Wind Driven Ventilation occurs as a result of various pressures created by wind on the building envelope. According to Kleiven (2003), as naturally occurring wind blows towards a building, the wind hits the windward wall causing a direct positive pressure. The wind moves around the building and leaves the leeward wall with a negative pressure also known as a sucking effect. If there are openings on the windward and leeward sides of the building, fresh air enters the building through the openings on the windward side and exit through the openings on the leeward side to balance and relieve the pressures on the windward and leeward sides. Figure 2.1 demonstrate formation of positive and negative pressures as a result of naturally occurring wind blowing towards a building.

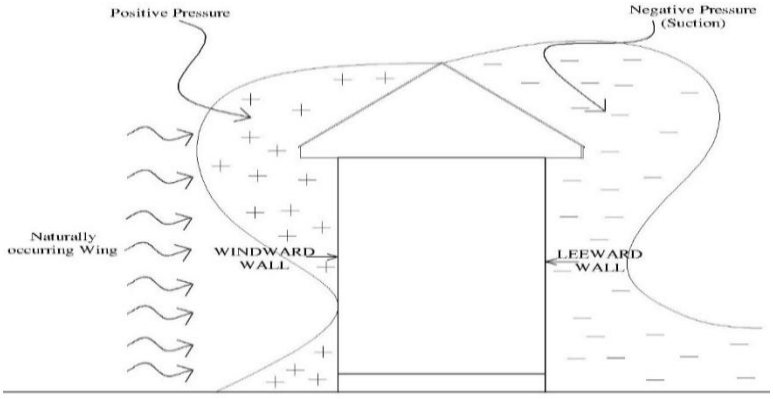


Figure 2.1 Positive and Negative air pressures on buildings.
Source: Kleiven, (2003)

Two (2) basic classes of wind driven ventilation have been identified by Kleiven, (2003), namely:

i. Single-sided Ventilation

ii. Cross Ventilation

2.3.3.1 Single-sided Ventilation.

The Single Ventilation relies on opening(s) on only one side of the ventilated enclosure. Fresh air enters the space through the same side as used air is exhausted as shown in Figure 2.2. A typical example is the rooms of a cellular building with open able windows on one side only and closed internal doors on the other side. This type of ventilation, the main driving force for is wind turbulence. In this case, lower ventilation rates are generated and the ventilation air does not penetrate so far into the space.

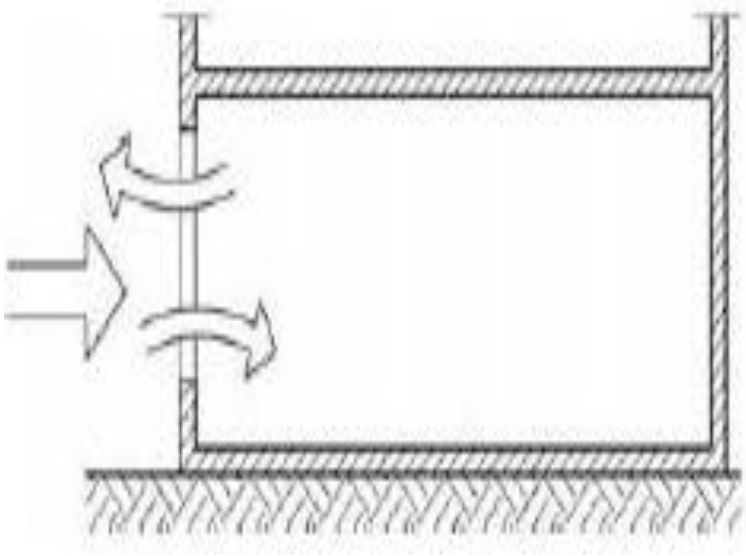


Figure 2.2 Inflow of fresh air and outflow of vitiated air in a single sided opening space. Source: Kleiven, (2003).

2.3.3.2 Cross Ventilation

Cross Ventilation is the case when air flows between two sides of a building envelope by means of wind-induced pressure differentials between the two sides. In this case, The Ventilation air enters the space through windows, grills and other opening integrated in the façade. The air usually moves from the wind-ward side to the lee-ward side. Figure 2.3 shows air entering the space from one side, picks up heat and pollutants and leaving from the opposite side of the space.

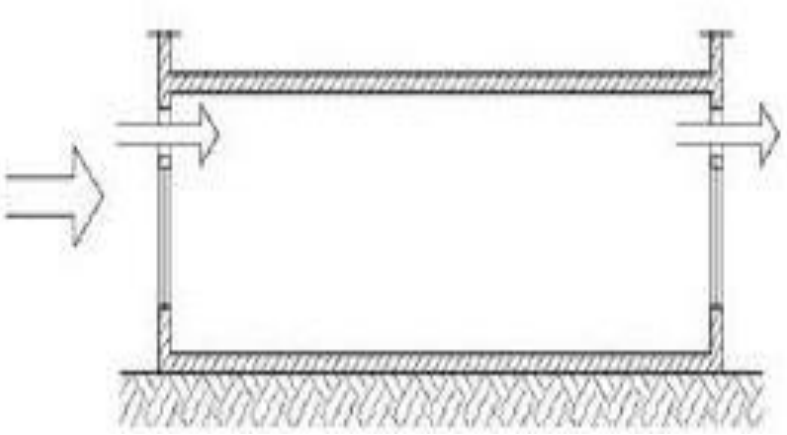


Figure 2.3 Inflow of fresh air and outflow of vitiated air in a double-sided opening space. Source: Kleiven, (2003).

2.3.4 Thermal Buoyancy Driven Ventilation

According to Kleiven (2003), Thermal Buoyancy driven ventilation occurs when there is a density difference between the internal and the external air which is caused by temperature difference between the inside and the outside. This type of ventilation is also referred to as stack effect or chimney effect. The difference in density between the internal and the external air creates pressure difference that pulls air in and out of a building through suitably placed openings in the building envelope. In addition, when the indoor air temperature exceeds the outdoor temperature, an over-pressure is built up in the upper part of the building and an under-

pressure is formed in the lower part, but at certain height, the indoor and outdoor pressures equals each other and this level is referred to as the neutral plane. An over-pressure above the neutral plane drives air out through openings in the building envelope while an under-pressure below the neutral plane pulls air in through the openings in the building envelope. Figure 2.4demonstrate thermal buoyancy driven ventilation with pressure distribution outside and inside a space as a result of temperature differences.

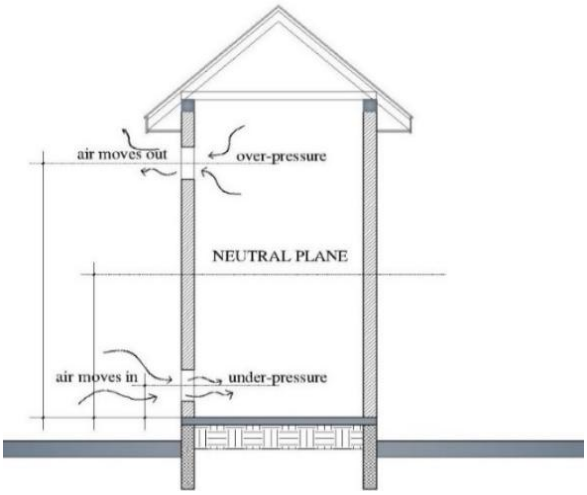


Figure 2.4 Thermal Buoyancy in a space with two openings. Source: Kleiven, (2003).

Stack Ventilation also occur when fresh air enters a space through ventilation openings at a lower level, while the used and contaminated air is exhausted through high level ventilation openings. A reverse flow can also occur during different condition. Placing the outlet on a region of wind-induced under-pressure can enhance the effectiveness of stack ventilation. A typical example is a building with an elevated central part in which warm and contaminated air from the surrounding space rises to be exhausted through wind towers located on the roof. The greater the vertical distance between the openings and the greater the temperature differences between the

inside and the outside, the stronger the effect of buoyancy. As a rule of thumb, stack ventilation is more effective across a width of five (5) times the floor to ceiling height from the inlet to where the air is exhausted. Figure 2.5 demonstrate stack ventilation where air enters a space from two different sides and is exhausted through a central opening located high above the space.

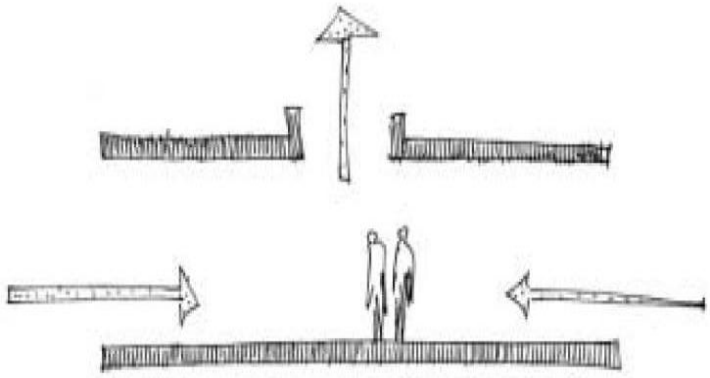


Figure 2.5 Inflow of fresh air from two sides and the outflow of vitiated air in an opening above the space.
Source: Kleiven, (2003).

2.3.5 Combining Thermal Buoyancy and Wind Driven Ventilation

When thermal buoyancy and wind driven ventilation occurs at the same time, thermal buoyancy will typically be the dominating driving force on a calm cold day with practically no wind. This is demonstrated in Figure 2.6, a building with clerestory windows spin away roof ventilators, vented ridges, eaves and ceilings which allow heat to exit the building in a nil breeze situation through convection.

On the other hand, pressure differentials created by wind will typically be the dominating driving force on a windy hot day. Their forces can oppose or complement each other depending on the placement of the inlet and the outlet openings in relation to the wind direction (Kleiven, 2003).

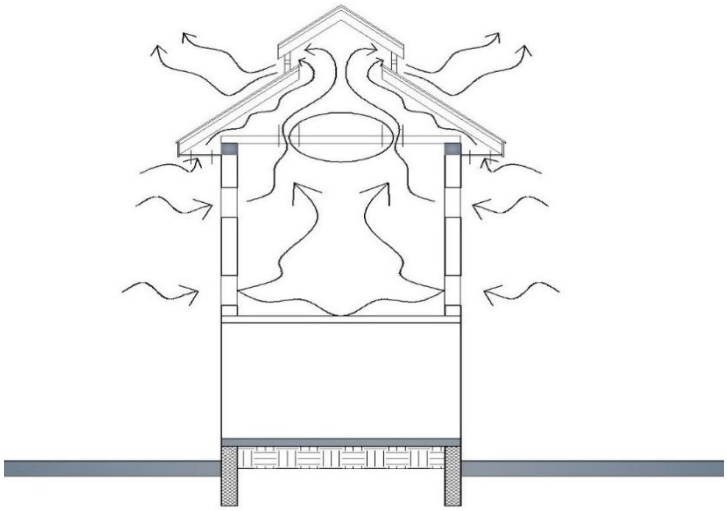


Figure 2.6 Convective air movement in buildings as a result of stack effect. Source: Kleiven, (2003).

2.3.6 Strategies for passive cooling in hotel buildings.

According to Kleiven (2003), cooling can be achieved naturally using elements of natural ventilation which are used to harness natural driving forces for natural ventilation and to support airflow through a building. Table 2.1 below gives an overview of elementsof natural ventilation together with their strategies and the mode of air supplying or extracting air each individual element is associated with. It also show whether the individual element is used to extract or supply end of the air-path.

Table 2.1 Relationship between the Elements of natural ventilation and ventilation principles.

Elements of Natural Ventilation	Ventilation Strategies	Supply or Extract
Wind Scoop	Cross and Stack	Supply
Wind Tower	Cross and Stack	Extract
Chimney	Cross and Stack	Extract
Double Facade	Cross, Stack and single sided	Supply and Extract
Atrium	Cross, Stack and single sided	Supply and Extract
Ventilation Chamber	Cross and Stack	Supply and Extract
Ventilation opening in the facade	Cross, Stack and single sided	Supply and Extract

Source: Kleiven (2003)

i. Atriums

An Atrium is large open space within a building providing daylight and visual amenity for the surrounding building space (Kleiven, 2003). Vitiated air from the building is removed by the process of stack effect through atriums as warm air is lighter and rises up while cold air is denser and falls to the ground.It also gives an attractive environment that can be used for many purposes ranging from gardens, cafes or canteens and traffic areas. Figure 2.7 illustrate various types of atria on building plans.(Kleiven, 2003).

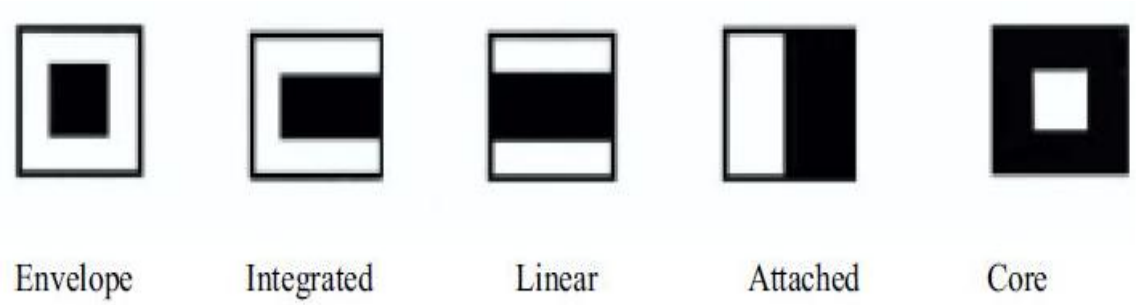


Figure 2.7 Various types of Atria. Source: Kleiven (2003).
Source: Kleiven (2003).

2.3.6.1 Ground Cooling/Coupling

Ground cooling is a technique used for passive cooling as well as heating of buildings which is made possible by the earth acting as a massive heat sink. It is also referred to as geothermal, geoexchange or earth energy cooling/heating system. This cooling system take advantage of the stable temperature underground using a piping system, commonly referred to as a "loop." Water circulates in the loop to exchange heat between the building's floors, the ground and the earth, providing geothermal heating, cooling, and hot water at remarkably high efficiencies. At a depth 4-5m below the surface of the earth, both daily and seasonal fluctuations die out and the soil temperature remains constant throughout the year. This temperature can be used to cool the floors of buildings using coils of pipes laid below the earth surface with help of compressor pump which circulate water in the pipes. The water in the pipes gets cooled on reaching the ground by losing its heat to the earth by conduction, as it returns to the building its cools the floors of the building by conduction. This process continues until there is temperature equilibrium between the floors of the building and the earth (www.greenbuilding.com, 2015). Plate III shows process of laying copper pipes in a floor to be used for ground cooling.



Plate III Laying of copper coil pipes for passive cooling.
Source: www.greenbuilding.com (2015).

In winter, water circulating inside the sealed pipe loop system absorbs heat from the earth and carries it to cool the floors of the building while in summer; the system reverses and expels heat from the building to the cooler earth via the same close loop system. This system is not only a natural process but also highly efficient way to create comfortable climate in buildings. Plate II describes the process of cooling and heating in winter and summer.

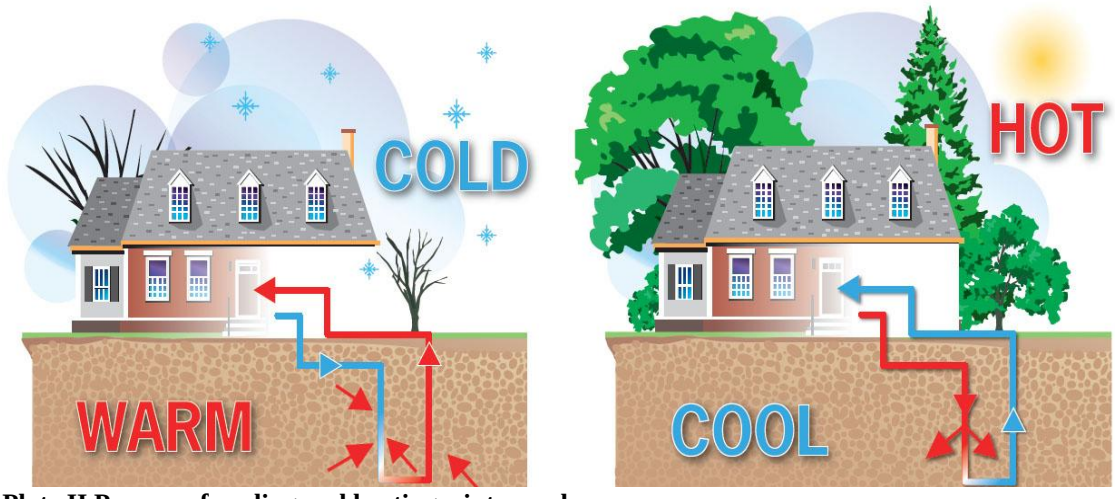


Plate II Process of cooling and heating winter and summer.
Source: www.greenbuilding.com (2015).

2.3.6.2 Types of Earth Coupling in composite of hot-humid/hot-dry climate

There are four basic types of earth coupling methods. These are as follows:

i. Vertical ground loop system

ii. Horizontal/slinky ground loop system

iii. Lake/pond loop system

iv. Open loop system

2.3.6.2.1 Vertical ground loop system

This type of system is employed mainly in commercial buildings or where space is limited. Vertical holes of 150 to 400 feet deep are drilled in the ground and a single loop of pipe with U-shape is inserted to have good contact with the ground. Plate IV is a vertical ground loop arrangement in a building.

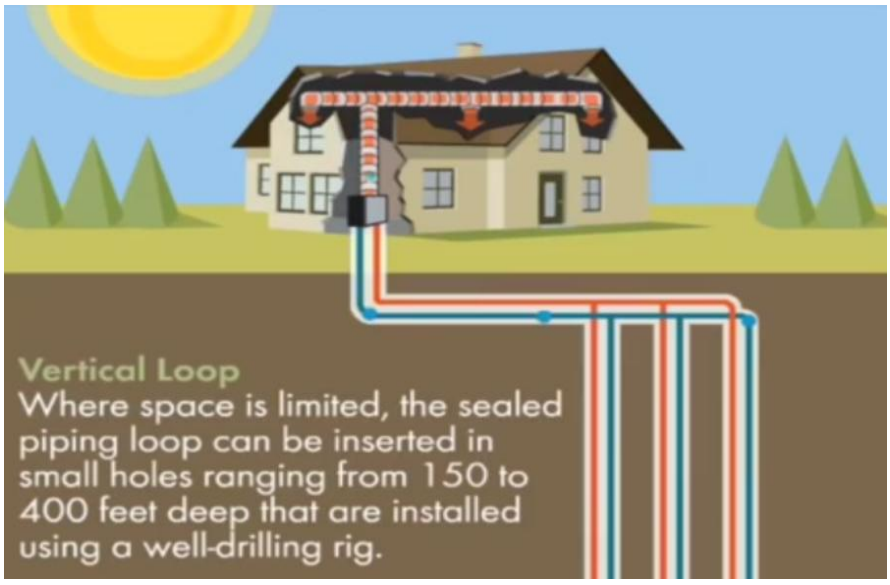


Plate IV Vertical ground loop system.
Source: www.greenbuilding.com (2015).

2.3.6.2.2 Horizontal/slinky coil ground loop system

This type of system is cost effective for projects where there is sufficient space for the loops. Trenches 3-6 feet deep are created and series of parallel pipes or loops are laid inside them. Plate V describes the process of horizontal or slinky ground loop system.

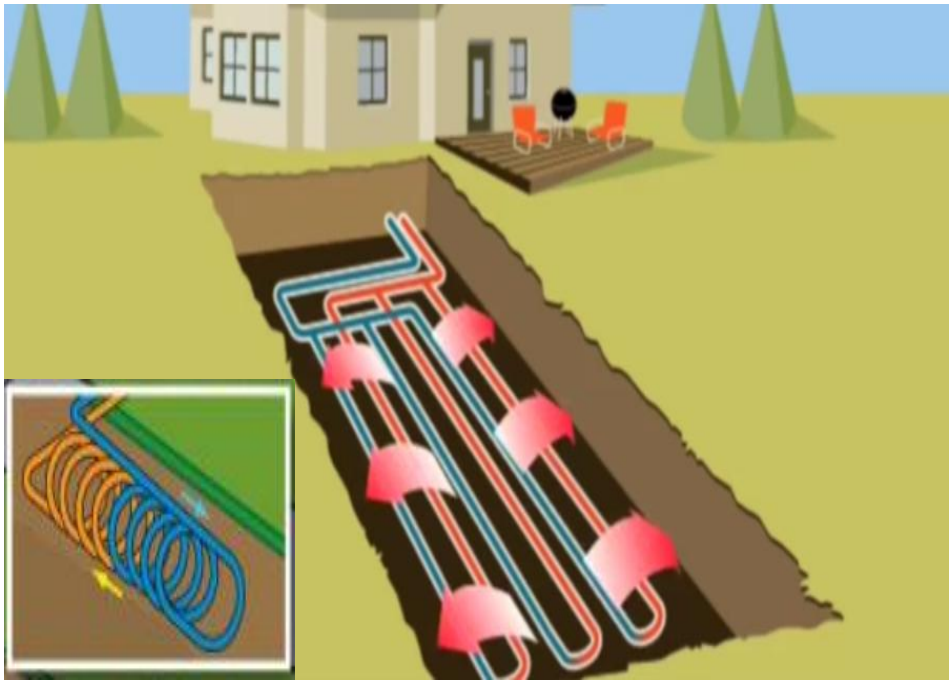


Plate V Horizontal and slinky coil loop system.
Source: www.greenbuilding.com (2015).

2.3.6.2.3 Lake/Pond loop system

This system is economical when a building is close to water body. The pipes are laid under water and the fluid in the pipes circulates in a closed loop similar to that of underground loop system. The pipes have no adverse effect to the aquatic system. Plate VI is a lake/pond loop system.

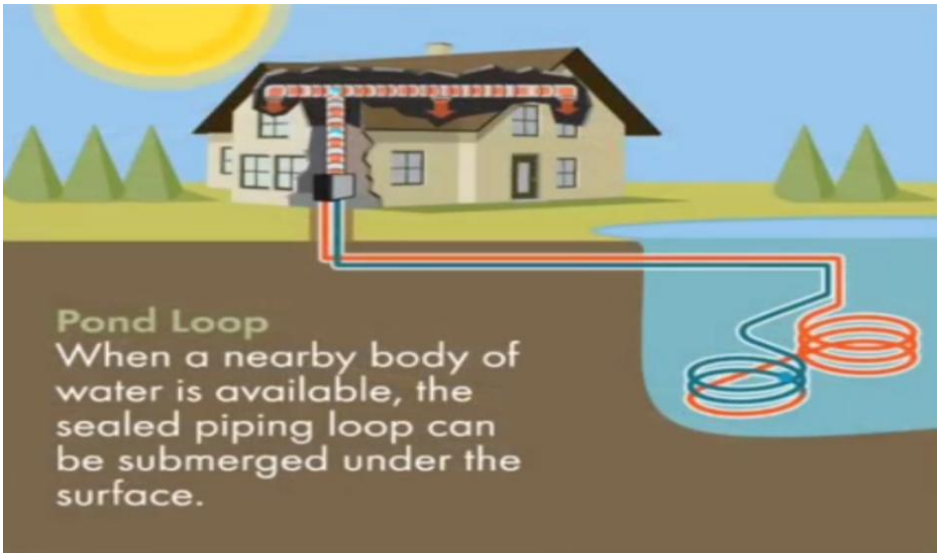


Plate VI Lake or Pond loop system.
Source: www.greenbuilding.com (2015).

2.3.6.2.4 Open loop system

This system is more economical where ground water is of adequate quantity and quality. In this system, the pipes are inserted into a well and the cool water drawn from the well is circulated into the building and finally discharge through an open ended pipe into the surroundings. Plate VII shows a typical layout of an open loop system.

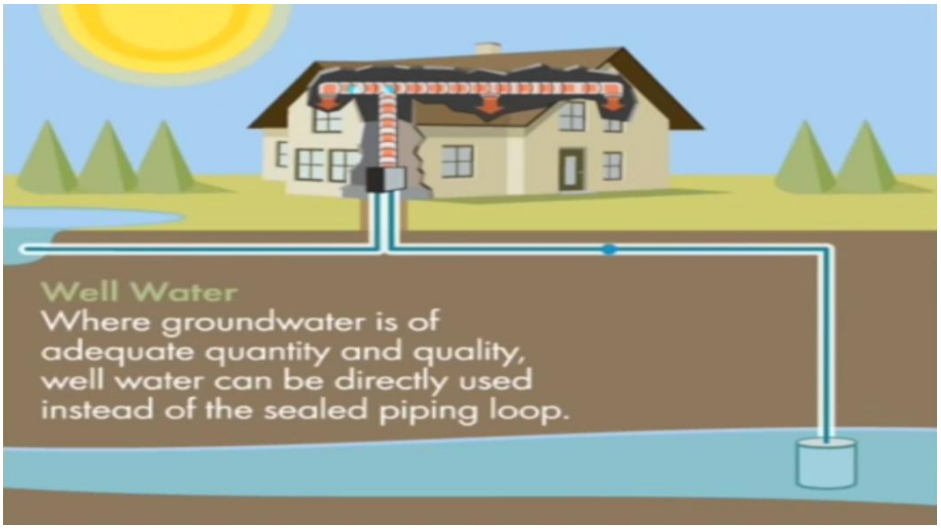


Plate VII: Typical layout of an Open loop system
Source: www.greenbuilding.com (2015).

2.4 Principles of Passive Cooling

The principles of passive cooling and ventilation are architectural design approach and strategies that are climate responsive which provide comfortable indoor conditions naturally. These principles help in collection, storage, distribution and control of energy flow by natural process of cooling and ventilation into the building. To prevent heat from entering a building or to remove it depends on two conditions:

i. Availability of heat sink which is at a lower temperature than the indoor air.
ii. The promotion of heat transfer towards the heat sink.

Some of the passive cooling principles as outline by Holtz (2001) are shown in Table 2.2 with their features and applications.

Table 2.2 Passive cooling principles, their features and application

PASSIVE COOLING		
Principles	**Features**	**Application**
Building Orientation	The building should orient toward North-South direction.	The longer side of the building faces North-South axis while the shorter side faces East-West axis to minimize Solar heat gain
Building form	A compact building	Decreases building energy performance in heating down spaces.
Natural Ventilation	-Openings & windows sizes -Atrium for stack effect ventilation. -Vents and Chimneys for dissipation of heated air	Proper location of opening to enhance cross or stack ventilation in the building. Vent should also be located in heat generating spaces such as kitchen and laundry to easily dissipate heat out of the spaces.

Shading devices	-Roof shading, -Overhang shadings -louvers and awning -buffer zones	Textured surfaces, overhangs, roof shading and shading by tree.
Landscaping	Landscaping environment with trees, green and soft elements to absorb solar radiation rays.	Green plants provided on the surrounding environment of the building for solar radiation absorbance reduces ambient temperature near the walls by 2 to 3 degrees Celsius.

Source: Holtz (2001)

According to Marin, (2007), there are five basic principles of passive cooling peculiar to composite of hot-humid/hot-dry climate namely:

i. Building orientation/Massing
ii. Thermal mass/insulation
iii. Ventilation/Air movement
iv. Overhangs/Shading devices
v. Materials/Construction

2.4.1 Building orientation/Massing

Good building orientation increases the energy efficiency of a building making it more comfortable to live in and cheaper to run (Marin, 2007). Orientation refers to the azimuth angle of a surface relative to true north (eCubed, 2008). With regard to building design, Orientation of a building can significantly affect its potential to capture prevailing breezes and its exposure to solar radiation (Marin, 2007). An effective passive solar design should assume that the building is oriented to receive direct solar radiation the most in winter (when heating is required) and

much less in summer (when cooling is required) (Marin, 2007). Figure 2.8 illustrated good building orientation for passive solar design.

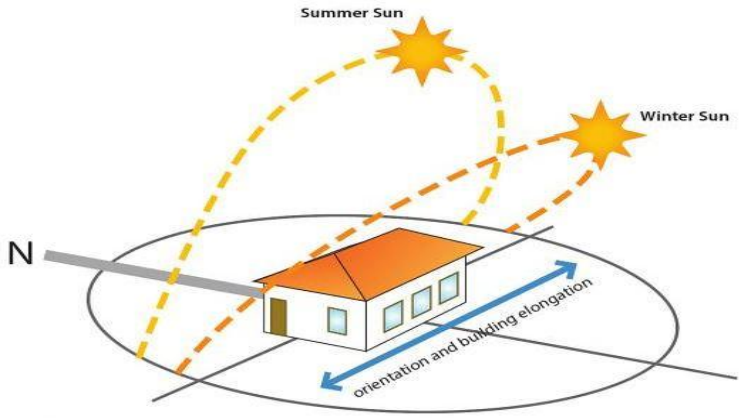


Figure 2.8 Proper Building Orientation for passive cooling and lighting. Source: Marin, (2007).

Good orientation for passive cooling and lighting ensures the optimum sun radiation from South, East, West and North and excludes cold unwanted winds during winter and cold months while ensuring cooling breezes and optimum sun radiation for lighting and excludes unwanted sun and hot winds during summer and hot months (Marin, 2007).

Similarly, good building orientation greatly influences the solar heat gains and loss of the building and maintains thermal comfort within the interior spaces (eCubed, 2008). Figure 2.9shows that the sun's altitude in Nigeria is high in summer when the solar radiation is at its peak. Therefore, orienting the longest façade of the building towards South/North makes it much easier to effectively apply passive design strategies for passive cooling.

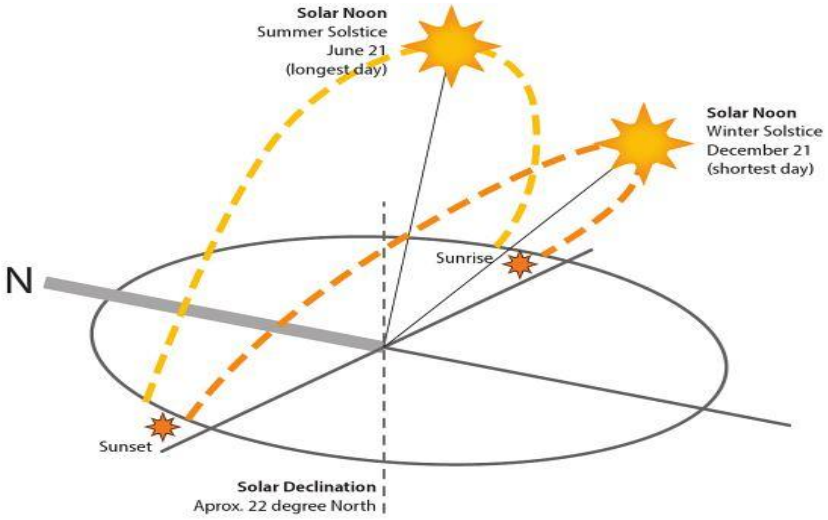


Figure 2.9 Solar Altitude in Nigeria. Source: Marin, (2007).
Source: Marin, (2007).

Windows on the south/north facing façade can be more easily shaded using overhangs to block the high angle sun while the east and west facing facades, however are subjected to direct solar radiation in the morning and evening (eCubed, 2008).

Marin, (2007), suggest that buildings should be oriented to maximize benefits from cooling breezes in hot weather and shelter from undesirable winds in cold weather. Generally, building should be oriented so that its shorter axis aligns with prevailing wings to provide most of the air ventilation required.On the other hand, orienting it perpendicular to prevailing winds will provide least passive ventilation (Marin, 2008). Figure 2.10 illustrates building orientation for maximum and minimum passive ventilation.

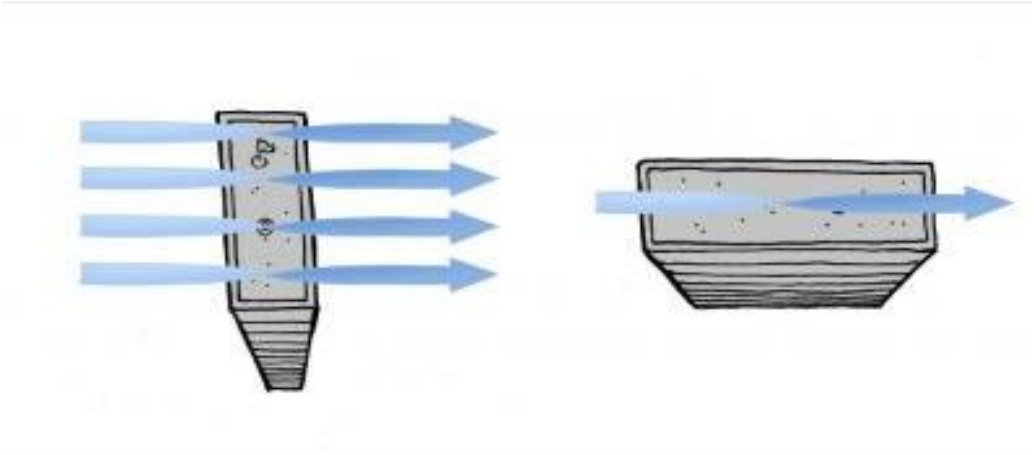


Figure 2.10 Orientation for maximum and minimum passive ventilation.
Source: Marin, (2007).

2.4.2 Thermal mass/insulation

Thermal mass is the ability of a material to absorb and store heat when there is an excess of solar energy and/or internal gain in buildings and releases the stored heat when the building starts to cool down. Thermal mass also reduces the extreme swings in peak temperature (Donn, Grant, 2010).Chris R,(2008)states that the rate of heat transfer through building materials and the effectiveness of thermal mass is determined by a number of parameters and conditions. These are:

i. Properties of the building materials
ii. Building orientation
iii. Thermal insulation
iv. Ventilation
v. Climatic conditions
vi. Use of auxiliary cooling systems
vii. Occupancy patterns

The distribution of thermal mass is based on the orientation of the given surface and the desirable time lag. During the night when outdoor temperatures are lower than indoor temperatures, it is possible to cool the structural mass of the building by natural ventilation. Such a technique is known as ‘night ventilation’ and may help in decreasing the cooling load of air conditioned buildings by up to 60%, or decreasing the overheating hours of naturally ventilated buildings to up to 75% (Chris, 2008).

Buildings with heavy mass releases heatat night, making it ready to absorb heat again the next day.Materials with high thermal mass which have the ability to absorb, store and reradiate heat work well for passive cooling. During the day, thick walls of concrete, adobe, or brick act as a heat sink which absorbs heat from the solar radiation andslowly releases the heat at night when temperatures drop (Chris R, 2008). This is illustrated in Plate VIII.

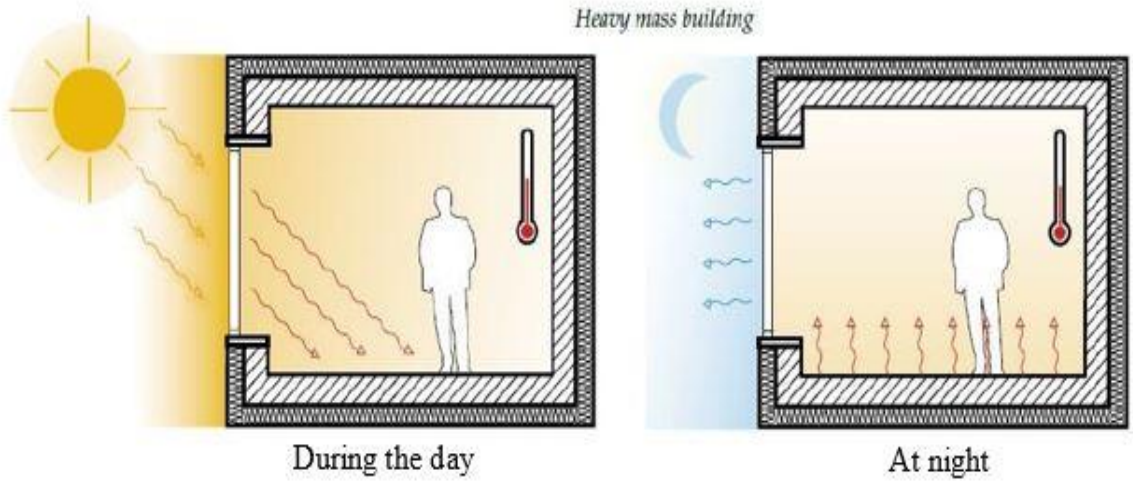


Plate VIII Heavy mass building absorbing heat in the day time and releasing it at night.
Source: Chris R, (2008).

Similarly, buildings with light thermal mass allows heat from the sun to be reflected into the interior spaces making it uncomfortablyhot during the day time while at night, the spacesbecome uncomfortably cold as a result of cold night air breezes which find their way into the building and cool up the spaces (Chris, 2008). Plate IX illustrates light thermal mass buildings during the day time and at night.

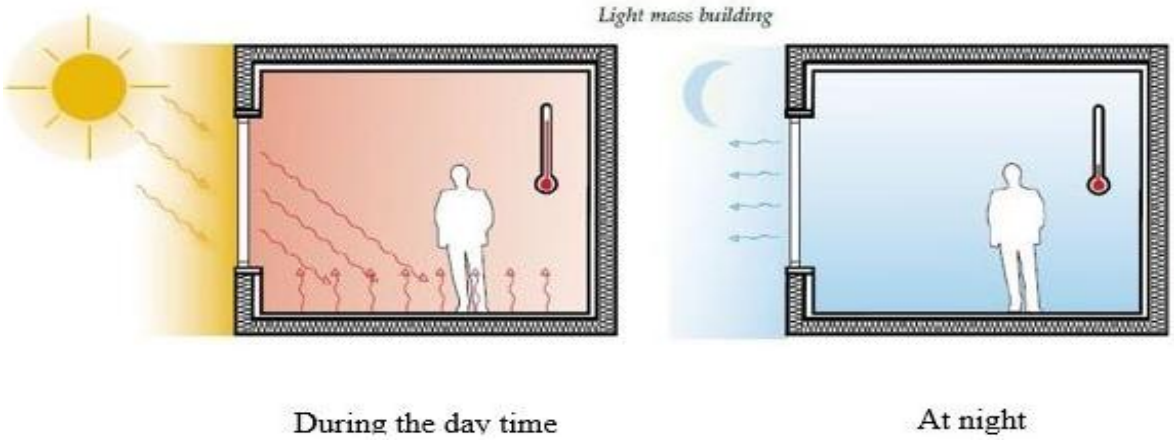


Plate IX: Light mass building uncomfortably hot and cold during the day night respectively. Source: Chris R, (2008).

On the other hand, thermal mass can have a negative impact on energy performance in cases where there is no opportunity to release the stored heat into ambient air (in climates with no diurnal swing) or there is no opportunity for solar gains to be absorbed and stored (in climates with cold temperatures and low solar incidence (Vladimir, 2008).Thermal insulation is a measure taken to prevent heat transfer through the walls, floors and ceilings from both directions, inside to outside or outside to inside. This leads to a drastic reduction of energy costs. On the other hand, thermal insulation retains heat in the building during winter and keeps the building cool during summer thereby enhancing thermal comfort for occupants in the building (Donn, Grant, 2010).Insulation minimized unwanted heat or heat gain through component of the building

envelope such as roof, floor, wall, doors, windows and other openings. Building envelope should be designed with an effective insulation that would considerably shrink the need for heating or cooling. Example of insulation materials are as fallows cotton wool, fiberglass insulation, polyurethane insulation, mineral wool insulation, perlite insulation, rock wool insulation and so on. Plate X illustrate different types of insulation materials in a building at different places that is required so as to prevent heat from gaining access into the interior spaces of a buildings.



Plate X: Different types of Insulation materials used in different location in buildings.
Source: Shanghai ABM rock wool company ltd, (2014).

2.4.3 Ventilation/Air movement

Willmert, (2001) stated that Ventilation/Air movement is a process of removal of moisture from buildings to alleviate dampness by the circulation of air around the building.

Openings are important design elements for ventilation and air movement. Openings help in admitting daylight, air flow, providing cross ventilation and views. Gut (1993)recommend that windows should be large and fully operable, with inlets of a similar size on opposite walls for proper cross-ventilation in a composite of hot-humid and hot-dry climates. Lipping et al. (2007)

claim that ventilation and indoor air quality can be improved by increasing the window to wall ratios (WWR), but it would also increase solar heat gain. There has always been a conflict with daylight provision and exclusion of solar penetration in designing windows.

Glazing play a vital role in allowing heat gain into the indoor spaces and can have a significant effect on energy consumption. Therefore, proper glazing of windows and other opening with glass of low thermal conductivity (double glazing with inert gas) and coated with reflective film keep out more heat while remaining transparent (Donn, Grant, 2010). Plate XI and Plate XII is an illustration of proper glazing with insulation frame to prevent heat transmission through window openings and their frame.



Plate XII Double glazing.
Source: Passive design tool kit, 2004.

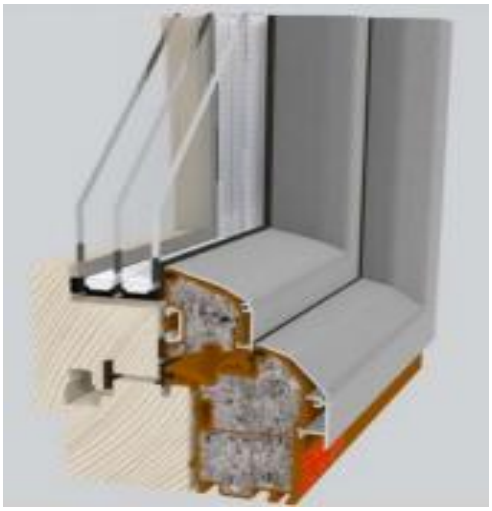


Plate XII Triple glazing.
Source: Passive design tool kit, 2004.

2.4.4 Overhangs/Shading devices

Overhangs and shading devices prevent solar access and exclude rainfall into the building and thereby helps to keep the building cool. Providing shades over building openings and outdoor spaces can reduce temperatures and save energy. It is more difficult to shade east and west faces

as they receive low morning and afternoon sun. Where low sun is a problem, keep east and west facing glazing to a minimum(Passive design tool kit, 2004). Table 2.3 recommends shading options for different situations.

Table 2.3 Shading options for different situations

Orientation	Sun direction	Time of day	Type of shading
North	High angle	Middle of day	Fixed or adjustable above window
East-west	Low angle	Morning/evening	Adjustable screens/shutters
NE/NW	Low angle	Morning/evening (winter)	Adjustable shading

Source: Passive design tool kit, 2004.

At high angles of incidence, where the sun's rays are almost parallel to the window surface (at glazing angles), glass becomes more reflective. At incidence angles of 80°, both single and double pane glazing (clear plate glass) become about 50% reflective. This geometry occurs when profile angles are very high, window azimuth angles are high, or both. This will reduce solar radiation transmitted through the window openings by an equal percentage. Some other problems like interior glare or reflected glare from the facade to the exterior may occur.

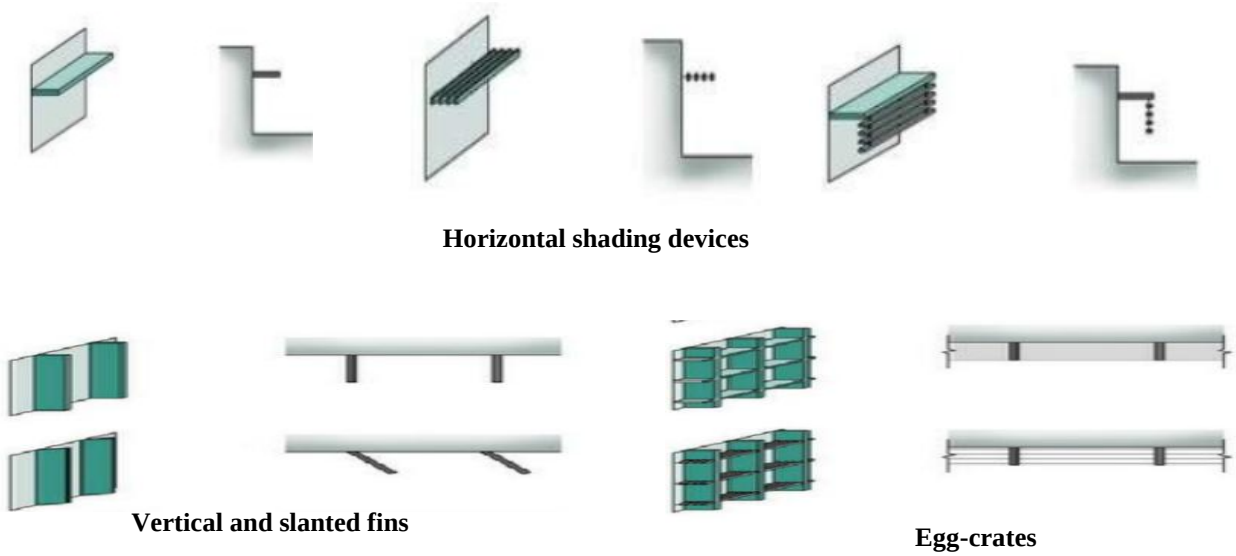
Overhangs and Shading devices are classified based on their position in buildings(Passive design tool kit, 2004) and these include:

i. External shading devices

ii. Internal shading device

2.4.4.1 External shading devices

These are horizontal, vertical or inclined overhangs or projections placed outside the building to minimise solar heat gain into the interior spaces. This type of shading devices include; over hangs, vertical or inclined fins and egg-crates. The external shading device elements have efficiency in controlling solar energy penetration to the interior spaces(Passive design tool kit, 2004). Figure 2.11 gives manifold forms of External shading devices used in buildings to cut off excessive solar radiation into the interior spaces.



Horizontal shading devices

Vertical and slanted fins

Egg-crates

Figure 2.11 Manifold forms of External shading devices.
Source: Carbon neutral design, (2011).

Vegetation and other buildings in the immediate environment can also serve as shading to the building against solar radiation. Shading needs to be provided in form of landscaping and foliage. Deciduous trees are effective as they block the sun in the summer when it is not desired and allow sun penetration during the winter. Fences work to block the sun and view at all times of the year and so is not so climatically responsive. Vines on more transparent "fence like" elements are effective as they too bear leaves to shade in the summer, and keep their leaves until

later in the fall when sun is again desired. Vines are often used as well on south facing elevations on trellises to achieve seasonal variation in the opaqueness of the overhangs(Passive design tool kit, 2004).Plate XIII illustrateshading with deciduous trees in summer and winter.

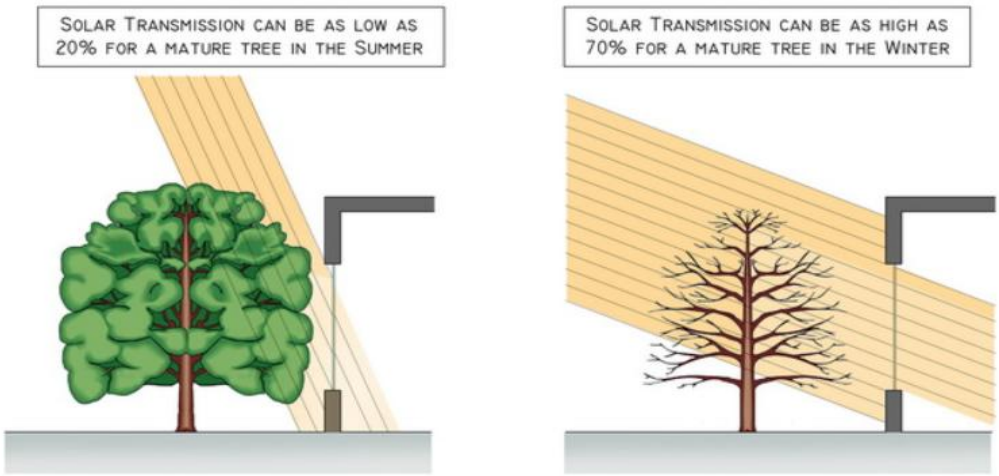


Plate XIII Solar shading with Vegetation in summer and winter
Source: Passive cooling design tool kit (2003).

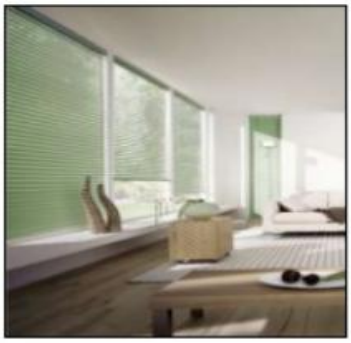
The natural environment can be used to shade low rise buildings. Deciduous trees can effectively shade the facade when heat avoidance is desired, and permit solar penetration where passive solar gain is sought. Vines can be used on trellises or trellis like shading devices to the same effect. Vegetative shading also works well with the shoulder heating and cooling seasons. In the spring when heating is still often desirable, leaves are not yet present, allowing continued passive heating. In the fall, when continued warm days might suggest cooling, the leaves have not yet been shed. If natural ventilation is also desired, it is important to allow adequate wind penetration around exterior plantings or potential natural cooling will be blocked(Passive design tool kit, 2004).

2.4.4.2 Internal shading devices

These are shading devices placed in the interior of the building to minimise the intensity of solar radiation from heating up the interior spaces. Internal shading devices are usually adjustable and allow occupants to regulate the amount of direct solar radiation entering the building. In most cases they take the form of horizontal or vertical blinds attached above window openings. These types of shading devices include; curtains, venetian blinds, vertical louver blinds, roller blinds, pleated blinds and blackout blinds (Carbon neutral design, 2011). Plate XIVgives various configurations of internal shading devices that can be used internally to limit the amount of solar heat gain that penetrates into the building.



Curtains



Venetian



Vertical louver blinds



Roller blinds



Pleated blinds



Blackout blinds

Plate XIV Different types of Internal shading devices
Source: Carbon neutral design, (2011).

2.4.5 Materials/Construction Technique

International Federation of Consulting Engineers (IFCE, 2015) state that the choice of materials and construction techniques for a project requires considerations of aesthetic appeal and initial and ongoing costs, life cycle assessment considerations (such as material performance, availability and impact on the environment) and the ability to reuse, recycle or dispose of the material at the end of its life. Building design and material selection must contribute to good thermal performance and reduced energy demand by including insulation and thermal mass in the building. In addition, Building design and material selection provide Protection from fire including fire compartment separations, allowing the occupants safe escape from the building and allowing fire service personnel safe access to the building. Materials must be selected for ignitability, surface spread of flame, fire loading, and fire resistance and stability.

Reinforced concrete framed construction system is one which is made firm by a skeletal system capable of standing alone by itself as a rigid structure. Reinforced concrete frame structure is made up of Reinforced concrete, which is strong in both tension and compression and it is the best construction technique for achieving thermal mass in a composite of hot-humid and hot-dry climate(IFCE, 2015).

Proper material selection and construction technique is considered for flooring, walling, ceiling and roofing in buildings for passive cooling and energy conservation purpose(IFCE, 2015).

2.4.5.1 Flooring Material

Concrete floors are increasingly popular and it can be an excellent environmentally friendly flooring material, particularly when manufactured out of recycled materials(IFCE, 2015).

Polished concrete has long life cycles and is energy efficient. It improves indoor environmental quality and there are endless design options. Concrete floors can be not just functional but also aesthetically beautiful and are excellent for trapping and releasing heat(IFCE, 2015).

2.4.5.2 Walling Material

Wall is a structural element which demarcates spaces and makes it serve the function of sheltering the inhabitants. It is also the building component which serves as a barrier to the natural environment; however, the walls have the highest percentage of controlling indoor climate of buildings(Greenbuildingtalk, 2010). It is however; very important to select external walling materials that have good thermal mass by preventing much heat from penetrating to the interior spaces during hot days and dissipate the absorbed heat into the external environment at night(IFCE, 2015)..

InnoVida Fiber-Composite panels are made of a polyurethane insulation foam core that is sandwiched between two composite structural skins bonded together with InnoVida Resin. Once the panels are bonded together, with InnoVida Bond, they are seamless. The closed foam core becomes a monolithic structure that reduces air leakage and thermal bridging through the panels by providing a continuous span of structural and insulating material. The structure also becomes 100 percent water-proofs, much like the hull of a boat(Greenbuildingtalk, 2010).

InnoVida Panels make stronger, more energy efficient, cost effective homes and buildings. The superior insulation significantly reduces the amount of energy needed to heat and/or cool the structure and provides excellent noise reduction(Greenbuildingtalk, 2010).

The panels provide a lifetime of comfort through their high performance structural and insulation(Greenbuildingtalk, 2010).

They are stronger, more flexible than cement, steel or bricks and also non-flammable, waterproof and hurricane resistant. InnoVida panel can be employed to respond to construction result which can be used to build homes, commercial buildings, warehouses and any other form of structure that are normally built using conventional construction approaches and materials (Greenbuildingtalk,2010).

Published R-values for the panels are roughly 5.88 per inch meaning R-14.6 for a 2" panel and R-23.7 for 4" panels. This is significantly more efficient than a typical 2x4 wood stud exterior wall with R-13 batt insulation. As far as size, the panels can be made up to 19’-6" by 8’-3" and for structures up to eight stories tall(Greenbuildingtalk, 2010). Plate XV is a profile of InnoVida fiber composite panels with different colours.

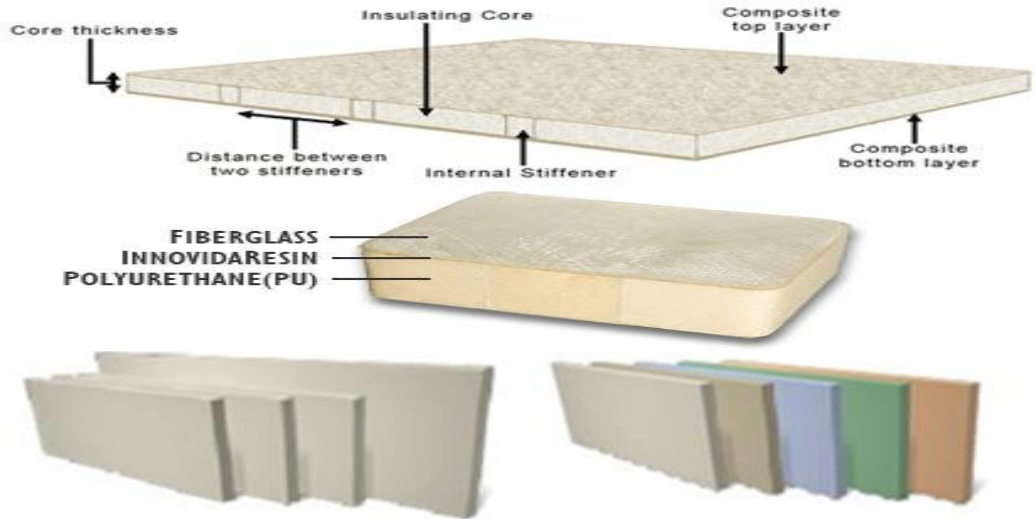


Plate XV: InnoVida fiber Composite panels
Source: Kleiven (2003).

2.4.5.3 Ceiling Material

Ceiling is the upper interior surface of a habitable space. Ceilings and roof spaces account for 25–35% of winter heat gain in buildings and must be well insulated. To prevent heat gain, place most of the insulation next to the ceiling as this is where the greatest temperature control is required. Properly insulating the ceilings of a building will allow ceiling temperatures to remain closer to room temperatures, providing an even temperature distribution throughout the building. Plenum space provided between the roof and the ceiling in suspended or dropped ceiling accumulate a lot of heat that penetrates through the roof and needs to be ventilated (USDOE, 2012).

Suspended or dropped ceilings are very efficient in minimising solar heat gain from reaching the habitable spaces. They are also used to house or conceal the mechanical, electrical and fire safety appliances such as sprinkler systems while still providing full fire suppression functionality.

Plaster of Paris (POP) is commonly used for constructing suspended ceilings. The extensive use of POP ceilings can be attributed to the versatility of Plaster of Paris. The first unmatched advantage is that POP can be easily molded into any shape. This allows the creation of beautiful designs and patterns on the ceiling (Topcon Interiors, 2011). Plate XVI is a sample of Plaster of Paris (POP) suspended ceiling.



Plate XVI: Plaster of Paris (POP) suspended ceiling. Source: Bolee.com Source: Topcon Interiors (2011).

2.4.5.4 Roofing Material

The selection of the appropriate material for the roofing of a building also plays a very important role in achieving thermal comfort within the building.

Gut and Ackerknecht (1993) recommend the use of green roofs as means of passive cooling in buildings.Green Roofs can be classified into two main categories namely:

i. Extensive Green Roofs
ii. Intensive Green Roofs.

2.4.5.4.1 Extensive Green Roofs

These are the more common of the two categories. It employs a shallow growing medium of five inches or less. The usual plants chosen for extensive roofs include succulents and moss. The design of extensive Green Roofs aims at reducing the cost of maintenance and frequency of irrigation.

2.4.5.4.2 Intensive Green Roofs

The intensive green roofs use heavier plants that require a growing medium of at least 6-12 inches. This type of roofs can serve many purposes such as providing an outdoor garden space for food production. Intensive Green Roof often requires more active maintenance with regular watering, fertilization, and pruning. Furthermore, intensive Green Roofs require more structural support than extensive roofs due to heavier weight loads. If the intent of an intensive Green Roof is to provide public access, then additional design features for safety must be considered (Jamie, 2006). Plate XVII is the configuration of Extensive and Intensive green roofs.

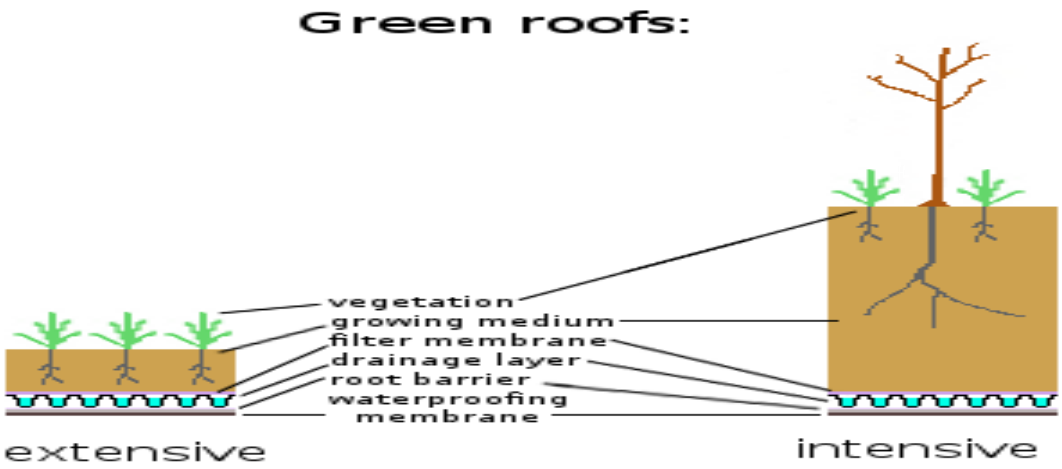


Plate XVII: Extensive and Intensive Green roofs
Source: Jamie C. (2011).

2.5 Passive cooling strategies in a Composite of Hot-Humid/Hot-Dry Climate

The passive cooling strategies for a composite of hot-humid/hot-dry climate which focuses on reducing solar radiation and promoting ventilation have been summerised by Vallabhaneni A, (2014)as follows:

i. Courtyards or atria should be provided for effective natural ventilation by stack effect.

ii. Orientation of building to take advantage of prevailing condition into the indoor spaces.

iii. Materials selected should have lighter or brighter colour for good reflective of heat capacity as darker colour or materials absorbed heat and solar radiations.

iv. Building materials should be poor conductors of heat having high time lag effect to minimise heat transfer into the building interior.

v. Good landscaping is necessary to reduce radiation of sun at the outdoor environment

vi. Good orientation of the building on site and spaces in the building is important to take advantages of the sun radiation.

vii. The use of sun shades and sun breakers is necessary in the building design.

viii. Shading of fenestration, provision of canopies, covered walkways and wider verandas should be consider in order to avoid direct solar radiation also to boost better natural ventilation.

2.6 Passive cooling for Energy Conservation

Energy conservation is defined as a process of reducing energy consumption to acceptable level of comfort, air quality and other occupancy requirements (World Business Council for Sustainable Developmen, 2007). It is estimated that buildings contribute as much as one third of total global greenhouse gas emissions and consumes up to 40% of all energy (Adeleke et al, 2010). United Nations World Tourism Organisation (United Nation World Tourism Organisation (UNWTO), 2010) reported that,given the massive growth in new construction in developing countries such as Nigeria and the inefficiencies of existing building stock worldwide, if nothing is done, greenhouse gas emissions from buildings will be more than double in the year 2050.

Similarly, World Watch Institute (2007) reports that buildings uses approximately 40% of energy consumed globally and produces 33% of all annual carbon dioxide emission that causes acid rains and contributes to smog formation. Studies of the United States Department of Energy (USDOE, 2007) have also shown that 60% out of the 40% of energy consumed by buildings globally is used up in heating, cooling and ventilation in hotel buildingsduring their operational phase. This indicates that hotel buildings could make a far greater contribution to sustainable development if their energy consumption patterns are understood to ensure continuous improvement in their energy conservation(Oke et al., 2008).

2.6.1 Energy Consumption in Hotel buildings

According to Oke*et al* (2008), energy consumption in hotel buildings can be grouped under the following end-uses:

i. **Space Cooling**: This includes all the energy used for ventilation and air conditioning.
ii. **Lighting:** This comprises energy used by all forms of lighting appliances ranging from incandescent lamps to fluorescent lamps, halogen lamps, street lights and large stage light.
iii. **Refrigeration:** This is the energy used by food and drink cooling (water dispensers, fridges and freezers)
iv. **Water Heating:** This is the energy used by water heaters for heating water in the kitchens and toilets.

v. **Cooking:** This is the energy utilized by cooking equipment (Electric cookers, Gas cookers, electric toasters, microwaves, ovens etc.)

vi. **Office Machines:** This includes the energy used for office equipment such as computers, fax machines, photocopiers, scanners etc.

vii. **Electronics:** This considers energy used by electronic appliances such as television sets, video compact disc (CD) players, decoders and projectors.

viii. **Ordinary machines:** This is the energy used by machines such as water pumps, grinding machines, sewing machines and washing machines.

ix. **Others:** This includes energy used by pressing irons, hair dryers, blenders etc.

Similarly, United NationsWorld Tourism Organisation (United Nation World Tourism Organisation (UNWTO), 2010) states that the main energy consuming activities in hotel buildings are classified as:

i. Heating and cooling rooms

ii. Lighting

iii. Preparing meals

iv. Swimming pool and hot water use

2.7 Climate

Climate is defined as a pattern of weather conditions prevailing in a particular area over a long period of time usually measured by assessing the variation in Temperature, Humidity, atmospheric pressure, Wind and Precipitation. Small-scale patterns of climate, resulting from the influence of topography, soil structure, ground and urban forms, are known as microclimates

(Geetha and Velraj, 2012). The climate of a location is affected by the Latitude, terrain, altitude, vegetation pattern as well as nearby water bodies and their currents. The climates prevailing around the globe vary greatly, ranging from the polar extreme to tropical climates. These are primarily influenced by the sun's energy heating up the land and water masses.

According to, the world tropical and subtropical regions have been divided into three main climate zones:

i. The hot-arid zone, including the desert or semi desert climate and the hot- dry maritime climate.
ii. The hot-humid zone, including the equatorial climate and the warm-humid climate
iii. The temperate zone, including the monsoon climate and the tropical upland zone

Figure 2.12is the different climatic zones in the world is classified by Olgyay, (1963).

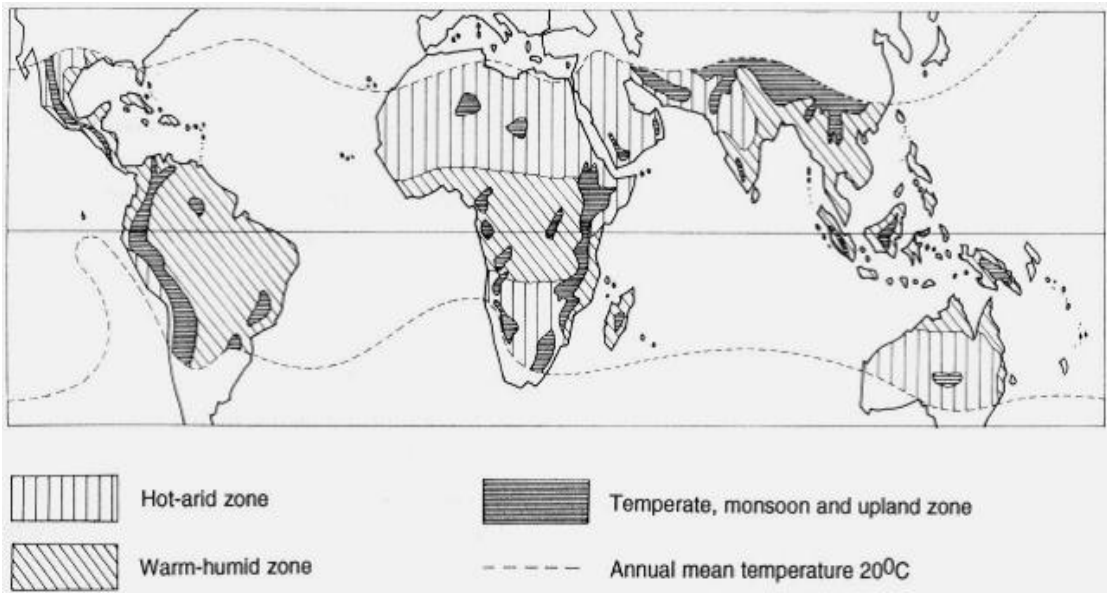


Figure 2.12 World climatic zones, Source: Design with Climate,
Source: Olgyay, (1963).

2.7.1 Classification of Nigeria's Climate

Nigeria experiences a variation of climate as one move from the coast to the northern parts of the country. The climate of a particular location also varies with the time of the year, latitude of the location and landscape (Ajibola, 2001). Nigeria is classified based on indices such as geo-political zones, vegetative belts and design climates.

Batagarawa, *et al* (2013) in (Ajibola, 2001), (Ogunsote, 1991) and UNEP/GRID, (2002) have classified Nigerian climates as shown in Table 2.4.

Table 2.4 Climatic Classification of Nigeria by different Authors

S/N	Batagarawa Design Climate, (2003)	Komolafe in Ajibola, (2001)	Design Climatesin Ogunsote. (1991)	Vegetative Climate in Ogunsote, (1991)	Climate Classification in Africa (UNEP/GRID, 2002)
1	Hot and Dry	Hot-dry	Hot and Dry	Coastal	Humid
2	Hot and Humid	Temperate-Dry	Warm and Humid	Forest	Moist-Humid
3	Composite of 1 and 2	Temperate-Humid	Composite of 1 and 2	Transitional	Dry sub-humid

Source: Batagarawa, 2013

The National University Commission (NUC), 1997)classified Nigeria into two climatic zones which are; the Northern climatic zone and the Southern climatic zone. The Northern zone corresponds to Hot-Dry climate and a composite of Hot-Dry and Hot-Humid climate while the

Southern zone corresponds to Warm-Humid climate. Table 2.5 shows the Climatic variations between the two climatic zones by the National University Commission.

Table 2.5 Climatic Variation between the two climatic zones in Nigeria

Zones	Seasons	Air Temperatures		Humidity (%)	Rainfall (mm)	Wind (km)
		Day (°C)	Night (°C)			
Northern	Hot-Dry (Nov/Dec to April/May)	32 - 43	15 - 27	20 - 55		1 -10
	Hot-Humid (May/June – Sept)	27 -32	24 -27	55 - 95	500 - 1300	1 - 10
	Cool-Dry (Sept/Oct – Nov)	18 - 27	4 - 15	20 - 55		1 - 10
Southern	Warm Humid (All year round)	27 - 32	21 - 27	55 - 95	2000 - 5000	Calm to 10

Source: NUC, (1997)

2.8 Thermal comfort

Thermal comfort is defined as that condition of the mind which expresses satisfaction with the thermal environment. It is said to be a condition in which someone is not feeling too hot or too cold. (HSE, 2011).

Health and safety executive (HSE, 2011) suggest that an environment can be said to achieve "reasonable thermal comfort" when at least 80% of its occupants are thermally comfortable.

2.8.1 Factors affecting thermal comfort

According to Health and Safety Executive (2011), there are two classes of factors that affects thermal comfort; these are:

i. Environmental factors
ii. Personal factors

2.8.1.1 Environmental factors

This is the condition of the environment around an individual and this includes:

i. Air temperature
ii. Radiant temperature
iii. Air velocity
iv. Air humidity

2.8.1.1.1 Air temperature

This is the temperature of the air surrounding the body. It is usually given in degrees Celsius (°C) or degrees Fahrenheit (°F).

Radiant temperature: This is the heat radiating from warm objects or heat source within the environment. This could be from the sun, fire, furnace, and any other electronic that generate heat during its operation. Radiant temperature can be minimized by using reflective surfaces to reflect back the heat from the environment (HSE, 2011).

2.8.1.1.2 Air velocity

This describes the speed of the air moving across a space which may help to cool the space if it is cooler than the temperature of the space. Air velocity is important factor in thermal comfort because people are sensitive to air movement around them. Still or stagnant air in an indoor space that is artificially heated may cause people to feel stuffy and may lead to a built-up in odour. Moving air in warm or humid conditions can increases heat loss through convection without any change in air temperature? Small air movement in cool or cold environment may be perceived as draught. If the air temperature is less than the skin temperature it will significantly increase convective heat loss. Physical activity also increase air movement, so air velocity may be corrected to account for person's level of physical activity (HSE, 2011).

2.8.1.1.3 Air Humidity

Relative humidity is the ratio between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can hold at a given temperature (HSE, 2011).

Health and Safety Executive (2011) stated that relative humidity between 40% and 70% does not have a major impact on thermal comfort. This led to maintaining a relative humidity of 40% to 70% because of electronic equipment. However, spaces which are not air conditioned or where the outdoor climatic conditions influences the indoor thermal conditions, relative humidity ids kept higher than 70% in warm or hot-humid days.

High humid environments have lots of vapour in the air which prevents the evaporation of sweat from the skin. In hot environments, humidity is important because less sweat evaporates when

humidity is high (above 80%). The evaporation of sweat is the main method of heat loss in human body (HSE, 2011).

2.8.2 Personal factors

These are factors that are dependent on individual state as at a particular period of time and this include:

i. Clothing
ii. Work rate/metabolic heat

2.8.2.1 Clothing

This is the insulating covering on the body which by its nature interferes with the ability to lose heat to the environment. Thermal comfort is very much dependent on the insulating effect of the clothing on the body (HSE, 2011).

Wearing too much clothing or personal protective equipment (PPE) may be the primary cause of heat stress even if the environment is not considered warm or hot. If clothing does not provide enough insulation, the body may be at risk from cold injuries such as frost bites or hyperthermia in cold conditions. Clothing is both a potential cause of thermal discomfort as well as a control for it as the body adapt to the climatic condition of the environment (HSE, 2011).

2.8.2.2 Work rate/Metabolic heat

This describes the heat the body produces inside as it carry out physical activity. The more the body is subjected to physical work, the more heat it produces and the more heat it produces, the more heat needs to be lost to be thermally comfortable (HSE, 2011).

2.9 Hotels

According toHotels and Catering Economic Development Committee, South Africa, (2002), a hotel is an establishment of a permanent nature, which consists of four or more bedrooms, and offers bed and breakfast on a short term contract and provides certain minimum standards. Similarly, Lawson F. (2007) defined hotel as “a public establishment which offers traveler and visitors two basic services of accommodation and meals against payment of money for the services.A 'hotel' or 'inn' is defined by the British law as 'the place where a bonafide traveller can receive food and shelter, provided he is in a position to pay for it and is in a fit condition to be received.

2.9.1 Types of Hotels

Since hotel guest are transient, special consideration must be given to the potential threat to their life safety and comfort while they stay in the hotel. This led to development of diverse hotel types. Depending upon the guest type, hotels are generally classified based on their location, expected market and other special characteristics which include; size and class. Although, a given hotel may fall into more than one category since each hotel has different goal as to the kind of guest it seeks (Lawson F. 2007).

2.9.1.1 Resort Hotels

A resort is a full-service lodging facility that provides access to or offers a range of amenities and recreation facilities to emphasize a leisure experience. Resorts serve as the primary provider of the guests' experience, often provides services for business and meetings and are characteristically located in vacation oriented settings like beaches and Tourist attractions area like games reserves. Example of a resort hotel is Sheraton Damesha resort located in Damesha district in China (World Class Hotels, 2007).Plate XVIII show an aerial view of Sheraton Damesha resort hotel.



Plate XVIII: Aerial view of Sheraton Damesha resort hotel.
Source: World Class Hotels, (2007).

2.9.1.2 Airport Hotels

This type of hotel is located near airports and target business clientele, airline passengers with overnight travel layovers or cancelled flights and airline personnel. It also provide meeting facilities for guests who travel to a meeting by air and wish to minimize ground travel instead of charging guests by day basis, the guests can also pay for their room by hourly basis. Example of airport is the Grand Hyatt hotel, Dubai(World Class Hotels, 2007). Plate XIX how three dimensional view of Grand Hyatt hotel, Dubai.



Plate XIX: Grand Hyatt Hotel, Dubai.
Source: World Class Hotels, (2007).

2.9.1.3 Garden Hotels

These are hotels that have made important environmental improvements to its structure in order to minimize its impact on the environment. The basic definition of a garden hotel is an environmentally responsible lodging that ensures that their guests are staying in a safe, non-toxic and energy-efficient accommodation. These types of hotels are particularly notable for their gardens(World Class Hotels, 2007). Example is Hilton Garden hotel in Plate XX.



Plate XX: Hilton Garden inn hotel,
Source:World Class Hotels, (2007).

2.9.1.4 City centre hotels

These types of hotels are located in urban areas, usually reserved for people who intend to stay a while (in the short term). City Hotels are also known as a transit hotels because theyare usually occupied by business people who use the facilities and business services provided by the hotels (World Class Hotels, 2007).Example is the Cardiff city centre hotel in Plate XXI.



Plate XXI: Cardiff City Centre Hotel.
Source:World Class Hotels, (2007).

2.9.1.5 Conference hotels

This hotels focus on meeting and conferences and overnight accommodation for meeting attendees. Provide high quality audio-visual equipment, business services, and flexible seating arrangements. Hotels mostly located outside the metropolitan areas. Have facilities like golf, swimming pools, tennis courts, fitness centres and spas (World Class Hotels, 2007). Plate XXII shows a picture of double three hotel & Conference Centre, Warsaw as an example of this type of hotels.



Plate XXII: Double three hotel & Conference Centre, Warsaw.
Source:World Class Hotels, (2007).

2.9.1.6 Motels

Motels are a contraction of motor hotel.It a lodging that caters primarily to guests arriving by automobiles. Motels are located in any setting, but are usually found in suburban or roadside areas. Motels can be two storeys or low rise building located near major highways. Motels may contain pool areas with shrubbery tree and children play ground (World Class Hotels, 2007). Platte XXIII is Avalon Motor Hotel, Vancouver.



Plate XXIII: Avalon Motor Hotel Vancouver.
Source:World Class Hotels, (2007).

2.9.2 Hotel Star Rating

The quality of the hotel andits services is usually marked by stars rating. There have been attempts at unifying the classification system to become a reliable standard, but still large differences exist in the quality of accommodation, food and service. Most countries have an official body to set criteria forclassifying hotels; unfortunately, to some degree, the criteria differ from one country to another.The general classification widely accepted in most countries is the "star rating" classification system. The star rating classification byECC-Net, (2008)is:

i. One star hotel
ii. Two star hotels
iii. Three star hotels
iv. Four star hotels
v. Five star hotels

2.9.2.1 One star hotel

Hotels are mostly small and privately owned, services may be provided by the owner and the family. Meals may be fairly simple. Rooms are small (single 8m2 double 12m2). All rooms have a shower and a toilet in the room. Some rooms may not have en suite bathrooms. All rooms have a handbasin with hot and cold running water and heating. Telephone is available. Breakfast and drinks are available. Guests can enter or leave any time of the day or night (WTO, 2012).

2.9.2.2 Two star hotels

These classes of hotels are small to medium size (single rooms 12m2, double 16m2). They are well equipped, offering comfortable accommodation with en-suite bath/shower rooms. Reception staff is professional, food and drinks are offered(WTO, 2012).

2.9.2.3 Three star hotels

These classes of hotels are usually hotels of medium size to support higher staffing levels (single rooms 14m2and double 18m2). They have spacious reception with seats and other public rooms. Their employees speak at least one foreign language. Their restaurants normally also cater for non-residents. All rooms have en-suite bath and shower rooms with toiletries and good equipment, such as a TV set, a hair dryerand direct dial telephone. They usually offer room service and some business services. These types of hotels also have more than two floors with lifts. Access to the internet is available(WTO, 2012).

2.9.2.4 Four star hotels

They maintain a high quality of furnishings, decorations and equipment. Bedrooms are spacious (single 16m2, double 22m2) and well designed, with en-suite bathrooms with a bath and shower.

There is enough staff to provide all necessary service; there is a24-hour room service, laundry and dry-cleaning; a lobby, an a la carte restaurant and a bar. All rooms are equipped with mini-bars and access to internet (WTO, 2012).

2.9.2.5 Five star hotels

Accommodation is spacious (single 18m2, double 26m2) and luxurious, matching the best international standards. There are safe-boxes, access to internet and air conditioning in every room. Personalized guest welcomewith flowers/sweets can be expected. Suites are available. The hotels have special interior design and elegant furnishings. Service is formal and flawless, round-the-clock room's service is available. These hotels have a lift if there is more than one floor. Their restaurants offer high quality cuisine. The staffs are very efficient, courteous and helpful. An indoor swimming pool is available, as well as porter service, laundry, dry-cleaning, ironing and sale of gifts (WTO, 2012).

2.9.2.6 Seven Star Hotels

In the recent years, the zenith of hotel star rating has emerged which is the "Seven Star". These classes of hotels are regarded as the most luxurious hotels in the world. The first of this class is the Burj Al-Arab while the second is the Laucala Island in Fiji, Morgan Plaza in Beijing, China. Several "Seven Star" hotels are under construction worldwide(WTO, 2012).

2.9.3 Hotels standard requirement

Hotel standard requirement is a "model to refer to "or" a procedure which is used for a successful delivery of a hotel design. However, what are at stake here are formal standards developed within the context of official standardisation bodies such as the World Tourism Organisation

(WTO). Such bodies exist at several levels. The hotel standard as outlined by the World Tourism Organization is show in Appendix II.

2.10 Conclusion

The need for passive cooling as means of energy conservation in hotel buildings is discussed in this chapter.Two basic classes of passive cooling functional in a composite of hot-humid/hot-dry climate were identified as heat prevention and heat dissipation. Principles of passive cooling for achieving energy conservation were also covered. Thermal comfort and factors affecting thermal comfort were discussed. The Nigerian climate and classification was also covered. Hotel types and rating and hotel standard requirement were also.

3 RESEARCH METHODOLOGY

3.1 Preamble

This chapter describes the methodology adopted during the process of this research. It also describes the methods adopted in data collection and how the data collected is analyzed to achieve some of the set objectives in Chapter One.

3.2 Research Strategy/Methodological approach

The research strategy is quantitative in nature. This study aimed at minimizing energy use by the climate control system while providing acceptable thermal comfort in a hotel building. The case study outlined in this study describes the following process:

i. Define thermal comfort level(s) for the building indoor spaces considering their function and pattern of use.
ii. Select climate control system(s)consuming least energy in order to maintain indoor thermal comfort level(s).
iii. Use energy simulation software (Ecotect) and computational fluid dynamic technique (CFD) to gain insight into the predicted operation of the climate control system thus allowing for the optimization of passive cooling.

3.3 Research Design

This research adopts a descriptive and a quasi-experimental approach to achieve the answers to the research questions paving way to realizing the research aim and objectives. In the process, Descriptive and Quasi-Experimental approaches are employed for achieving the different set objectives.

3.3.1 Descriptive Approach

The descriptive approach was used for exploratory studies with little or no interest in finding out the relationship between the identified variables. For the objectives to identify the natural means of cooling and ventilating and to identify energy consumption patterns for cooling and ventilation in hotel buildings, a descriptive approach is used.

3.3.2 Quasi-Experimental Approach

The evaluation of the potential of using natural ventilation to achieve energy conservation in hotel building requires a quasi-experimental approach. The hypothesis here is "Natural Ventilation conserves energy in buildings", as such, the dependent variablesareelectricity consumption and thermal comfort while the independent variables examined are classified into two groups: Climatic design variables and Natural Ventilation design variables. The Climatic design variables are; temperature, relative humidity and wind velocity while the Natural Ventilation design variables areStack Ventilation, Single-sided Ventilation and Cross Ventilation.

Electricity consumption is measured in Watt-hours while thermal comfort is measured in terms of indoor dry bulb air temperature and operative temperature both measured in degree Celsius.

3.4 Research Method

The research has adopted both primary and secondary sources of data collection. The primary source employs the use of case studies of related buildings while the secondary source utilizes the review of works done on the subject drawn from both published books, articles, journals, papers and official documents of professional bodies. Case study method of data collection

withenergy auditing was used. During the case study, a physical inventory of electrical equipment use for ventilation and cooling were documented. Self-administered questionnaire was also used to obtain statistical information on the buildings energy consumption for a minimum period of one year.

The research instruments utilized during the course of the study include:

i. Self- administered questionnaire
ii. Non-participant observation

3.4.1 Self-administered questionnaire

The Self-administered questionnaire comprises of structured questions printed and issued to sample of respondents. The questions include both open and close ended questions. The open ended questions has a provision of space left for the respondent's own answer while the close ended questions comprises of list, category or scale/rating for the respondents to select to facilitate analysis. Questions were asked on electricity consumption within the hotel building in order determine the potential for energy savings within the cooling load.

3.4.2 Non-participant observation

During the process of the study non-participant observation is employed so as not to influence the activities being observed. This will involve a visual survey of various processes and equipment that demand the use of energy in the buildings.

3.5 Method of Energy Audit

The energy audit of each building is conducted using a uniform data collection process and tools. It involved the use of self-administered questionnaire, observation, taking inventory and pictures. The objective is to investigate electricity consumption in hotel buildings resulting in disaggregation of total consumption into cooling lighting and appliances.

Electricity consumption in hotel buildings located warm climates is dominated by cooling the interior of the building for thermal comfort of the guest occupant. Therefore, the hypothesis "Natural Ventilation conserves energy in buildings" is strongly correlated to electricity consumption and ambient air temperature. These savings, in particular are in cooling consumption by modifying the building construction in an attempt to attain and maintain thermal comfort.

3.5.1 Walk Through

The walk through exercise involves issuing and filling of self-administered questionnaire, physical observation, inventory and taking of pictures. This exercise is guided by a professional in the field of energy management. The self-administered questionnaire is used to collect essential data on the building characteristics and the energy consumption. It consist of and introduction/consent form at the beginning and nine sections as follows:

i. Building characteristics
ii. Occupancy schedule
iii. Site sketch
iv. Electricity from utility use

v. Electricity from alternative source use

vi. Heating ventilation and air conditioning

vii. Cooling load

viii. Lighting load

ix. Appliances

The building characteristics section covers the gross and conditioned floor areas and building envelope characteristics. It also treats general aspect of architecture of the building. The occupancy schedule section covers the number of building users and the pattern of usage. The site sketch section was used only in buildings where the building plans were unavailable. Electricity from utility covers quantity consumed per month as recorded from utility bills in the electricity from utility use section. The electricity from alternative use section treats electricity consumption from back-up power generators used during power failure.

The last three sections comprising of cooling, lighting and appliances load sections deal with aggregate loading of each end-use in the building. It questions the quantity, energy rating from manufacturer and annual hours of use of each brand of product within each section.

3.5.2 End-Use Calculations (Electricity Usage)

The total electricity consumption in the buildings is disaggregated into end-uses. The end-use consumptions are the aggregate loads in the buildings. This includes, cooling and ventilation, lighting, and Appliances for Refrigeration, water heating, cooking, office machines, electronics, ordinary machines, etc. Figure 3.1 illustrate the demand and supply load distribution for the total electricity consumption.

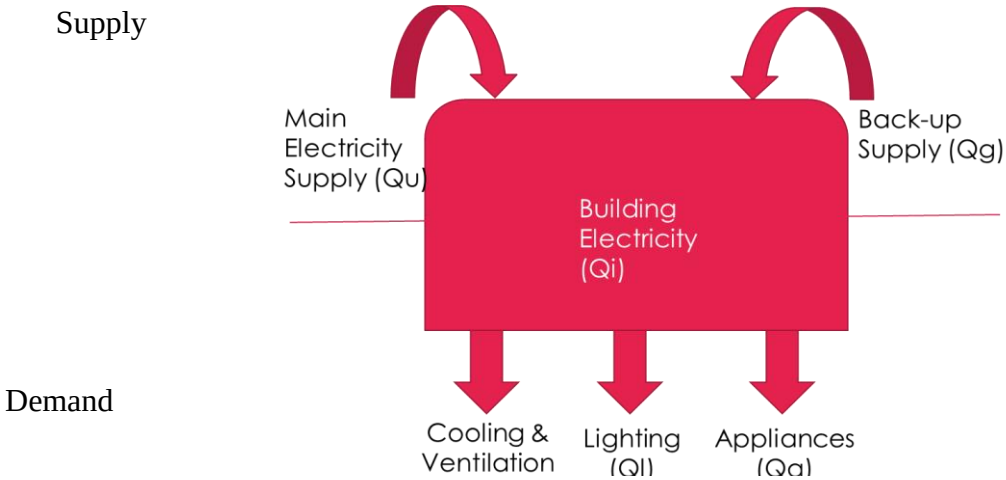


Figure 3.1 Demand and Supply load distribution for electricity consumption in a building
Source: Batagarawa (2013).

3.5.2.1 Total Electricity Supply (Qt)

Total electricity supply (Qt) is the total supply for a particular period of time usually one year in this case. It is the quantity of electricity recorded by a maximum demand (MD) meter supplied from the utility company together with the quantity supplied by the back-up power generator. This is represented by a formula as:

$$Qt = Qu + Qg \quad \text{.....4.7}$$

The method adopted to determine the quantity of electricity supplied by the back-up generator is estimated. The estimation is based on the recorded number of hours of supply by the back-up generator per annum conducted by the buildings' management to track their fuel consumption. The difference in the working hours from hours of the back-up power recorded is the hours the building enjoys electricity supplied by the utility company. This is represented in a formula as:

$$Qg = (Qu\ x\ G)/U \quad \text{.....4.8}$$

Where U and G are the percentages of the time utility and the back-up power are in use respectively.

3.5.2.2 Total Electricity Demand

The total electricity demand (Qt) is the total electricity that is consumed in the building in kWh. It is the sum of electricity used for cooling & ventilation (Qc), Lighting (Ql) and Appliances (Qa). The total electricity demand is represented by;

$Qt = Qc + Ql + Qa$……...3.1

3.5.2.2.1 Cooling and Ventilation demand (Qc) is:

$Qc = Qc1 + Qc2 + Qc3 + \cdots Qcn$……. ……..3.2

Where $Qc(c - n)$ represent the variation in type and specification of cooling and ventilation equipment.

3.5.2.2.2 Lighting demand (Ql) is:

$Ql = Ql1 + Ql2 + Ql3 + \cdots Qln$…….. 3.3

Where $Ql(l - n)$ represent the variation in type and specification of lighting fixtures.

Appliances demand (Qa) is:

$Qa = Q - (Qc + Ql)$ ……3.4

Where $Qa(a - n)$ represent the variation in type and specification of appliances,

$EnergyratingxQuantityxhoursofusage$……..3.5

The hours of use is estimated based on the answers supplied by the respondents and limited observation. A physical count of all appliances for cooling and ventilation, lighting and other equipment was made by the researcher.

Cooling and ventilation load is the demand from the cooling systems installed estimated from an inventory of the units in the building and is similar to the lighting load, which is done from the light fixtures.

Appliances loads encompass all other aggregate end-uses that do not fall under cooling and lighting. The appliance demand load is calculated by energy rating as provided by the manufacturer or recorded from the nameplate of the electric consuming appliances and the quantity of appliances. In the case that the energy rating was not available from the appliance, a search on the product detail on the internet was conducted. If that also failed, the rating of a similar appliance was used. The difficulty therefore in using the same method of calculation as with cooling and lighting loads lies in accurate estimation of hours of use for the multiple types of appliances that constitute this end use. A better formula, shown in Equation 4.6 is:

$$Qa = Qt - (Qc + Ql) \quad \text{..... 3.6}$$

3.6 Sampling

The sampling technique used for this research is purposive sampling. Three major cities were identified within the hot-humid climatic classification that composes of large number of hotel buildings. Similarly, hotels with peculiar features of natural ventilation element across the hot-humid climatic zone were identified. Those hotels with track records of electricity consumption data for a minimum of a yearare studied for it is crucial in investigating theirenergy usage.

3.7 Computer Simulation

The study conducted a simulation analysis using Autodesk Ecotect tosimulate the effect of passive cooling strategies on energy consumption in a proposed hotel.

3.7.1 Model Description

A complete design of a five star hotel consisting of six floors is simulated using Ecotect software. The model is developed using Autodesk Revit Architecture, all spaces were tagged and volumes were also checked according to specified room heights. The model is then exported as gbxml format which is a recognizable format for Ecotect software.

The 3D model loaded into Ecotect undergoes series of settings in both zone management and material properties. In the zone management, the rooms were selected as ‘zones’ while in the material management, each zone is given a material property. Under the material property, the thickness, R-Value and the admittance properties of each material is imputed while the Ecotect software automatically calculates the solar absorption, thermal decrement, thermal lag and the weight of the material.

Finally, the total energy consumption for the monthly cooling loads of both the conventional materials and construction is that of the selected materials and construction are calculated by running the simulation. Comparing the two results determine if there is energy savings between the two buildings or not. The model is then exported as gbxml format which is a recognizable format for Ecotect software as shown in Figure 3.2.

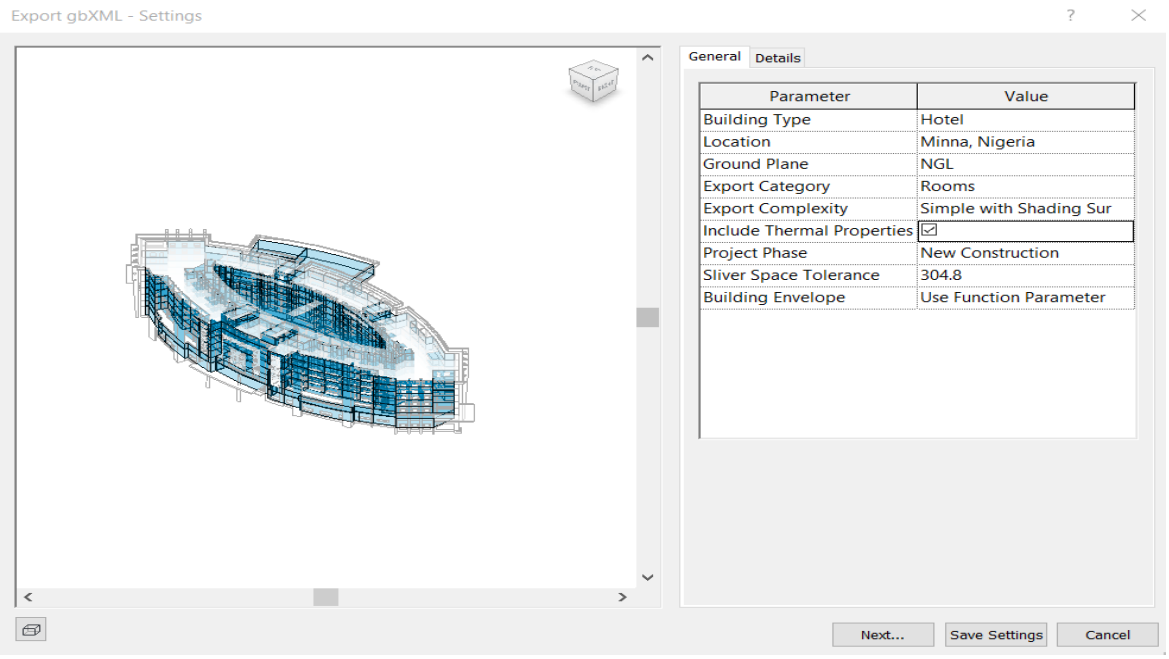


Figure 3.2Model of Six Floor building of a three star hotel

3.7.2 Data Analysis

Statistical and parametric analysis is conducted during the research. The Computer is used for carrying out simulations of Quasi-Experiment to evaluate the potential of using Natural Ventilation to achieve energy conservation in hotel building. Software will be run in the computer which will assist in moulding the Quasi-space in which the experiment will be carried out and analyzed to validate by comparing two similar buildings with different materials and construction.

The data collected in the field is analyzed using descriptive approach. The parametric analysis gives the analysis of predictions made from the simulation conducted by the modification of variables in the computational fluid dynamic (CFD) software in Ecotect.

3.8 Conclusion

This chapter provides information on how the study is conducted in order to achieve the aim of minimizing energy usage for cooling in hotel buildings through the evaluation principles of passive cooling techniques within the composite of hot-humid/hot-dry climatic zone of Nigeria. It also gives a holistic approach of collecting electricity consumption data. Methods and Instrument of data collection, and analysis is also covered.

4 DATA PRESENTATION AND ANALYSIS OF ENERGY AUDIT

4.1 Preamble

This chapter presents the findings of energy audit exercise of three cases located within the composite of hot-humid and hot-dry climate of Nigeria. These are:

i. Reverton Hotel, Lokoja.
ii. Shiroro Hotel,Minna.
iii. Sheraton Hotel and towers, Abuja.

This is to achieve the objectives:

i. To identify energy use patterns in selected hotel buildings
ii. To identify the principles of passive cooling consideration in the selected hotel buildings.
iii. To identify the architectural requirement of hotel buildings.

4.2 Energy usage in selected hotel buildings

Energy usage of the selected hotel buildings is presented under the following headings:

i. Estimated electricity supply
ii. Estimated electricity demand.

4.2.1 Reverton Hotel, Lokoja, Kogi State.

The estimated electricity supply for Reverton hotel is discussed under estimated electricity supply and estimated electricity demand. This identifies the amount of energy supplied to the hotel and at the same time determines the end-use energy usage of the supplied energy.

4.2.1.1 Estimatedelectricity supply

Reverton hotel has an average monthly electricity supply of 15,500kWh from utility bills with average supply time of nineteen (19) hours per day. The back-up supply time is five (5) hours per day usually from two generators of 375kVA and 275kVA of Mikano brand with three (3) and two (2) hours shift respectively. Plate XXIVis the back-up generators used in Reverton hotel.



Plate XXIV Generators used for Back-up supply in Reverton hotel
Source: Researcher's Field work

The estimatedelectricity supply is calculated based on the average hours of supply of nineteen (19) hours and five (5) hours by both the utility and the back-up generators respectively. Table 4.1 shows the estimated electricity supply from both the utility and back-up.

Table 4.1 Estimated electricity supply for Reverton hotel..

Electricity supply	Average hours of supply/day (hrs)	Average supply/hour (kWh)	Average electricity supply/day (kWh)	Average monthly electricity supply (kWh)	Average annual electricity supply (kWh)
Utility Supply	19	27.19	517	15,500	186,000
Back-up Supply	5	520	2600	78,000	936,000
Total	24	547.19	3117	93,500	1,122,000

Source: Researcher's Field work

The combined estimated utility supply and back-up supply shows that utility supply has the highest number of hours per day compared to the back-up supply but the average electricity supplied by the back-up supply per day is greater than the quantity supplied by utility. This is because the back-up supply has a capacity it is capable of supplying while running whilethe utility supply provide only the amount required by the appliances during supply to the building. Figure 4.1 shows the percentages of the two alternatives sources of power suppliedto Reverton hotel to be 17% for utility and 83% for back-up supply. This also led to having a lower electricity consumption of 186,000kWh per annum by the utility supply and a higher electricity consumption of 936,000kWh per annum from the back-up supply as alternative electricity supply to the building.

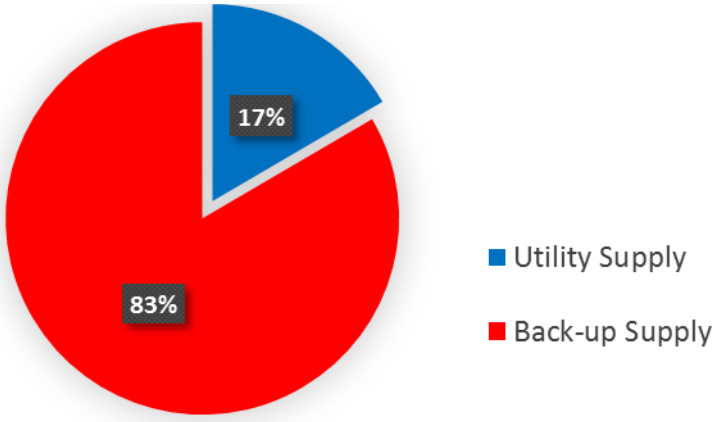


Figure 4.1 Percentages of Utility and Back-up Power supply

4.2.1.2 Estimated electricity demand

This gives the total estimated demand from the three end-uses as categorized by Oke et al (2008) for Reverton hotel.

i. Cooling & ventilation (Qc),

ii. Lighting (Ql

iii. Other Appliances (Qa).

The appliances demand covers all other appliances beside cooling, ventilation and lighting. This include; washing machines, dryers, electric cookers, ironing machines, televisions, elevators refrigerators, photocopiers, computers, printers etc.Table 4.2 describe the various cooling and ventilation system together with their location of usage in the building.

Table 4.2Cooling and Ventilation system

COOLING AND VENTILATION SYSTEM		
Cooling and Systems	Appliances	Location
Air Conditioning System	Split Units of Air Condition and Packaged units	Provided in each guest room, public spaces and administrative areas.
Fans	Standing fans and Wall mounted fans.	Provided in some public spaces such as conference hall, bars etc.
Mechanical ventilation (Exhaust)	Extractors fans	Provided at highest level in Kitchen, Laundry and storage areas to dissipate the generated heat.

Source: Researcher's Field work

4.2.1.2.1 Estimatedcooling and ventilation demand

Cooling and ventilation demand is from the cooling systems installed in the building and it is estimated from an inventory of the cooling demand in the building. Table 4.3 shows the disaggregation of the cooling and ventilation demand for Reverton hotel using equation 3.6 for each of the cooling and ventilation appliances.

Five (5) ton packaged unit air conditioners (AC) of Panasonic brand with capacity 6.5kWh were used in public spaces which accommodates large number of people at a time. This includes; reception hall, restaurants, bars, syndicate room and conference hall.

One and half (1.5) horse power (hp) split AC of capacity 1.1kWh were used in bedrooms, offices and shops which accommodate small number of people at a particular time. ‘OX” brand standing fans of capacity 0.08kWh were positioned at the conference hall and bars to boost air movement in case of overcrowding while the wall fans were mounted in laundry ironing areas. The extractor fans were located in the kitchen and ironing areas to easily dissipate heat out of the building. Table 4.3 shows the different cooling and ventilation appliances and their corresponding ratings and energy demand.

Table 4.3 Cooling and ventilation demand appliances with ratings and energy demand

S/N	Appliances	Quantity (Nr)	Energy Rating (kW)	Average hours of usage/day (hrs)	Average Energy consumed/ day (kWh)	Average energy consumed/ month (kWh)	Average Energy consumed/ annum (kWh)
1	5 tons packaged unit AC Panasonic brand Haier	12	6.5	6	468	14,040	168,480
2	thermocool 1.5hp split unit AC	112	1.1	6	739.2	22,176	266,112
3	Standing Fans "OX" brand	12	0.08	6	5.76	172.8	2,073.6
4	Wall fans "OX" brand	6	0.08	6	2.88	86.4	1,036.8
5	Extractor fans	8	0.08	12	7.68	230.4	2,764.8
Total							440,467.2

Source: Researcher's Field work

4.2.1.2.2 Estimatedlighting demand

This is the total energy consumed by all the individual lighting appliances. The lighting demand comprise of lighting appliances ranging from twenty six (26) watt energy saving bulbs to bright incandescent lamps of five hundred (500) watt.Table 4.4 shows the types of lighting, their rating and energy consumption per annum.

Table 4.4 Estimated lighting demand

S/N	Lighting	Location	Quantity (No)	Rating (kWh)	Average hours of usage/day (hrs)	Energy consumed/ month (kWh)	Energy consumed/ annum (kWh)
1	Wall bracket luminaires	Corridors and offices	106	0.04	12	1,526.4	18,316.8
2	Bed side energy saving lamp	Bedrooms	180	0.026	0.5	70.2	842.4
3	Recessed ceiling light	Bedrooms, and offices	226	0.06	12	4,881.6	58,579.2
4	Dimmable recessed light	Bar and Restaurant	32	0.036	6	207.36	2,488.32
5	Bollard Light	Garden and car parks	46	0.04	12	662.4	7,948.8
6	security street light	Walk ways	12	0.2	12	864	10,368
7	Security Flood light	Property boundary	4	0.2	12	288	3,456
8	Under water light	Swimming pool	8	0.5	12	1,440	17,280
Total							**119,279.52**

Source: Researcher's Field work

4.2.1.2.3 EstimatedAppliances Demand

From Equation 4.1,

$Qt = Qc + Ql + Qa$……...4.1

$Qt =$ 440,467.20 + 119,279.52 + 562,253.28

$Qt = \mathbf{1,122,000}\boldsymbol{kWh}$(Total estimated electricity demand)

Table 4.5and Figure 4.2 shows that appliances has the highest quantity of electricity consumption followed by the cooling demand. The lighting demand has the lowest electricity consumption as most of the lighting appliances that consume the highest quantity of electricity are only on at night. The substantial contribution by cooling is an indication that targeting this end-use will provide significant energy saving.

Table 4.5 Average estimated demands for the three (3) end-uses

End-use Electricity Demand	**Average total estimated Demand (kWh)**
Cooling and Ventilation Demand	440,467.20
Lighting Demand	119,279.52
Appliances Demand	562,253.28
Total	**1,122,000**

Source: Researcher's Field work

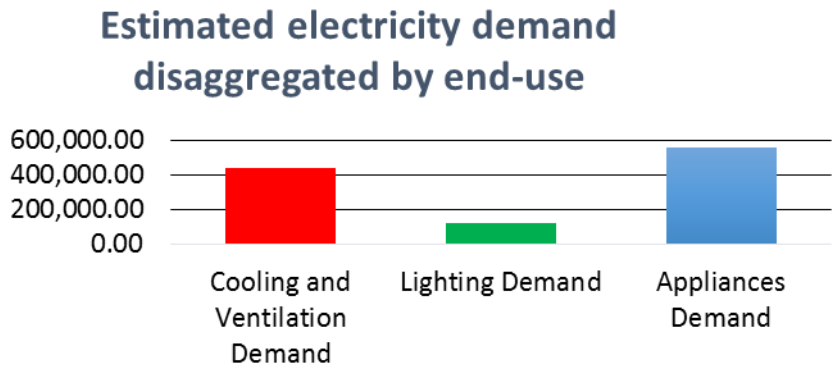


Figure 4.2 Estimated electricity demand disaggregated by end-use

4.2.2 Shiroro Hotel, Minna, Niger State.

Shiroro hotel energy use is discussed under the following headings:

i. Estimated electricity supply

ii. Estimated electricity demand

iii. Estimated electricity supply

Shiroro hotel uses single back-up generator of capacity 670kVa equivalent to 536kWh of Mikano brand as alternative to utility supply from power holding company (PHCN). The hotel has an average monthly electricity supply of 13,780kWh from utility bills as recorded by the maximum demand meter (MDM) of skipper brand (Indian made) with average supply time of eighteen (18) hours per day. The estimated back-up supply time is six (6) hours per day. The estimatedelectricity supply for both the utility and back-up supply is shown in Table 4.6.

Table 4.6 Utility and back-up supply in Reverton hotel

Electricity Supply	Average hours of supply/day (hrs)	Average supply/hour (kWh)	Average electricity Supply/day (kWh)	Average monthly Electricity Supply (kWh)	Average Annual electricity supply (kWh)
Utility Supply	18	25.52	459.33	13,780	165,360
Back-up Supply	6	536	3216	96,480	1,157,760
Total	**24**	**561.52**	**995.33**	**110,260**	**1,323,120**

Source: Researcher's Field work

Comparison of the utility supply and the back-up supply in Figure 4.3 shows that the back-up supply of six (6) hours per day is greater than the utility supply of eighteen (18) hours per day with 54% and 46% per annum respectively.

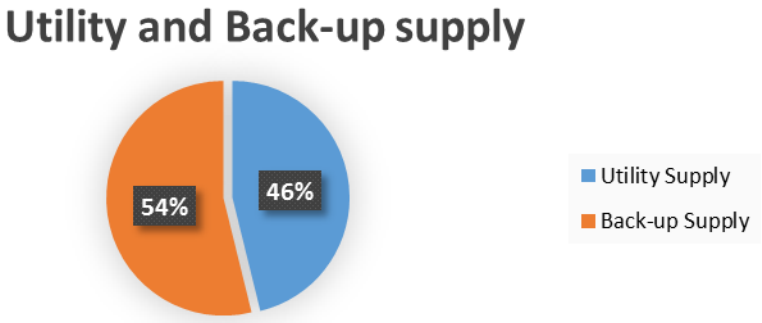


Figure 4.3 Percentages of utility and back-up electricity supply

4.2.2.1 Estimated electricity demand

Just like Reverton hotel, the estimated electricity demand for Shiroro hotel has been aggregated into three (3) end-uses of cooling and ventilation, lighting and other appliances demand.

4.2.2.1.1 Estimated Cooling demand

The cooling demand is distributed among air conditioning system of five (5) tons packaged unit AC, one and half (1.5) hours power (hp) split and window unit air condition, the standing and extractor fans. Table 4.7 shows the various cooling appliances with their ratings and corresponding electricity demand per annum.

Table 4.7 Cooling and ventilation appliances with their ratings and energy demand per annum

S/N	Appliances	Quantity (Nr)	Rating (kWh)	Average Time of use/day (hrs)	Average Energy consumed/day (kWh)	Average Energy consumed/annum (kWh)
1	5 tons packaged unit AC	8	6.5	6	312	112,320
2	1.5hp window unit AC LG brand	218	1.1	6	1438.8	517,968
3	1.5hp split unit AC LG brand	12	1.1	6	79.2	28,512
4	Standing Fans	4	0.08	6	1.92	691.2
5	Wall fans	6	0.08	6	2.88	1,036.8
6	Extractor fans	8	0.08	8	5.12	1,843.2
Total						**662,371.2**

Source: Researcher's Field work

4.2.2.1.2 Estimated lighting demand

The lighting covers all lighting fittings both internally and externally. The lighting demand in Shiroro hotel is from all the lighting fittings in the various spaces in the hotel. The individual lighting demand rating is recorded and their average daily usage time as shown in Table 4.8.

Table 4.8 Lighting appliances with their ratings and electricity demand per annum

S/N	Lighting	Location	Quantity (No)	Rating (kWh)	Average time of use/day (hrs)	Energy consumed/ annum (kWh)
1	Fluorescent light Bedrooms	corridors and offices	274	0.04	12	47,347.2
2	bed side lighting fitting	Bedrooms	208	0.026	0.5	973.44
3	Recessed ceiling light	Hall, offices & Public areas	120	0.06	12	31,104
4	Decorative Dimmable recessed light	Banquet Hall, Restaurant & Restaurant	14	0.036	6	1,088.64
5	Bollard Light	Garden and car parks	26	0.04	12	4,492.8
6	Halogen security street light	Walk ways	38	0.2	12	32,832
7	Security Flood light	Property boundary	8	0.2	12	6,912
Total						**124,750.08**

Source: Researcher's Field work

4.2.2.1.3 Estimated appliances demand

The appliances demand covers all other appliances other than cooling and ventilation and lighting demand. It covers heating appliances, cooking appliances, Electronics and machines. From Equation 4.1,

$Qt = Qc + Ql + Qa$……...4.1

$Qa = 1{,}323{,}120 - (662{,}371.2 + 124{,}750.08)$

$Qa = 1{,}323{,}120 - 787{,}121.28$ $Qa = \mathbf{535,998.72k}$Wh

Similarly, the total estimated electricity demand for Shiroro hotel is calculated using equation 3.1

$Qt = Qc + Ql + Qa$……...3.1

$Qt = 1{,}323{,}120 + 662{,}371.2 + 124{,}750.08$

$Qt = 1{,}323{,}120\boldsymbol{kWh}$ (Total estimated electricity demand)

Shiroro hotel cooling and ventilation demand is greater than other appliances demand. This is because there are more number of rooms to be cooled compared to the number of appliances. Lighting also happen to have the lowest demand. Table 4.9 shows end-use average electricity demand for Shiroro hotel.

Table 4.9 End use Average electricity demand per annum

End-use Electricity Demand	Average Electricity Demand (kWh)
Cooling and Ventilation Demand	662,371.2
Lighting Demand	124,750.08
Appliances Demand	535,998.72
Total	**1,323,120**

Source: Researcher's Field work

Comparing the three end-uses, it shows that cooling load demand has the highest consumption per annum with cooling and ventilation covering 50% of the total supply followed by other appliances with 41% and lighting demand with 9%. This indicates that the higher the number of rooms in a hotel, the higher the cooling demand. Figure 4.4shows the percentages of the three end-uses for Shiroro hotel.

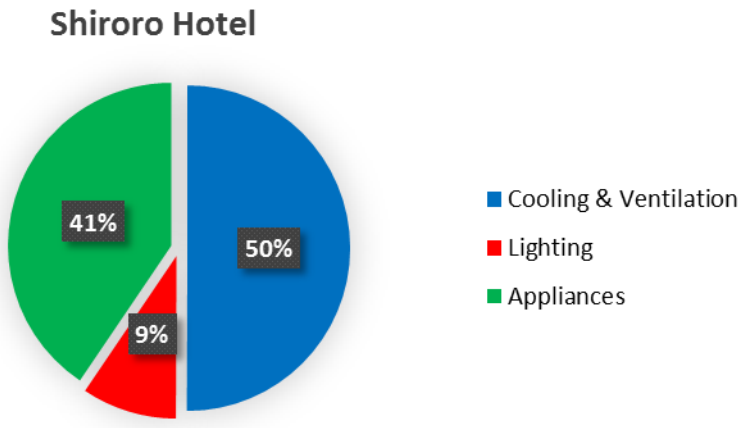


Figure 4.4 Percentages of electricity demand by end-use in Shiroro hotel

4.2.3 Sheraton Hotel and Towers, Abuja.

Sheraton hotel and towers Abuja energy use is discussed under the following headings:

i. Estimated electricity supply

ii. Estimated electricity demand

4.2.3.1 Estimated electricity supply

Sheraton hotel electricity supply is recorded from utility bills from utility company and back-up supply from two back-up generators of 1500kWh and 750kWh working on daily shift bases. It has a minimal power outage as it receives supply from the utility company for a period of twenty hours (20) daily with only two hours of back-up supply from generators. Hence, this led to having a higher utility supply per annum compared to back-up supply. Table 4.10 shows the utility and back-up supply for Sheraton hotel and towers.

Table 4.10 Utility and back-up supply for Sheraton hotel and towers, Abuja.

Electricity Supply	Average hours of supply/day (hrs)	Average supply/hour (kWh)	Average electricity Supply/day (kWh)	Average monthly Electricity Supply (kWh)	Average Annual electricity supply (kWh)
Utility Supply	22	432.6	9,517.2	285,516	3,346,192
Back-up Supply	2	2250	4,500	135,000	1,620,000
Total	**24**	**2682.6**	**14,017.2**	**420,516**	**4,966,192**

Source: Researcher's Field work

Figure 4.5 shows that in Sheraton hotel, the utility supply covers 67% while back-up supply covers 33% of the total supply. This implies that the long period of supply by the utility company of 20 hours compared to just two (2) hours of back-up supply contributed to the higher percentage.

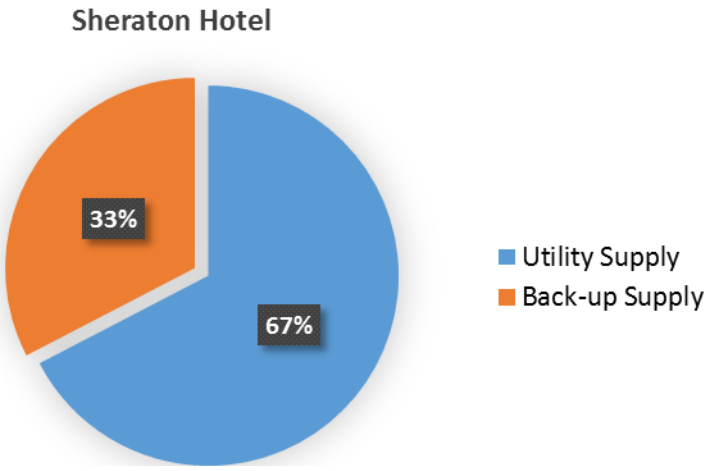


Figure 4.5 Percentages of utility and back-up supply in Sheraton hotel and towers

4.2.3.2 Estimated electricity demand

Just like other hotels, the estimated electricity demand is calculated from three (3) end-uses of cooling and ventilation, lighting and appliances demand.

4.2.3.2.1 Estimated Cooling and ventilation demand

The cooling and ventilation demand is estimated from the installed cooling systems in the building and it is estimated from an inventory of the cooling and ventilation appliances in the building. Sheraton hotel consist of two (2) chilled water central air conditioning plants located in the central air conditioning plant room at the basement of the building. The plants alternate for a

period of twelve hours each. In the chiller plants, a solution of brine is chilled to a temperature of six (6) to eight (8) degree Celsius by a refrigeration plant. This chilled solution is pumped to various floors of the building and its different parts. The process comprise of cooling coils, blowers, and ducts. Table 4.11 shows the different cooling and ventilation appliances in the hotel with their ratings and estimated energy consumption.

Table 4.11 Cooling appliances with their ratings and annual energy demand

S/N	Appliances	Quantity (Nr)	Energy Rating (kW)	Average hours of usage/day (hrs)	Average Energy consumed/ day (kWh)	Average energy consumed/ month (kWh)	Average Energy consumed/ annum (kWh)
1	Chilled water central AC plant	1	350	24	8,400	252,000	3,024,000
2	Haier thermocool 1.5hp split unit AC	8	1.1	24	211.2	6,336	76,032
3	Standing Fans "OX" brand	18	0.08	6	8.64	259.2	3,110.4
45	Extractor fans	22	0.08	12	21.12	633.6	7,603.2
Total						**3,110,745.6**	

Source: Researcher's Field work

4.2.3.2.2 Estimated lighting demand

Just like the other hotel, the lighting demand was estimated using the same method. Table 4.12 shows the different lighting appliances with their ratings and estimated energy demands.

Table 4.12 Lighting appliances with their ratings and annual energy demand

S/N	Lighting	Location	Quantity (No)	Rating (kWh)	Average time of use/day (hrs)	Energy consumed/annum (kWh)
1	Fluorescent light Bedrooms	corridors and offices	1530	0.04	12	264,384
2	bed side lighting fitting	Bedrooms	1350	0.026	0.5	6,318
3	Recessed ceiling light	Hall, offices & Public areas	476	0.06	12	123,379.2
4	Decorative Dimmable recessed light	Banquet Hall, Restaurant & Restaurant	278	0.036	6	21,617.8
5	Bollard Light	Garden and car parks	314	0.04	12	54,259.2
6	Halogen security street light	Walk ways	312	0.2	12	269,568
7	Security Flood light	Property boundary	22	0.2	12	19,008
Total				**758,534.2**		

Source: Researcher's Field work

4.2.3.2.3 Estimated appliances demand

The appliances demand is obtained from equation 4.1. It covers heating appliances, cooking appliances, Electronics and machines.

$Qa = 4{,}966{,}192 - 3{,}869{,}279.8$ $Qa = \mathbf{1{,}096{,}912.2}$kWh

Similarly, the total estimated electricity demand for Sheraton hotel and towers is calculated using equation 3.1

$Qt = Qc + Ql + Qa$……..3.1

$Qt = 3{,}110{,}745.6 + 758{,}534.2 + 1{,}096{,}912.2$

$Qt = \mathbf{4{,}966{,}192}\boldsymbol{kWh}$ (Total estimated electricity demand)

4.2.3.2.4 Disaggregatedenergy demand

The total average annual estimated demand is separated into different end-uses. This is to observe the different consumption patterns of the individual selected buildings. Figure 4.6 shows the percentages of the disaggregated end-use demand for cooling, lighting and other appliances respectively.

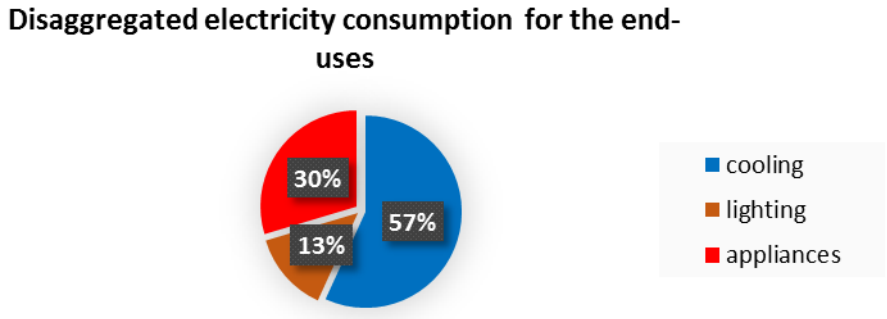


Figure 4.6 Percentages of Disaggregated end-uses

4.2.3.2.5 Normalized Energy Supply

Table 4.13 gives the Normalized energy supply for the three hotels as obtained after computation.

Table 4.13 Normalized Energy Supply per meter square

Hotel Buildings	Energy Supply (Hrs/day)		Energy Supply (kWh/month)		Total Energy Supply (kWh/ annum)	Approx. Bldg. Floor Area (m^2)	Normalized Energy Supply (kWh/m^2)
	Utility	Back-up	Utility	Back-up			
Reverton Hotel	19	5	15,500	780,000	1,122,000	6,841	164
Shiroro Hotel	18	6	13,780	96,480	1,323,120	4,429	298
Sheraton Hotel	22	2	285,516	135,000	4,966,192	15,928	311
Total	59	13	314,796	1,011,480	7,411,312	27,198	775

Source: Researcher's Field work

4.2.3.2.6 Normalized Energy Demand

The substantial contribution by cooling is an indication that targeting this end-use will provide significant energy savings.Table 4.14shows the normalized electricity consumption by area of each disaggregated end-use and the averages per annum across the three buildings studied.

Table 4.14 Normalized Cooling, lighting and appliances demand per meter square

Cases Studied	Cooling Demand (kW)		Lighting Demand (kW)		Appliances Demand (kW)		Approx. Floor area (m2)	Total Average annual demand	
	ECD (kWh)	NCD (kWh/m2)	ELD (kWh)	NLD (kWh/m2)	EAD (kWh)	NAD (kWh/m2)		AED (kWh)	AND (kWh/m2)
Reverton hotel	440,467.20	64.38	119,279.52	17.43	562,253.28	82.18	6,841	1,122,000	164
Shiroro hotel	662,371.2	149.55	124,750.08	28.17	535,998.72	121	4,429	1,323,120	298
Sheraton hotel	3,110,745.6	195	758,534.2	47.78	1,096,912.2	69.10	15,928	4,966,192	311
Total	**4,213,584**	**473.55**	**1,002,563.8**	**110.88**	**2,195,164.2**	**354.1**	**27,198**	**7,411,312**	**775**

Source: Researcher's Field work

In the total annual average demand in Plate 4.7, the normalized values indicates that Reverton has the highest annual normalized demand of 327.93kWh/m2 followed by Sheraton hotel with 311.8kWh/m2, closely followed by Shiroro hotel with an average annual demand of 298.72kWh/m2. This gives a range of 298.72kHh/m2 to 327.93kWh/m2.

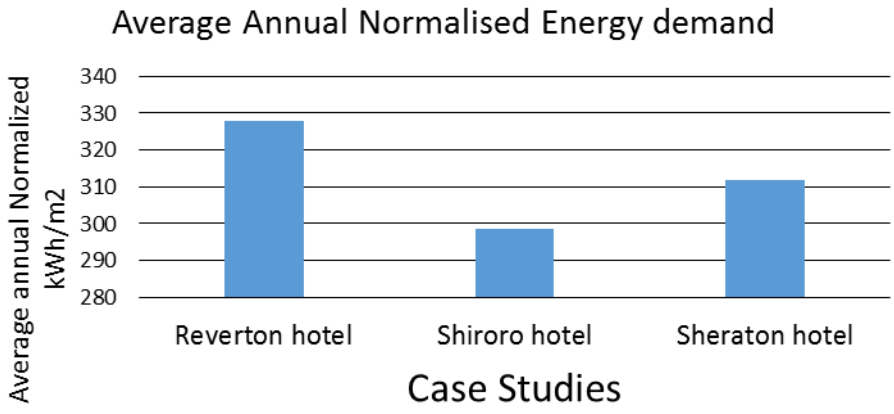


Figure 4.7 Average annual Normalized demand

Reverton hotel, Shiroro hotel and Sheraton hotel and towers have their cooling end-use normalized at 129kWh/m2, 149.55kWh/m2 and 195kWh/m2 equivalent to 39%, 41% and 63% respectively while their respective normalized lighting end-use is 11%, 9% and 15%. Their corresponding appliances values are; 50%, 50% and 22% respectively. Figure 4.8 shows the aggregate consumption in percentages across the three buildings. In the normalized end-use demand it gives a range of 129kWh/m2 to 195kWh/m2 for cooling and 34.93kWh/m2 to 47.78kWh/m2 and a range of 69.1kWh/m2 to 164kWh/m2 for other appliances energy demand.

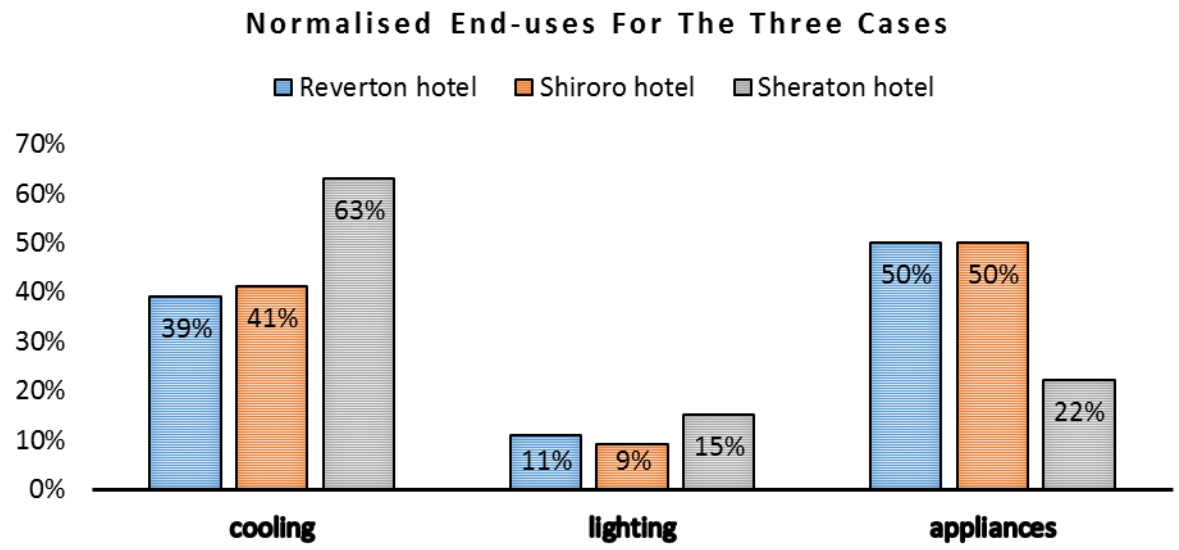


Figure 4.8 Percentages of the Normalized end-uses

4.3 Principle of passive cooling and ventilation in selected hotels

The principles of passive cooling and ventilation consideration looks out for architectural design strategies that are climate responsive that are incorporated in the hotel buildings which help provide comfortable indoor conditions naturally by preventing, reducing or dissipating the incident solar radiation to the building. These principles that help in collection, storage, distribution and control of energy flow by natural process of cooling and ventilation into the building.

4.3.1 Reverton Hotel, Lokoja, Kogi State.

Reverton hotel's principles of passive cooling and ventilation considerations are discussed under the following headings.

4.3.1.1 Building Orientation

The hotel has a good orientation relative to sun path. The shorter sides of the main building face east-west direction while the longer path faces north-south. On the other part, the multipurpose hall has poor orientation relative to sun path. Although, window openings have been avoided on the direction of the sun.In cases where they are provided, less activities takes place in such places. Figure 4.9 shows buildings orientation in Reverton hotel relative sun path.

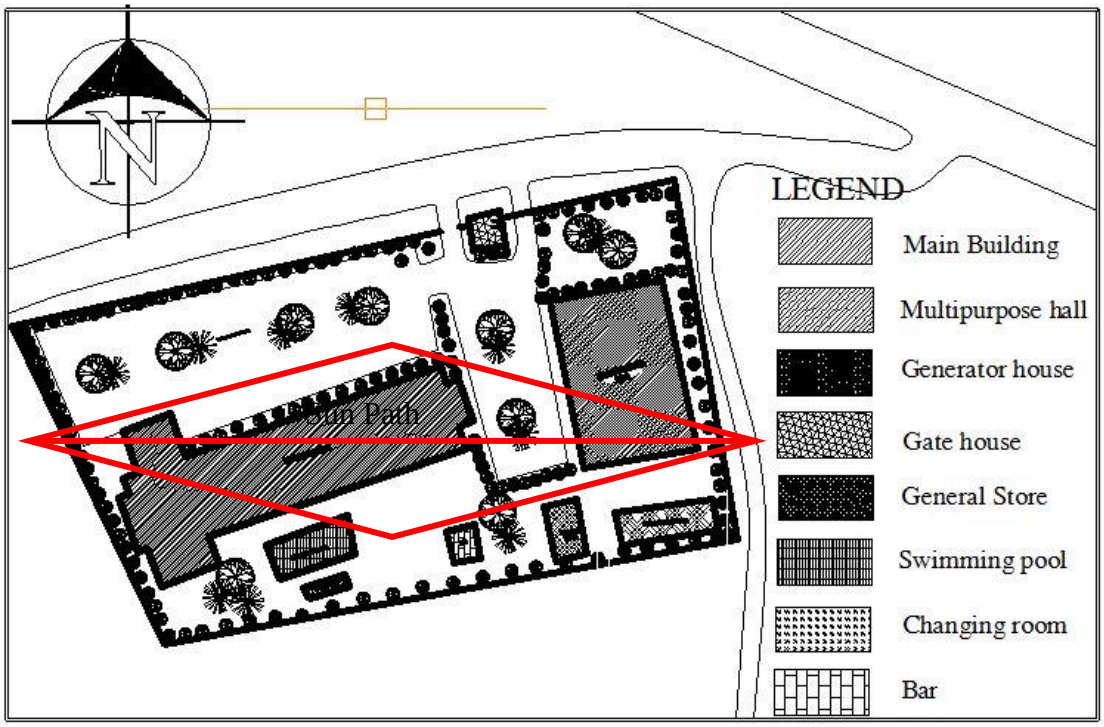


Figure 4.9 Reverton hotel buildings orientation with respect to sun path.
Source: Researcher's Field work, 2015

4.3.1.2 Thermal mass

The dominant building material for Reverton hotel is hollow sandcrete block of 225mmx225mmx450mm. The building is said to be "Thermally light" with less thermal mass and insufficient insulation to retain cooling for a longer period. Part of the building included the installation of Venetian blinds and curtains to reduce the amount of solar glare into the building.

These blinds and curtains are controlled by the occupants, and can be drawn up or down, as well as tilted to better control the amount of daylight entering the space. However, they were installed on the upper portion of the frame of the windows in each floor. When the blinds and curtains are all the way down, these blinds essentially cover the windows, restricting the amount of air that can enter (or exit) the building. Plate XXV shows the building envelope of sandcrete block rendered with sand/cement mortar and finished with emulsion paint.



Plate XXV Sandcrete Block of 225mmX225mmX450mm as building material.
Source: Researcher's Field work, 2015

4.3.1.3 Building Form

Reverton hotel isan elongated rectangular building shape which significantly reduces the building's energy intensity and reduces the need for active mechanical systems. This shape can have 15-25% reduction in energy use over a compact building of the same size as opined by Holtz (2002).

4.3.1.4 Openings, Windows and vents

The dominant window size in Reverton hotel is of single glazing of size 1200mm X 1500mm. This reduces the openings to wall ratio of 6% to 94%. This reduces the amount of solar penetration into the building.

4.3.1.5 Sun shading devices

Reverton hotel has a provision of roof overhang and recessed walls which help in cutting down amount of solar radiation entering into the building.

4.3.1.6 Landscaping

Reverton hotel has Trees and green landscape as ground cover around the building reduces the ambient temperature and limiting the heat island effect around buildings, thus reducing the cooling load and protecting the building from sun, wind and precipitation. Plate XXVIshows elements of green landscaping in Reverton hotel.



Plate XXVI Elements of green landscaping in Reverton hotel
Source: Researcher's Field work, 2015

4.3.2 Shiroro Hotel, Minna.

Shiroro hotel's principles of passive cooling and ventilation considerations are discussed under the following headings.

4.3.2.1 Building Orientation

Shiroro hotel has an "X" concept in the accommodation wing. Two blocks in the accommodation wing have been oriented facing North-south direction with their shorter sides facing the sun path. The other two blocks faces directly to sun path which allows much solar penetration into the rooms creating thermal discomfort. The admin block also has good orientation with respect to sun path.Figure 4.10 shows the different wings and their orientation with respect to sun path.

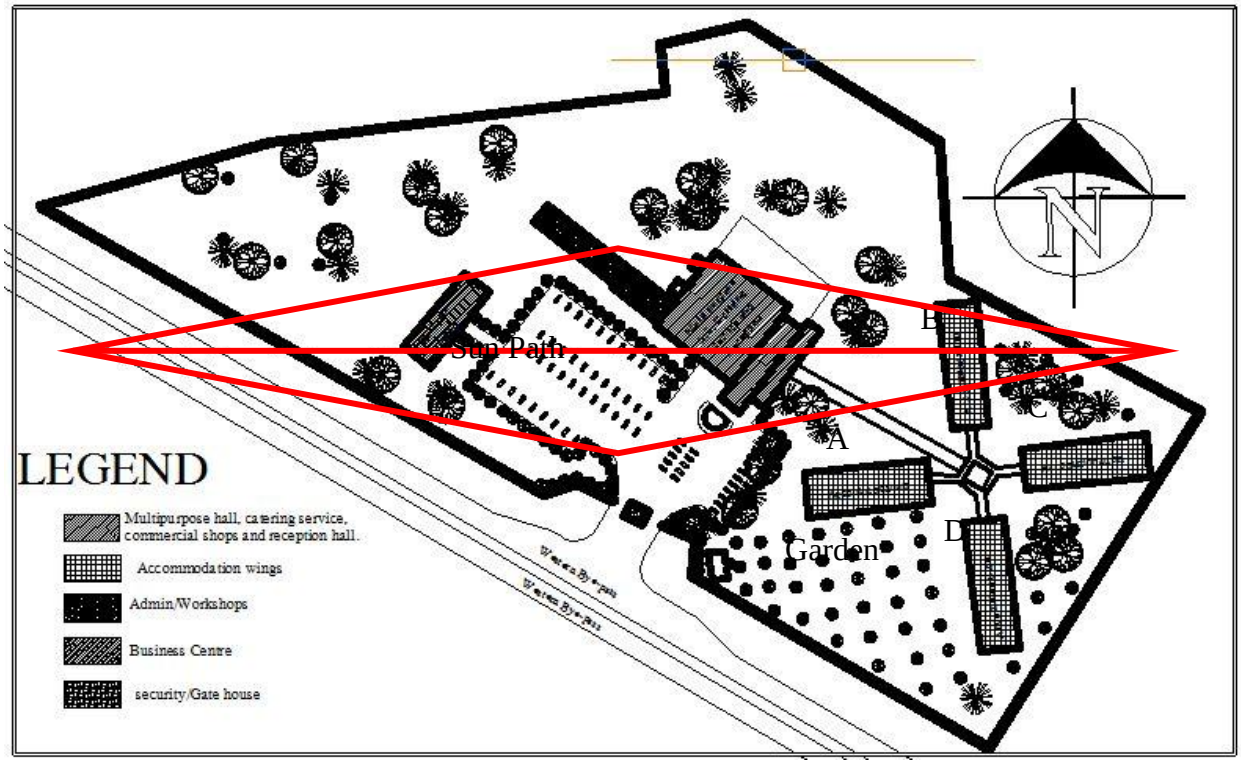


Figure 4.10 Buildings orientation with respect to sun path
Source: Researcher's Field work, 2015

4.3.2.2 Thermal Mass

The walls of Shiroro hotel are also constructed of sandcrete blocks of size 225mmX225mmX450mm with sand and cement mortar of ratio 1:6. Just like Reverton, the wall is thermally light as it does not retain heat or cooling for a longer period of time. Plate VI shows Sandcrete block construction of Shiroro hotel buildings rendered in sand/cement mortar and finished with emulsion paint.

Building Form

Shiroro building are dominantly of elongated rectangular in shape. This make it possible to minimize the amount of solar radiation penetration into the building for those Wing A and C which are oriented with their shorter parts facing the sun direction. Wing B and D has poor orientation as their longer sides are placed facing East-West direction. In this case, more solar radiation will penetrate into the building heating up the space and creating thermal discomfort. The elevation of the building constructed with sandcrete block is shown in PlateXXVII.



Plate XXVII Sandcrete Block construction in Shiroro hotel
Source: Researcher's Field work, 2015

4.3.2.3 Openings, Windows and Vents

Just like Reverton hotel, Shiroro hotel consist of dominantly single glazing aluminium windows of size 1200mmX1200mm with window to Wall ratio of 12% :88% in the accommodation wings. It also encompass an open court yard centrally located in the accommodation wings. The admin section has glazing from wall to wall mostly in the offices, restaurant, reception and multipurpose hall. Plate XXVIII shows window openings and open court yard centrally located in the accommodation wings.



Plate XXVIII Openings type and Court yard in Shiroro hotel
Source: Researcher's Field work, 2015

4.3.2.4 Sun Shading devices

All the buildings in Shiroro hotel has a provision of roof overhang and horizontal egg-crate shading devices which help in cutting the amount of solar radiation that penetrates into the building. Plate XXIX shows the horizontal egg-crates provided in Shiroro hotel.



Plate XXIX Egg-Crate overhang in Shiroro hotel
Source: Researcher's Field work, 2015

4.3.2.5 Landscaping

Shiroro hotel has been well landscaped with trees and green landscape around the buildings. It also consist of a garden at the southern part of the buildings. Trees were planted around the northern and eastern parts to serve as buffer spaces to cut off solar radiation and sound from penetrating into the building. Plate XXX shows a garden and buffer zone at the sides of the accommodation wings to help in minimizing solar radiation penetration into the building.



Plate XXX Garden and Buffer zone in Shiroro hotel accommodation wing
Source: Researcher's Field work, 2015

4.3.3 Sheraton Hotel and Towers, Abuja.

Sheraton hotel's principles of passive cooling and ventilation consideration are discussed under the following headings.

4.3.3.1 Building Orientation

Sheraton hotel orientation is not conforming to the North-South orientation. The accommodation wings are slightly tilted towards North-East and South-West direction with their shorter sides facing North-West and South-East. Although the Givoni angle of tilt

suggested buildings should be slightly tilted to face North-East and South-West. This is because the sun path is not constantly in one position. The tilt in the orientation will cut off unwanted solar radiation from entering the building. Figure 4.11 shows the orientation of Buildings in Sheraton hotel and towers.

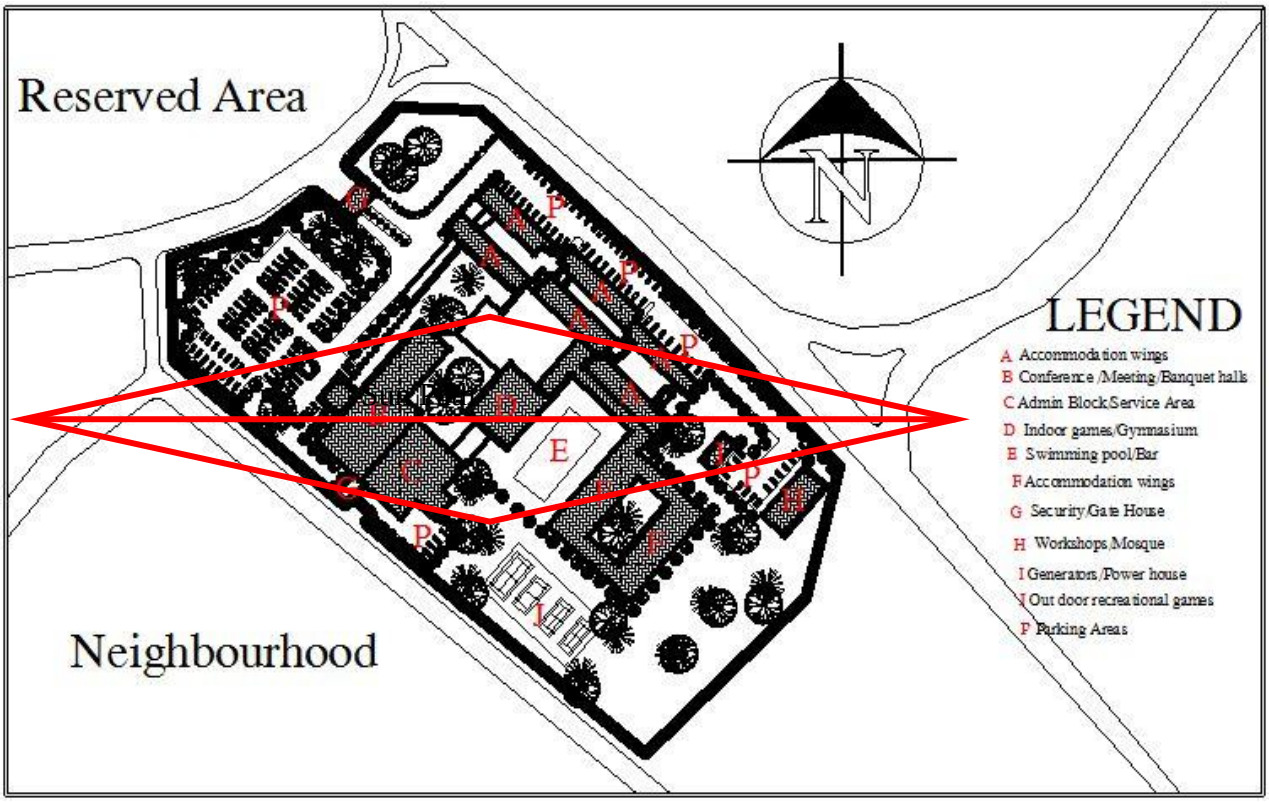


Figure 4.11Buildings orientation in Sheraton hotel and towers Abuja
Source: Researcher's Field work, 2015

4.3.3.2 Thermal Mass

The buildings in Sheraton hotel are constructed with sandcrete blocks and concrete panels. The concrete panel is mostly provided on roofs and some wall panels. Concrete panels are "Thermally" heavy as they retain heat or cooling for a longer period of time.

4.3.3.3 Building Form

The building in Sheraton hotel has simple rectangular forms which define the longer and shorter sides of the building. Rectangular forms in the buildings provide smaller surface area exposure to solar radiation hence, minimizes the amount of solar heat gains penetrating into the building.

4.3.3.4 Openings, Windows and Vents

Predominantly, the building was provided with single glazing panels to encourage infiltration. The guest bedrooms have a one way ventilation with wall to wall glazing which opens to balcony provided with overhangs which serve as sun shading device. Plate XXXI shows the various openings in Sheraton hotel.



Plate XXXI Sheraton Openings as doors and windows
Source: Researcher's Field work, 2015

4.3.3.5 Sun Shading devices

All round the accommodation wings were over hang serving as sun shading device. The central atrium also serve as means of shading and provide stack ventilation which help to suck out vitiated air out of the building. Plate XXXII shows Balcony at the external façade of the building and the central atrium located in the accommodation wings.



Plate XXXII Balconies and Central Atrium in Sheraton hotel
Source: Researcher's Field work, 2015

4.3.3.6 Landscaping

Landscaping is one of the dominant features around the environment in Sheraton hotel. There are different varieties of trees and green landscaping and gardens. The trees have created shading and a buffer to the buildings and have also created aesthetically pleasing views to the hotel. Plate XXXIII shows landscaping elements in Sheraton hotel. There are also water bodies within the central atrium which facilitate evaporative cooling.



Plate XXXIII Water body and Landscape elements in Sheraton hotel Abuja
Source: Researcher's Field work, 2015

4.4 Assessment of the Principles of Passive cooling consideration in the hotels

Principles of passive cooling consideration are given more attention in Sheraton hotel compared to Reverton and Shiroro hotel. Six principles of passive cooling were studied in

each case using a scale factor of: Very good, Good, Fair and Poor. Table 4.15 gives the scores for each of the case studies in terms of passive cooling consideration.

Table 4.15 Passive cooling consideration scores for the case studies

PASSIVE COOLING CONSIDERATION					
ASSESSMENT SCALE: Very Good, Good, Fair and Poor					
S/N	**VARIABLES**	**FEATURES**	**REMARKS**	**REMARKS**	**REMARKS**
1	Building Orientation	Shorter parts of the building facing sun path (East and West) with fewer openings to minimize heat gain on the building surface.	Very good	Good	Poor
2	Shading devices	Use of overhangs, recesses and shades to cut-off excess incident solar radiation on the building.	Poor	Good	Very good
3	Ventilation/Air movement	Use of openings (Windows and screens), Court yard and Atrium to aid cross ventilation or stack effect to enhance air movement.	Fair	Good	Very good
4	Materials/Finishes	Use of sustainable building materials that minimize/prevent solar radiation penetration into the building.	Good	Good	Very good
5	Landscaping	Use of natural vegetation such as trees, shrubs and other features which minimize the effect of solar radiation.	Fair	Good	Very good
6	Thermal Insulation	Use of insulating materials that minimizes solar radiation penetration into the interior spaces.	Fair	Fair	Good

Source: Researcher's Field work, 2015

In terms of building orientation, the accommodation units in Sheraton hotel have not been properly oriented with respect to sun path while in Reverton the accommodation units have their shorter side facing directly to East-West which also cut off some solar radiation while in Shiroro hotel, the concept of "X" adopted in the accommodation wings exposes some of the

rooms directly to sun path. Although, horizontal egg crate shading devices were used to shade the rooms to prevent the penetration of solar radiation.

The construction building material for Reverton and Shiroro hotel is sandcrete blocks with interior cavity, this material does not retain heat or cooling for a long time while Sheraton is of concrete construction which made the buildings thermally heavy as they tend not to easily allow heat penetration into the interiors. In an event of penetration, the walls also retain the heat for a longer period before it escapes out of the interior spaces.

In terms of Building form, all the three buildings were able to adopt an elongated rectangular building form which reduces the surface area of the building that gets in contact with the solar radiation which in turn minimizes heating up of the interior spaces. In addition, the building forms in Sheraton were also staggered to help in shading the individual towers from the radiating solar heat.

In all the three cases, the openings, shading devices and landscape elements were basically provided to minimize heating up of the immediate environment and to create a micro climate which will further enhance thermal comfort in the interior spaces.

4.5 Architectural Consideration

The Architectural Considerations of the selected hotels are coveredunder the following:

i. Spatial Planning
ii. Room types
iii. Spatial Planning

The spatial planning of the selected case studies is discussed under

i. Front of the house

ii. Back of the House

iii. Auxiliary Services

iv. Room types

Room types give the description of the various types of rooms provided for the satisfaction of the guest in the selected hotels.

4.5.1 Reverton Hotel, Lokoja, Kogi State.

Reverton Hotel is a four star hotel established and started operation in February, 2013. It is centrally located in the government reserved area (GRA) of Lokoja; Kogi State along Kunama Street Plate XXXIV shows a Google image of Reverton hotel in Lokoja.



A = Front of the house facilities, B = Back of the house facilities, A = Auxiliary

Plate XXXIV Google image of Reverton hotel, Lokoja
Source: Researcher's Field work, 2015

4.5.1.1 Spatial planning

The hotel comprises of ninety (90) rooms in the category of Standard Suites, Executive Suites, Business and Presidential Suites. It also consist of a multipurpose hall of sitting over 1,500 guest equipped with public address system. Other facilities include well secured car parks, two Restaurants, a bar and a swimming pool.

4.5.1.1.1 Front of the house

The hotel has an inviting reception which is the first place seen by the guest. Located within the front of the house is a bar close to the reception hall. It also houses a central distribution lobby which usher guest to the stair halls, guest rooms, restaurants. The lobby also leads to an exit which direct the guest to the multipurpose hall in case of any occasion taking place. Plate XXXV shows the drop off and the reception hall in Reverton hotel.

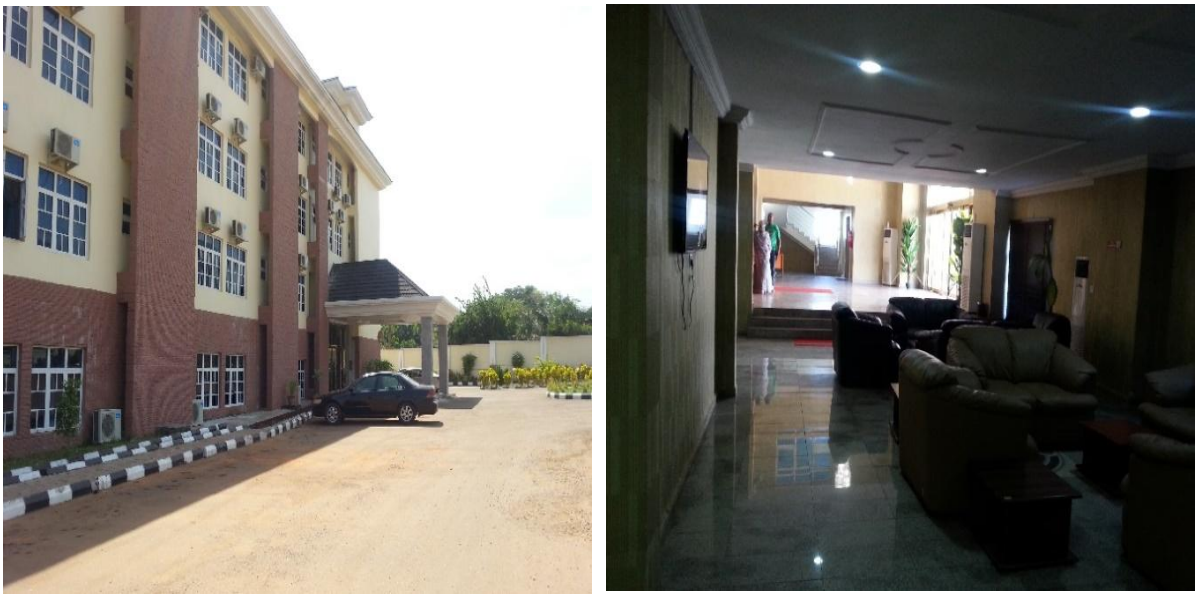


Plate XXXV Drop off and Reception hall in Reverton hotel
Source: Researcher's Field Work, 2015

4.5.1.1.2 Back of the house

The back of the house in Reverton is a conspicuous area located toward the western end of the building. It comprise of services such as the kitchen, laundry, supplies, evacuation, housekeeping and mechanical spaces. Plate XXXVIshows the kitchen and laundry facilities in Reverton hotel.



Plate XXXVI Kitchen and laundry facilities in Reverton hotel
Source: Researcher's Field Work, 2015k

4.5.1.1.3 Auxiliary Services

Reverton hotel consist of limited auxiliary facilities. Among the ones available is a conference hall having a capacity of accommodating five hundred (500) people with two (2) syndicate meeting rooms of capacity of twenty (20) people each for committees meetings while conference is going on, others include; a swimming pool, security/Gate house, generator houwa2se and an outdoor bar facility. Plate XXXVII shows the various auxiliary facilities in Reverton hotel.



A = Security/Gate house, B = Multipurpose hall, C = Outdoor bar facility, D =

Plate XXXVII Auxiliary facilities in Reverton hotel
Source: Researcher's Field Work, 2015

4.5.1.1.4 Rooms Types

The hotel comprises of ninety (90) guest rooms in the category of, Standard Suites, Executive Suites, Business and Presidential Suites.It consist Forty eight (48) Standard Suites with twelve (12) each on first floor, second floor, third floor and fourth floor respectively. It also consistof five (5) business and five (5) executive suites in each floor with only two (2) presidential suites in a pent house. Plate XXXVIII shows the different room types in Reverton hotel.



A = Standard suite, B = Executive suite, C = Business suite, D = Presidential suite

Plate XXXVIII Room types in Reverton hotel
Source: Researcher's Field Work, 2015

4.5.2 Shiroro hotel, Minna, Niger State.

Shiroro hotel is a three (3) star hotel established and started operation in 1986. It is located along eastern bye pass in the Minna the capital city of Niger State. Plate XXXIXshows a Google image of Shiroro hotel Minna.



F= Front of the house facilities, B= Back of the house facilities, A= Auxiliary facilities

Plate XXXIX Google image of Shiroro hotel, Minna
Source: Researcher's Field Work, 2015

4.5.2.1 Spatial Planning

Shiroro hotel comprise of two hundred and eight (208) rooms in the category of executive, deluxe, business and presidential suites. It also consists of a multipurpose hall of sitting capacity of 12oo people. Other facilities include a well secured car parks, restaurant, bar and discotheque. All the facilities in Shiroro hotel are distributed far apart from one another to create a barrier between the facilities. Plate XL shows the distribution of the various facilities in Shiroro hotel, Minna.



A= Reception lobby as part, B= Restaurant, C = Conference hall, D = Meeting room.

Plate XL Reception and restaurant as parts of the front of the house
Source: Researcher's Field Work, 2015

4.5.2.1.1 Front of the house

The front of the house is located at the right side of the buildings encompassing the reception, restaurant, and banquet hall and guest bedrooms located at the far east of the hotel and accessed via a ramp.

4.5.2.1.2 Back of the house

The back of the house comprises mainly the kitchen, service area and a laundry. These are located close to the admin section at the left side of the building. Plate XLI shows the kitchen and kitchen lobby leading to storage area as parts of the back of the house.



A= Kitchen, B = Kitchen to Storage area lobby. (Parts of Back of the house)

Plate XLI Kitchen and Kitchen lobby
Source: Researcher's Field Work, 2015

4.5.2.1.3 Auxiliary facilities

The auxiliary facilities in Shiroro hotel include; Let table shops, business centre and security/gate house.

4.5.2.1.4 Rooms type

The guest rooms are housed independently on a two storey building. It comprises of two hundred and eight (208) guest rooms in the category of, executives suites, deluxe Suites, super deluxe Business and Presidential Suites There are only eight (8) presidential suites with one (1) located in each floor of the four (4) wings of the accommodation. There aretwenty five (25) units of the remaining room types ineach of the floors of two (2) wings. Plate XLII shows the different room types in Shiroro hotel, Minna.



A= Executive, B = Executive Toilet, C = Deluxe, D = Super deluxe, E = Business suite, F = Presidential suite

Plate XLII Rooms Type in Shiroro hotel, Minna.
Source: Researcher's Field Work, 2015

4.5.3 Sheraton Hotel

Abuja Sheraton hotel and towers is a five (5) star hotel constructed and started operation in 1989.It was originally designed as Abuja Hyatt Regency hotel but later transferred to Sheraton group of hotels to manage. The hotel was designed by Skidmore, Owings and Merrill and was constructed by Cotinho, Caro and Co. Hamburg. The hotel is located along Ladi kwali way, beside Yar'adua centre, Wuse zone 4, Abuja. Plate **XLIII**shows the Google image of Sheraton hotel and towers, Abuja.



A= Accommodation, B=Admin and Conference/meeting/banquet halls, C=Kitchen/Supplies, D=Recreational Facilities, E=Workshops

Plate XLIII Google image of Sheraton hotel and towers, Abuja
Source: Researcher's Field Work, 2015

1.1.1.1 Spatial planning

Sheraton hotel and towers consists of twelve (12) floors housing five hundred and forty (540) guest single rooms with a toilet en suite, one hundred and thirty five (135) guest suites, three (3) restaurants, a bar/lounge, fourteen (14) conference/meeting/banquet halls., laundry services, business centers, shopping facilities and recreational facilities and car hire services.

4.5.3.1.1 Front of the house

The front of the house houses the front desk which is the reception hall. It is accessed via the main entrance after the drop-off. After checking into the hotel at the reception, the guest pass through the central atrium where the lifts that lead to the guests rooms is located. The guest rooms are located at the three (3) towers at the upper floors from first floor to the twelfth floor.

Other facilities within the front of the house are the multipurpose halls, banquet halls, and meeting rooms. They are located at the southern part of the hotel beside the general parking lots. The halls consist of demountable partitions which allows for extension of spaces within the halls.

In addition, other front of the house facilities include a bar, lounge and three (3) restaurants which are located attthe ground floor of the main towers and also at the central atrium between the towers.Plate XLIVshows some front of the house facilities.



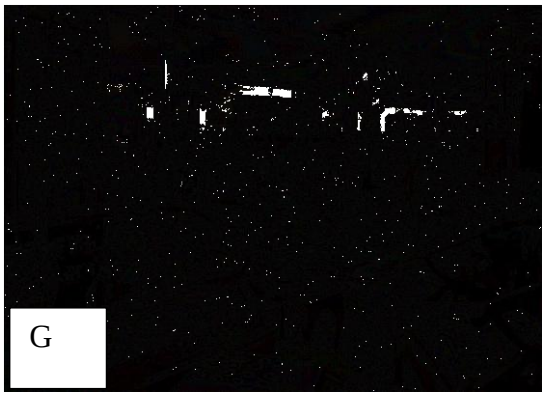
A= ICT Centre B = Reception hall,

















C = Pappilon restaurant, D = Ballroom banquet, E = Ballroom meeting room, F = G = Obudu grill, H = Luigi's Italian restaurant, I = Lobby bar, J = Bar





K = Conference hall, L = Banquet hall

Plate XLIV Front of the house facilities
Source: Researcher's Field Work

4.5.3.1.2 Back of the house

The back of the house in Sheraton hotel is located in the basement. It encompasses the Kitchen, laundry services, food and beverages delivery service/delivery area and waste evacuation area. These services are located at the basement to avoid the vision of the guests. The back of the house staff and delivery enters the hotel through the service gate which is located at the southern part of the hotel. Plate XLVshow some of the back of the house facilities.





A = Food and beverages supply, B = Waste evacuation area

Plate XLV Back of the house facilities
Source: Researcher's Field Work

4.5.3.1.3 Auxiliary facilities

The auxiliary facilities include the fitness centre, recreational facilities, workshops, swimming pools, indoor and outdoor games, indoor and outdoor bars, catering services and tour assist unit. These facilities are located centrally between the front of the house and the back of the house.Plate XLVIshows the various auxiliary facilities in Sheraton hotel and towers.



A = Swimming pool, B = Lawn tennis court, C = Fitness centre.

Plate XLVI Auxiliary facilities in Sheraton hotel and towers.
Source: Researcher's Field Work

4.5.3.1.4 Room types.

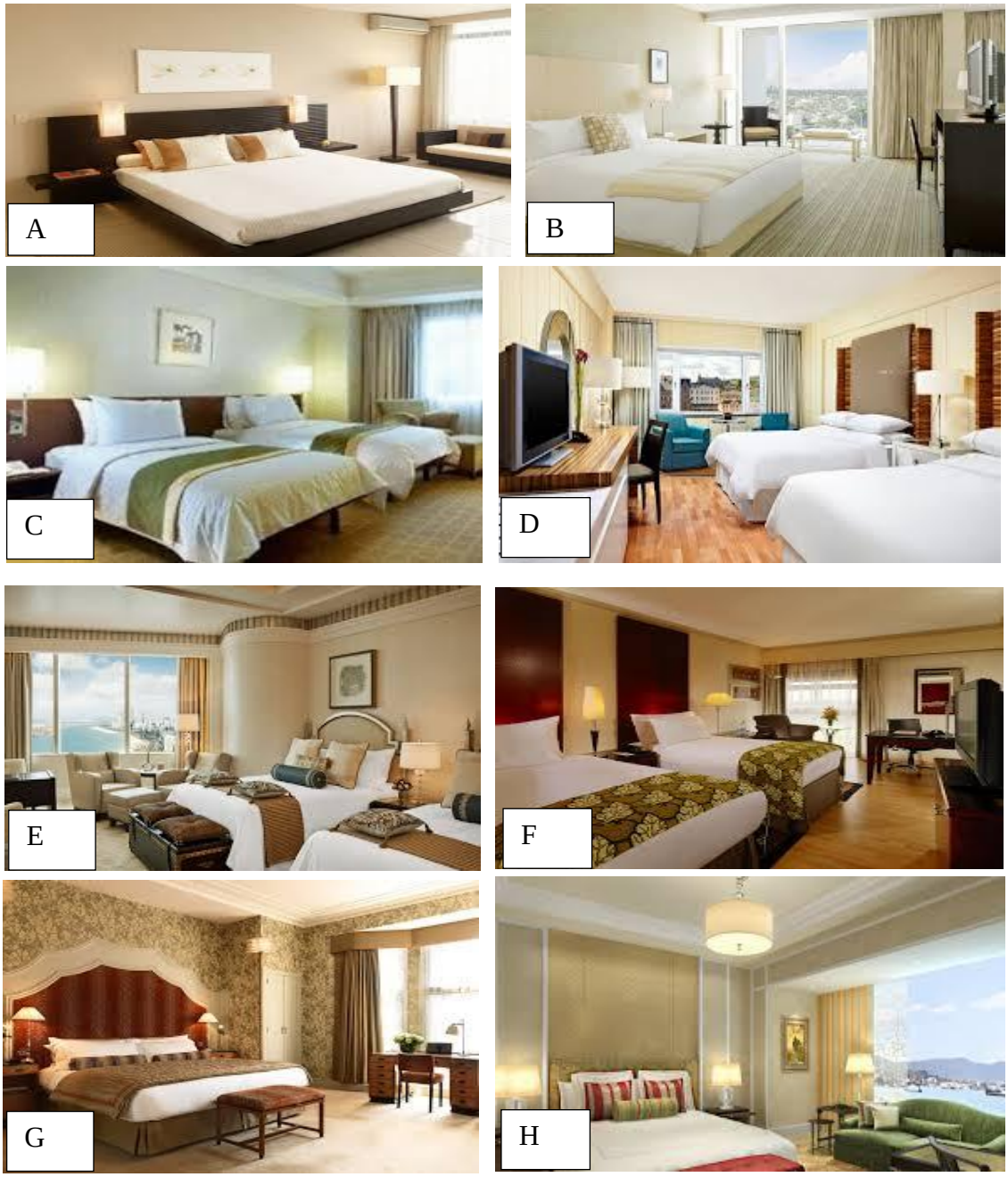
Most of the room types in Sheraton hotel are named after trees. The room names in Sheraton hotel are shown in Table 4.16.

Table 4.16 Different room types and their quantity in Sheraton hotel

S/N	Room types	Quantity
1	Tamarind A&B	70
2	Obeche A&B	60
3	Acacia A&B	60
4	Bibian A&B	60
5	Ballroom 1	30
6	Ballroom 2	30
7	Ballroom 3	30
8	Ballroom 4	30
9	Grand Ballroom	170
10	Tamarind A suite	20
11	Tamarind B Suite	25
12	Obeche A Suite	25
13	Obeche B Suite	25
14	Acacia A Suite	20
15	Acacia B Suite	20

Source: Researcher's Field Work

The different room types in Sheraton hotel and towers are illustrated in Plate XLVIII.



A = Tamarind "A&B", B = Obeche "A&B", C = Acacia "A&B", D = Bibian "A&B", E = Ballroom 1-4, F = Grand Ballroom, G = Tamarind Suites "A&B", H = Obeche & Acacia Suites "A&B"

Plate XLVII Different room types in Sheraton hotel and towers.
Source: Researcher's Field Work

4.6 Discussion on architectural considerations

Out of the three cases studied, Sheraton hotel and towers is the largest of all followed by Shiroro hotel then Reverton hotel, Lokoja. Similarly, Sheraton hotel has more architectural consideration facilities compared to the other two. All the three hotels has the following facilities in common:

i. Accommodation
ii. Catering services
iii. Laundry services
iv. Conference hall
v. Meeting rooms
vi. Commercial shops
vii. Parking spaces
viii. Security/Gate house
ix. Admin offices

WhileSheraton and Reverton hotelshas Swimming pool and outdoor Bar facility in common, Sheraton hotel also has the following facilities:

i. Indoor games
ii. Outdoor games
iii. Fitness center
iv. Tour Assist
v. Travelling agency offices

The Distribution of the architectural consideration in each of the hotels is shown in Table 4.17.

Table 4.17 Distribution of the architectural consideration in each of the hotel.

Hotel	Acc.	CF	SP	CS	LS	SF	TA	PS	AO
Reverton Hotel	✔	✔	✔	✔	✔			✔	✔
Shiroro Hotel	✔	✔		✔	✔			✔	✔
Sheraton Hotel	✔	✔	✔	✔	✔	✔	✔	✔	✔

Acc = Accommodation, CF = Conference facility, SP = Swimming pool, CS = Catering services, LS = Laundry services, SF =Sport facilities, TA = Tour assist, PS = Parking spaces,

Further breakdown of the basic architectural considerations in each individual hotel is shown inTable 4.18

Table 4.18 Breakdown of the architectural consideration in the individual hotels

Hotel	No of Floors			No of Rooms	No of conference & meeting rooms	Number of Parking space	Garden	Sports facilities	Swimming Pool
	B	G	U						
Reverton Hotel	1	1	3	90	2	104	-	-	1
Shiroro Hotel	-	1	1	208	280	250	1	-	-
Sheraton Hotel	1	1	11	675	200	3200	3	7	2

B = Basement, G = Ground floor, U = Upper floor

Source: Researcher's Fieldwork

4.7 Autodesk Ecotect Simulation

The study conducted a simulation analysis using Autodesk Ecotect to validate the Computational Fluid Dynamics (CFD) software's (Ecotect) and its user's ability to simulate passive cooling as means of Energy Conservation in hotel buildings.

4.7.1 Thermo-Physical properties

The 3D model loaded into Ecotect undergoes series of settings in both zone management and material properties. In the zone management, the rooms were selected as 'zones' as shown in Figure 4.12while in the material management, each zone is given a material property. Under the material property, The thickness, R-Value and the admittance properties of each material is imputed while the Ecotect software automatically calculates the Solar absorption, Thermal Decrement, Thermal Lag and the weight of the material.

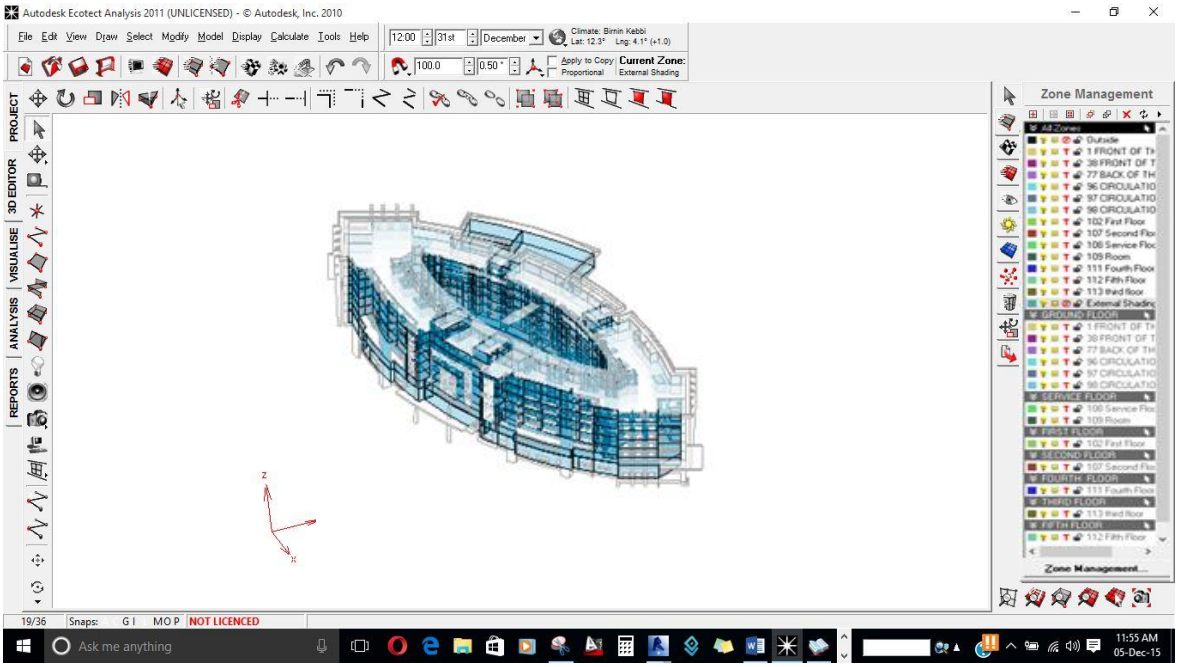


Figure 4.12 Setting of Zone Management of the 3D model in Ecotect software.

4.7.2 Simulating passive cooling principles in the proposed hotel

Building orientation study, monthly cooling loads and solar heat gains and loses simulations was carried out as it relates to the aim of the research (principles of passive cooling). In each case, two models of conventional materials and construction and that of controlled materials and construction are compared.

4.7.2.1 Building Orientation study

A solar radiation study is performed in Ecotectto provide an early indication of the building's optimal orientation with respect to the sun. It is hypothesized that this orientation will maximize passive solar gains through the large glazed areas, so long as the overhangs provide adequate shading in the warmer months. It is also performed to confirm the best orientation with the lowest energy requirement.The direction of north is then offset every 30°, simulating the effect of changing the building's orientation to the sun.The 150 degree orientation is shown to provide benefits of both the 120 and 180 degree orientations in Figure 4.13, and thus is chosen as the estimate for the best orientation.

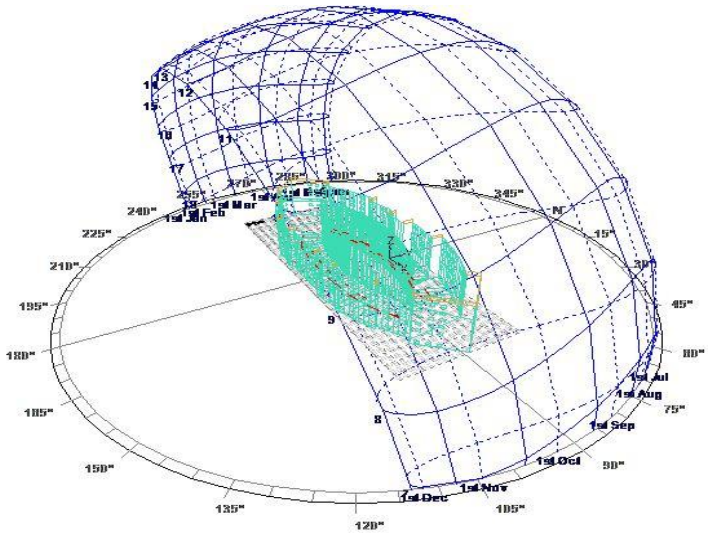


Figure 4.13The 150 degree Orientation to provide benefit of both 120 and 180 degrees

4.7.2.2 Monthly Cooling Loads of Conventional Materials and Construction

The total energy consumption for the monthly cooling loads of the conventional materials and construction is displayed in Table 4.19with the month of April having the highest cooling load of 175,574.60kWh and month of August having the lowest cooling load of 48,042.54kWh.

Table 4.19 Monthly Cooling Loads of Conventional Materials and Construction.

MONTHLY COOLING LOADS **Max Cooling: 870028 W (870kW) at 16:00 on 24th March**		
MONTH	TOTAL (Wh)	TOTAL (kWh)
January	121254008	121254.008
February	156540848	156540.848
March	214322272	214322.272
April	174574608	174574.608
May	150388960	150388.96
June	88377400	88377.4
July	70963120	70963.12
August	48042192	48042.192
September	49662544	49662.544
October	104258920	104258.92
November	115754488	115754.488
December	107492728	107492.728
TOTAL	1401632128	1401632.088
PER M²	126000Wh/m2	126kWh/m2
Floor Area:	**11,124.063 m2**	

The annual average cooling load per meter square is 126kWh. This is represented in Figure 4.14.

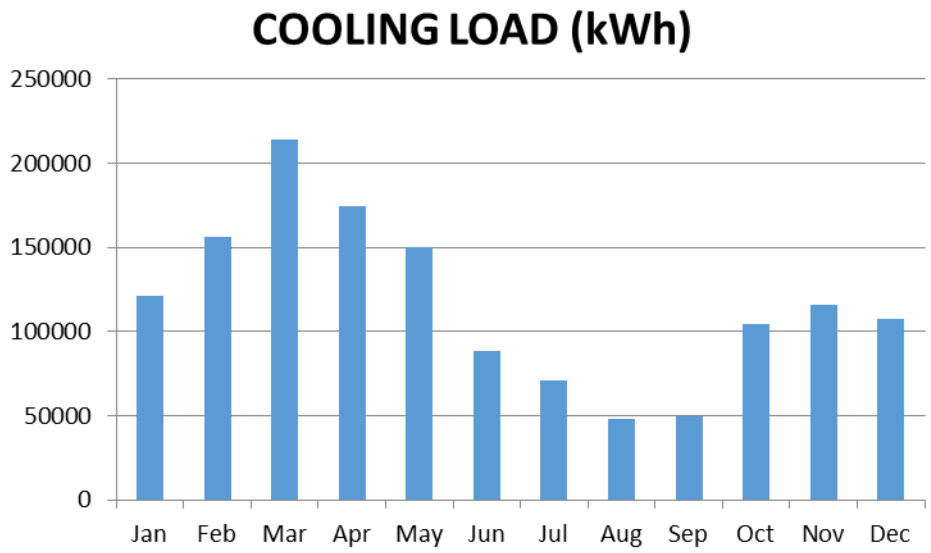


Figure 4.14 Monthly Cooling Load of Conventional Materials and Construction.

4.7.2.3 Solar Heat Gains and Loses for conventional materials and construction

This graph in Figure 4.15shows an average day each month, with months along the horizontal axis and hours of the day along the vertical. The colour of each grid square represents the average gain or loss.

Knowing the source of heat gains and losses can indicate where design efforts should be focused. Here it is shown that heat losses through the building envelope due to conduction and infiltration (shown in red and green, respectively) dominate the internal heat gains contributed by appliances, lighting, and occupants (shown in blue).

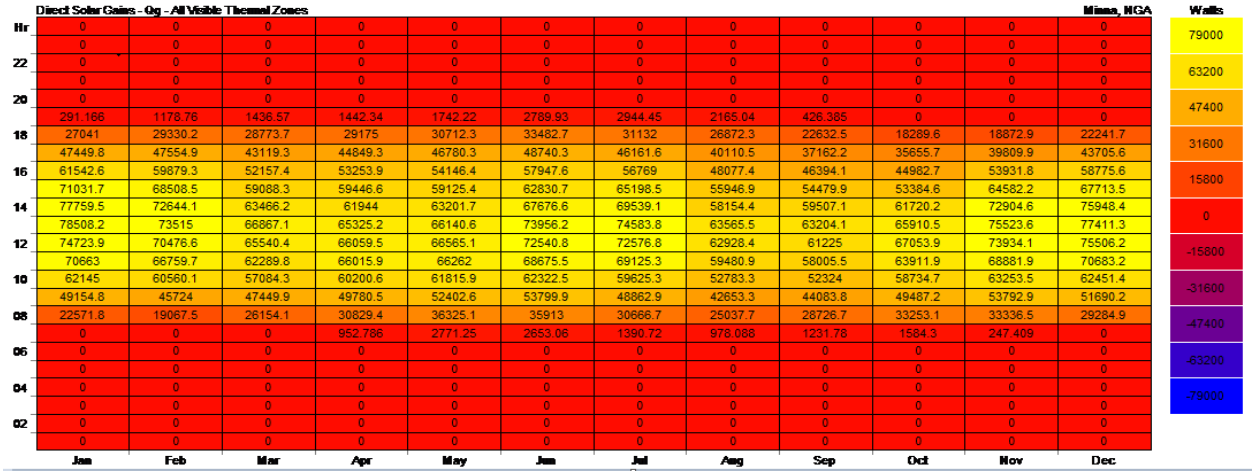


Figure 4.15 Solar gains for the year round from January to December

The figure also show that heat gains from the building fabric, due to both external temperatures and incident solar radiation occur mainly from about 9a.m. to4 p.m. during winter between the month of January to March and July to September. It also shows that summer gains occur from about 11a.m. to 3 p.m. This is mainly because the sun rises earlier in the months of April to June and October to Decemberand spends longer heating up the east wall. This would suggest that some form of shading on the east side may be required.

Figure 4.16also shows that inter-zonal heat gains occur at the worst possible time, middle of the day in summer. This suggests that steps to be taken reduce the effect.

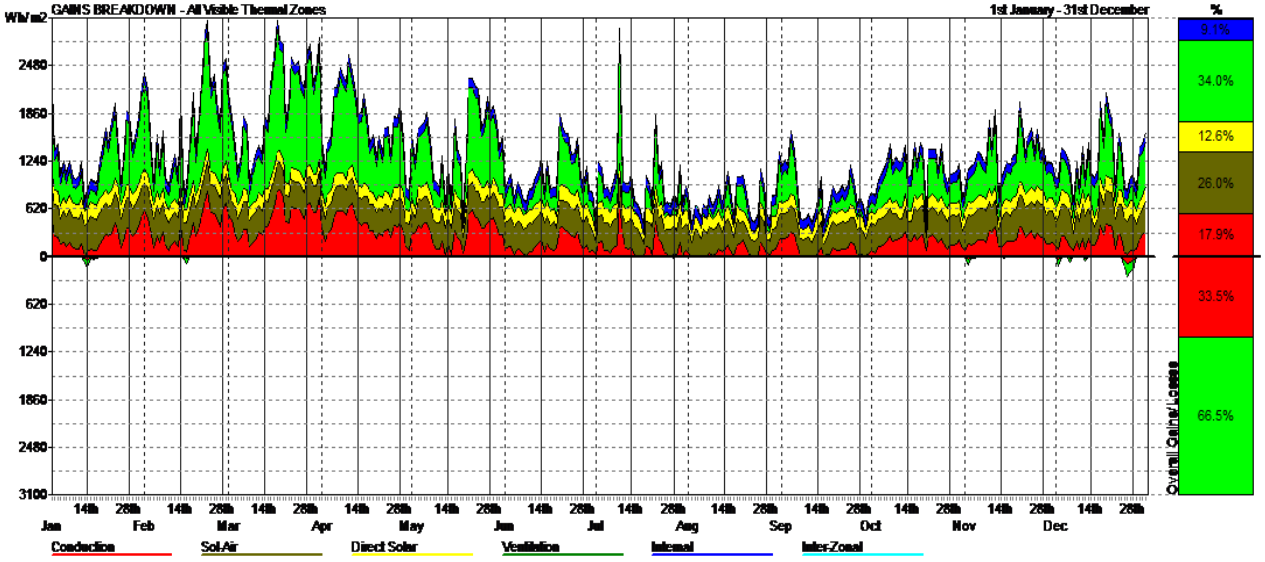


Figure 4.16 Solar heat gains and losses in conventional materials and construction

4.7.2.4 Monthly Cooling Loads of Optimized Materials and Construction

The total energy consumption for the monthly cooling loads of the optimized materials and construction is displayed in Table 4.20with the month of April having the highest cooling load of 128,905.752kWh and month of August having the lowest cooling load of 30,959.3384kWh. The annual average cooling load per meter square is 88kWh. This is represented in **Table 2.1**.

Table 4.20 Monthly cooling loads for optimized materials

MONTHLY COOLING LOADS **Max Cooling: 657739 W (657kW) at 16:00 on 24th March**		
MONTH	COOLING (Wh)	COOLING (kWh)
January	81799960	81799.96
February	112943488	112943.488
March	160155152	160155.152
April	128905752	128905.752
May	109091384	109091.384
June	58454784	58454.784
July	47014328	47014.328
August	30959338	30959.338
September	33463214	33463.214
October	71690720	71690.72
November	77900928	77900.928
December	70271768	70271.768
TOTAL	982650880	982650.816
PER M²	88336Wh	88kWh
Floor area: **11,124.063 m2**		

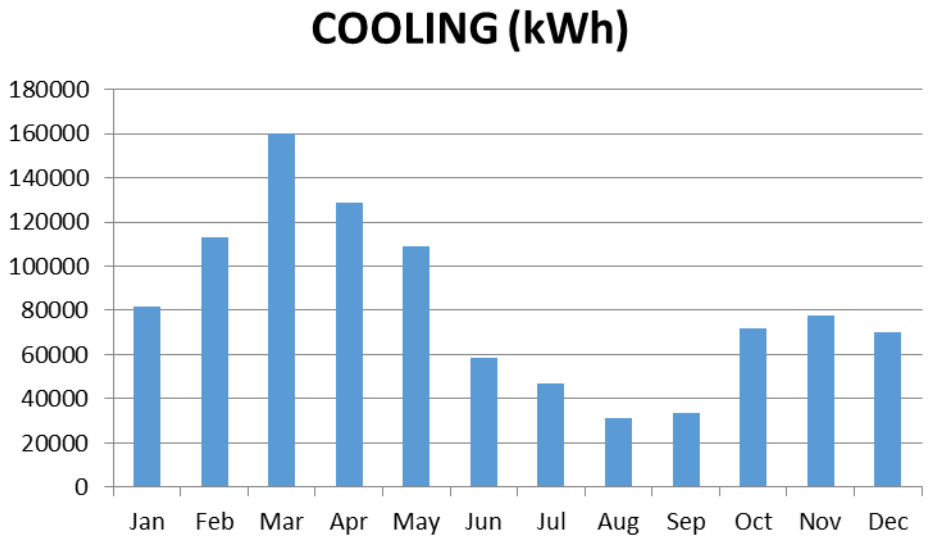


Figure 4.17 Monthly Cooling Load of Optimized Materials

4.7.2.5 Solar Heat Gains and Loses for Optimized materials and construction

Just like as in the conventional construction, Figure 4.188 show that heat gains from the building fabric, due to both external temperatures and incident solar radiation occur mainly from about 9a.m. to4 p.m. during winter between the month of January to March and July to September. It also shows that summer gains occur from about 11a.m. to 3 p.m. The shading devices and the thermal insulation provided and the green roof have shown a significant reduction in the solar heat gains.

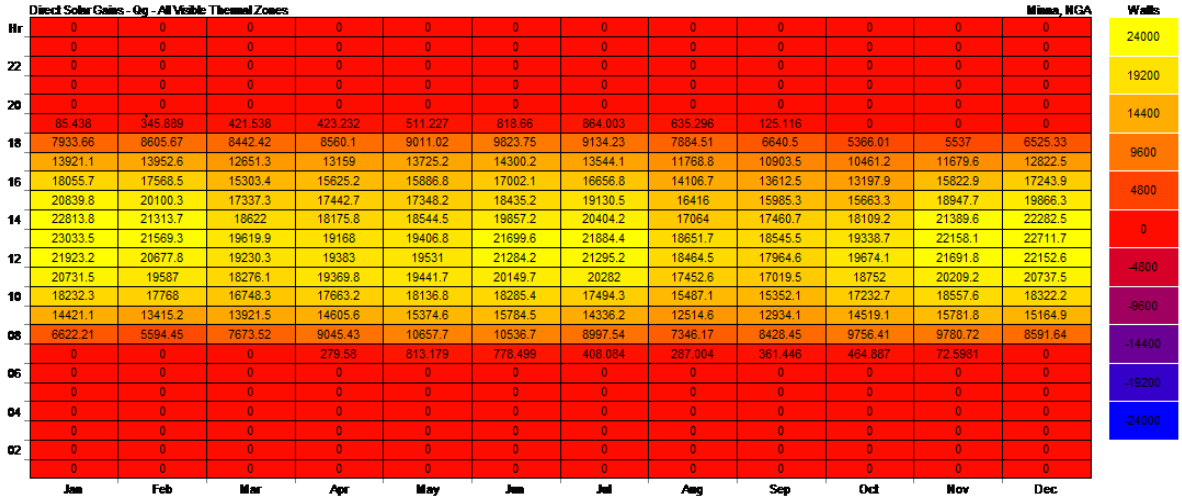


Figure 4.188 Solar gains from January to December

Similarly, the inter-zonal gains have reduced significantly as shown in Figure 4.199.

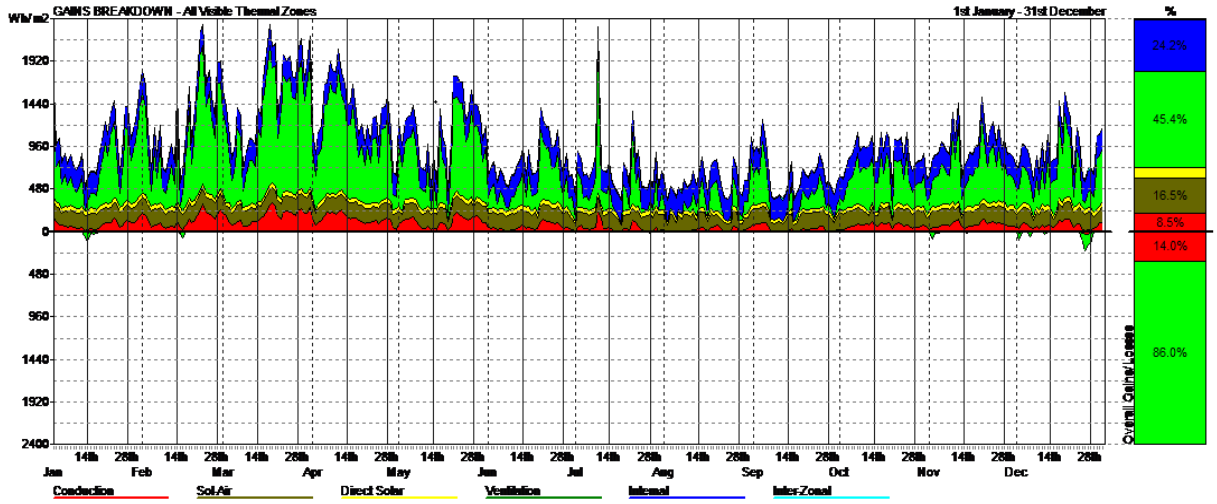


Figure 4.19 Solar heat gains and losses in controlled material and construction

4.7.2.6 Comparing Conventional material and Optimized material/construction.

The simulated value for the conventional material/construction is compared with the optimized material/construction and it reveals that the conventional material/construction has an average normalized cooling load of 126kWh/m² while that of optimized material/construction is 88kWh/m². The difference in the normalized cooling loads is 117kWh. This shows that there is 15% decrease in energy consumption when principles of passive cooling are adopted in the hotel design.

4.8 Conclusion

This study examines the demand and supply of electricity use in three (3) case studies visited through an energy audit within the composite of hot-humid/hot-dry climate. As a result of the need for cooling in this region and the need for comfort to aid patronage in hotel buildings necessitate this study. Similarly, energy consumed by back-up generators is high and unsustainable as such there is need for studying potentials of energy savings within the hotel

end-uses so as to aid energy conservation.It also identified the various principles of passive cooling considered in each of the hotels and evaluated the architectural consideration of each of the hotels. The studies have shown that the application of all the principles of passive cooling techniques inhotel buildings may decrease their cooling load up to 44% - 50%.

An energy audit is employed to collect data on electricity consumption which is broken down into; electricity demand, electricity supply, disaggregation into end-use and normalization of the end use.

In terms of demand, the end-uses are disaggregated into cooling, lighting and appliances. Results show that cooling accounts for the highest demand of an average of 57% of the total electricity demand across the three (3) hotel buildings within a range of 10% - 74%. Cooling is followed by appliances with an average of 30% within the range of 24% - 50%. Lighting accounts for the least demand with an average of 13% within the range of 12% to 76% across the three (3) buildings. This shows that targeting the cooling and ventilation end-use in the design of hotels will provide a substantial energy savings.

In terms of supply, the sources of electricity are utility and back-up from diesel generators in all the three (3) buildings. It was observed that Shiroro hotel which has the highest hours of back-up supply per day of six (6) hours has the lowest average annual back-up supply of 18% of the total supply from the three (3) hotels while Sheraton hotel which has the lowest hours of back-up supply of two (2) hours per day accounts for the highest average annual back-up supply of 67% of the total back-up supply from the three (3) hotels. This trend is attributed to the sizes of the hotels. This led to the conclusion that the bigger the hotel, the higher the amount of energy consume from back-up supply compared to smaller hotels of the same hours of supply.

On the part of the principles of passive cooling consideration, this study have also shown that the larger the hotel the more the facilities and the more the consideration on the principles so as to aid thermal comfort in the building in other to attract more customers. Consequently, this lead to more experiences on the cooling and ventilation demand as that's what keeps the building within thermal comfort range.

5 THE SITE

5.1 Preamble

This chapter discusses the site location for the proposed design of Minna city garden hotel. It also discusses the site selection criteria and how a favored site emerged out of the two potential sites in Minna city. It further gives the climatic and weather characteristics of Minna town before focusing on the specific site micro-climatic characteristics and features.

5.2 Site Selection Criteria

According to Layne Ridley, the site is the physical point of departure for any building project design. The selection of a suitable site for hotel development has a bearing on the success of the hotel.Therefore, adequate consideration is given to determinants such as the intended market or guest and their needs (Architectural consideration) and the research consideration of this thesis.

Two (2) locations were considered for the development of the proposed hotel. A physical observation was conducted round Minna city on the process of identifying the two (2) potential sites. The two locations are:

i. Site “A”, along Moris Road, by western bye-pass, Minna
ii. Site “B”, beside Imurat plastic company, along IBB way, Tudun fulani, Minna.

The suitability of the sites is assessed based on the following factors:

i. Location and accessibility
ii. Natural factors
iii. Availability of essential infrastructure
iv. Proximity to national landmarks
v. Proximity to business areas

vi. Land-use compliance

vii. Orientation along primary axis

The factors are ranked and each site is assessed and scored based on the following ranking scale:

i.	Excellent	=	5
ii.	Very Good	=	4
iii.	Good	=	3
iv.	Weak	=	2
v.	Poor	=	1

Table 5.1 Scores obtained by each site from the site selection ranking scale.

S/N	CRETERIA	SITE "A"	SITE "B"	REMARKS
1	Location and Accessibility	4	4	All sites are located within the city center.
2	Natural factors	3	5	Site "B" consist of more natural features
3	Availability of essential infrastructure	4	3	Site "A" has more infrastructure in place
4	Proximity to National landmarks	4	3	Site "A" is closest to notable landmarks
5	Proximity to business areas	5	3	Site "A" is closest to business areas.
6	Land-use compliance	4	3	Both Site "A" is close to other hotels
7	Orientation along primary axis	5	5	Both Site "A" and "B" are oriented along the primary axis.
TOTAL		28	26	Site "A" is the most favored.

From the site selection criteria, Site "A" is the most suitable for the proposed hotel development with a total score of twenty eight (28) compared to Site "B" which scores twenty six (26). Figure 5.1 show the Google images of the two potential sites.

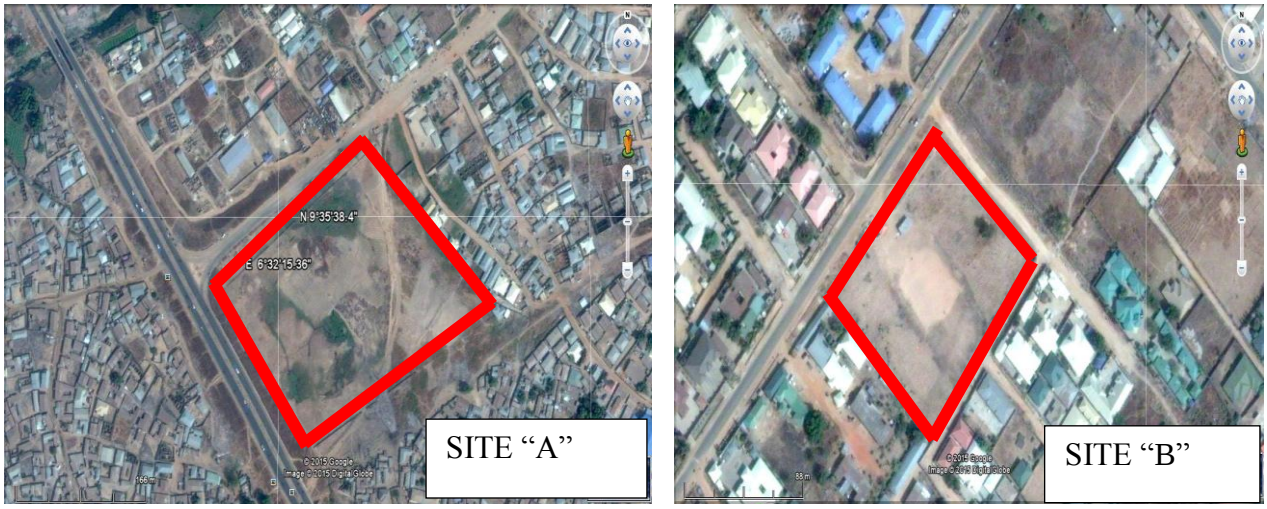


Figure 5.1Google images of the two potential sites.
Source: Researcher's Field Work

5.3 Sit Analysis

The site analysis examine the physical characteristics of the site and its immediate environment as it will influence the decisions to be made about the building's design and construction. The site analysis helps to locate the best position for the building, avoiding or accommodating identified problems where possible by making the best possible use of the physical features and the environment.

5.3.1 Site Location and Accessibility

The site is located along Moris road by western bye-pass in Minna city, the capital of Niger state.

Niger State is located within the north central part of Nigeria created on 3rd February, 1976 and became fully operational as a state in April, 1976. Minna, the capital of the state, is the headquarters of Chanchaga local government area. Minna town extends approximately from latitude 9º36'5" north to longitude 6º22'25" east with an altitude of 260m above sea level and has an estimated population of about 304,113 people (2006, National census). It is also

connected to neighboring cities by road. Abuja, the capital of the country, is only 150 km away. It is connected by railroad to bothKano in the north andIbadanand Lagos in the south which is also bordered by Ilorin city. The city is served by Minna Airport.Figure 5.2shows the map of Niger State and its various local government areas.



Figure 5.2 Map of Niger State and its Local Government Areas.
Source: www.google.com/mapofNigerstate

5.3.2 Climate and Weather

There are basically two main factors that influence weather and climatic conditions of Minna city. The first is its altitude above sea level and second is its location across the path of the seasonal migration of the inter-tropical convergence zone (ITCZ). Minna altitude above the sea level is a major influence on the temperature while its position in relation to the inter-tropical continental zone (ITCZ) determines the sequence of the seasons. The dry season is dominated by the North-Easterly tropical continental air masses usually between December to March while the Rainy season is dominated by South-Westerly moist tropical maritime air masses usually between April to November. The amount and distribution of Temperature,

Sun shine hours, Relative humidity, Rainfall and Wind flow pattern within Minna town follow the two seasons.

5.3.2.1 Temperature

The climate of Minna is influenced by North-East trade winds from the Saharan desert and the rain-bearing South-West monsoon winds from the ocean. Minna town has a high temperature range of 31º to 38º in the months of February to May and low Temperature of between 28º to 18º in the months of June to Januarywith the lowest temperature of 18°C in the month of January. The months of high temperatures gives a tendency of high energy consumption in an attempt to maintain thermal comfort in buildings.**Error! eference source not found.**shows the high and low temperaturesin Minna city throughthe year.

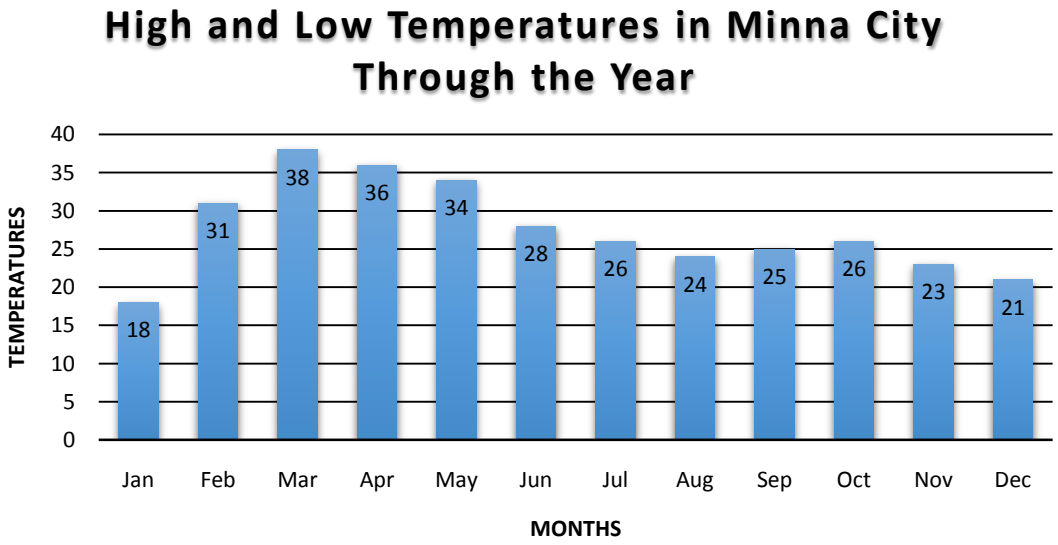


Figure 5.3High and Low temperatures in Minna city through the year

5.3.2.2 Sun Shine and Solar Radiation

The elevation angle of the sun is approximately 75 degrees which account for most of the solar radiation penetration into buildings. In Minna city, records show that there are longer

days than nights during the dry season. The highest sun shine hours are experienced during the months of December to March which last for as long as ten (10) to eleven (11) hours per day. The least amount of sun shine is experienced in the month of August which is predominantly a rainy month. During this period, Minna city experiences an average sun shine of four (4) hours per day. Figure 5.3 show the sun azimuth sun path with an angle of elevation of 75 degrees. It also gives the average sun rise and sun set time in a range of 6:15am to 6:45am and 6:19pm to 6:56pm respectively.

5.3.2.3 Relative humidity

Records show that relative humidity in Minna city is high during the rainy season and low during the dry season. Average monthly relative humidity recorded during the rainy season rises between 11% to as high as 68% in the months of March to August and falls between10% to as low as 7% during the dry season. Figure 5.4shows the average monthly recorded relative humidity for a period of one year.

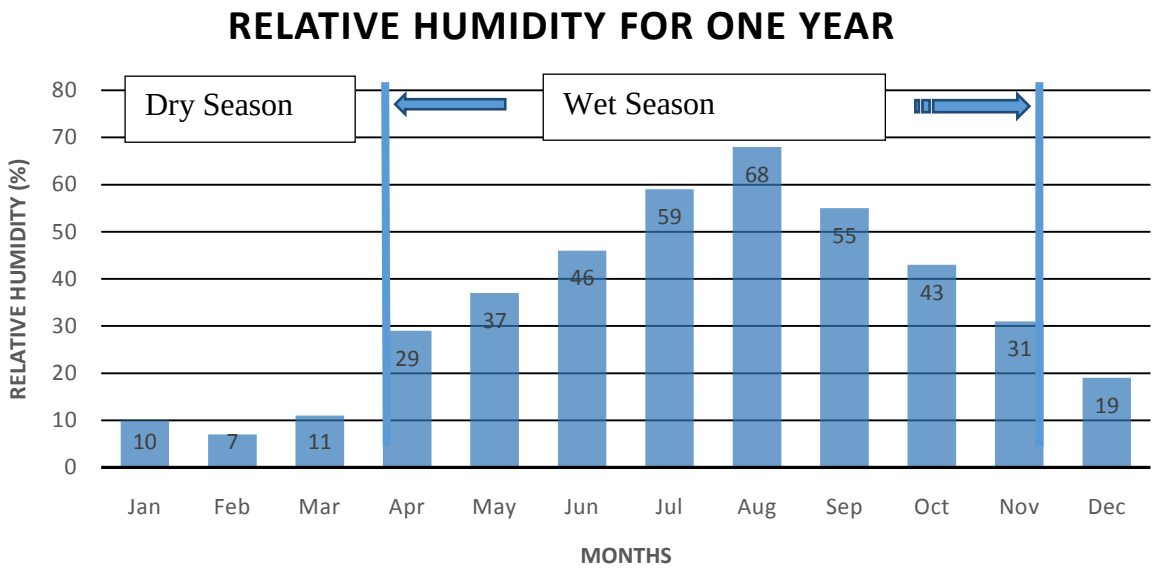


Figure 5.4 Average monthly recorded relative humidity

5.3.2.4 Rainfall

The rainy season in Minna stretches from April to November while the dry season is from December to March. The average rains recorded in Minna is 8mm in the month of April to 428mm in the month of August. An average of 3mm is experienced during the dry season. The month which records the highest rains is the month of August while the driest months are January and February. Figure 5.5shows the average monthly rainfalls for a period of one year in Minna city.

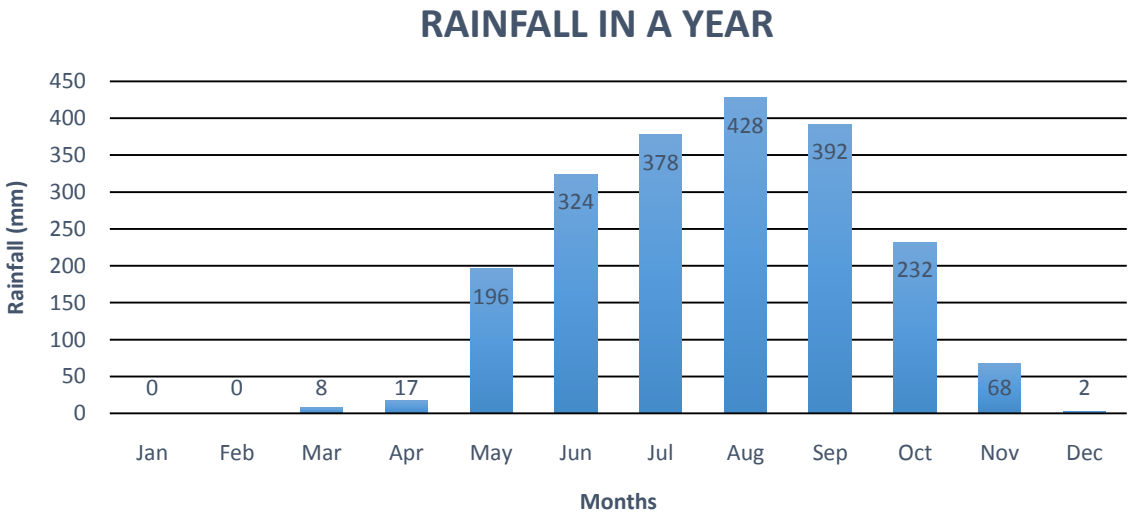


Figure 5.5 Average monthly rainfalls in Minna

5.3.2.5 Wind flow pattern

The wind speed in Minna town vary from 2.0m/s to 4.0m/s. most of the wind comes from the South-West trade wind. The angular direction of the prevailing wind is 108°S. The South-West and the North-East trade winds are attributed to the displacement of the inter-tropical convergence zone (ITCZ). There are variations in the wind speed at different times of the

day, low speed occur in the morning while high speed occur in the afternoon. This is the time when ventilation is mostly required for cooling of the interior spaces.

5.3.3 Specific site micro-climatic characteristics

Though the prevailing climatic conditions of the site are the same for the entire Minna city, slight weather variations occur as a result of certain features and characteristics peculiar to the site. The site micro-climate is influenced by the interaction of factors such as vegetation, topography, Elevation, orientation with the primary axis, wind flow pattern and surrounding development.

5.3.3.1 Accessibility and Infrastructure

The site is advantageously located within the city centre and about a kilometer from the Railway station. It is bounded by a major road along the western part and a minor road along the Northern part. The location also enjoys Impresit water pipe network which supplies the Niger State government house. Along the western part is also a network of electric poles from the power holding company of Nigeria (PHCN) national grid. Figure 5.6 show an outline of the site layout and some of its infrastructure.

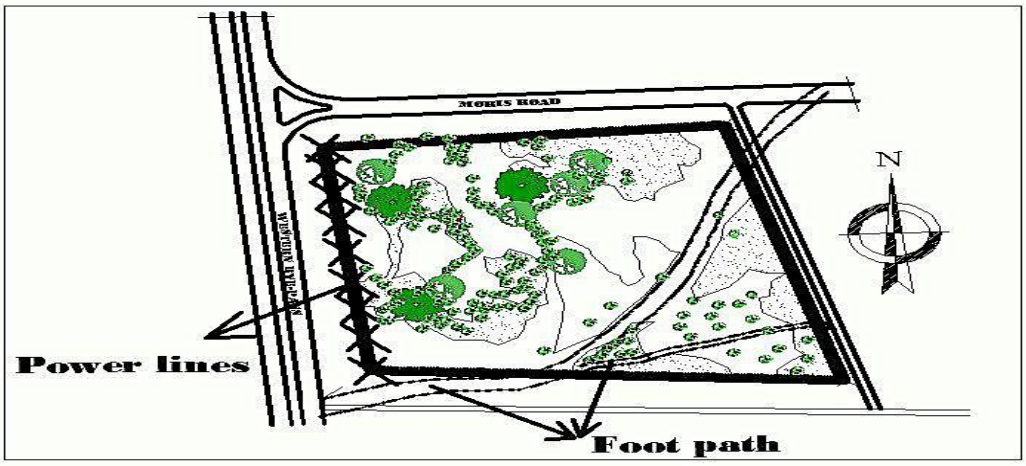


Figure 5.6 outline of the site layout

5.3.3.2 Vegetation and Topography

The site is characterized by sparsely distributed economic trees ranging from Mango trees, Neem trees and Gmalina trees. The trees are fully grown with an average canopy size of about six (6) meters with an average height of about twelve (12) meters. It also consist of patches of green grasses mainly of which grows up to 300mm to 600mm during the rainy season. The vegetation on the site helps to create cool and pleasant micro-climate by shading most parts of the site and absorbing most of the solar radiation incidence on the site.

The site topography is characterized by irregular terrain with a gentle slope of about three hundred (300) millimeters difference in every one (1) meter towards the eastern part This slope helps in draining run-off from the site during rainy season. Figure 5.7shows the site layout with sparsely distributed vegetation and contours showing the direction of slope on the site.

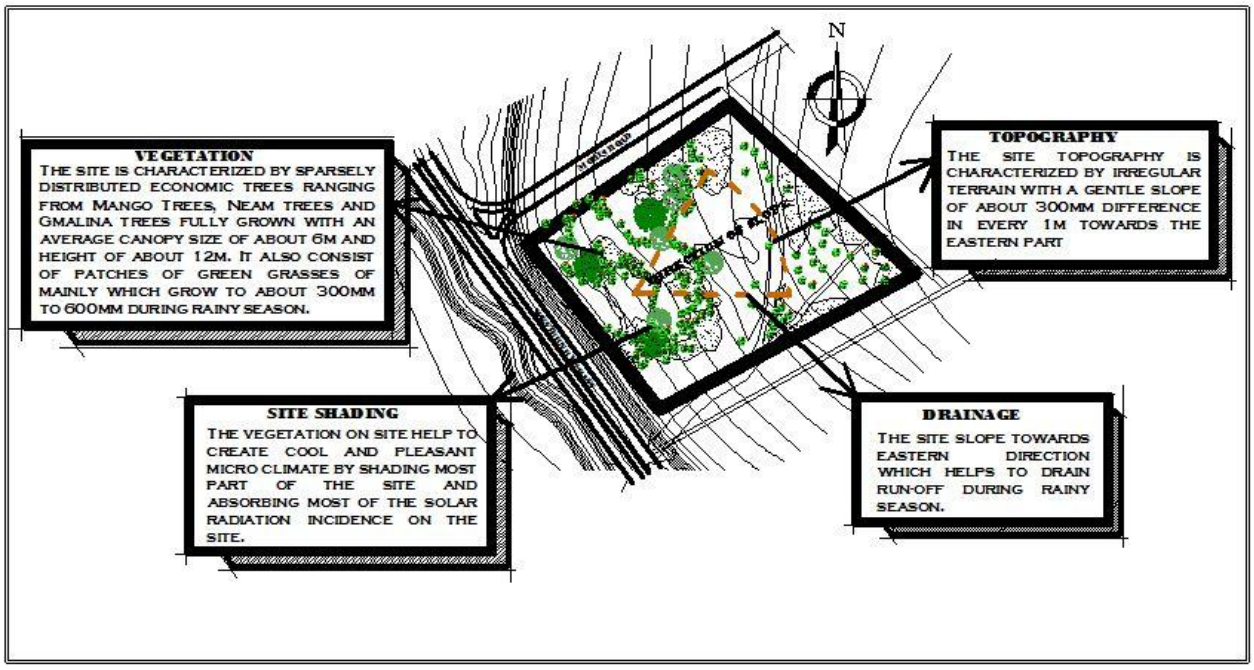


Figure 5.7 site layout with sparsely distributed vegetation

5.3.3.3 Site Orientation

The site has its longer sides facing North-South direction while its shorter sides face East-West direction. This gives an advantage of orienting the buildings to follow the orientation of the site so as to minimize solar radiation penetration in to the buildings while at the same time taking advantage of the prevailing winds to aid ventilation. This makes the site a favourable for energy conservation. Figure 5.8 shows the orientation of the site with respect to the primary axis.

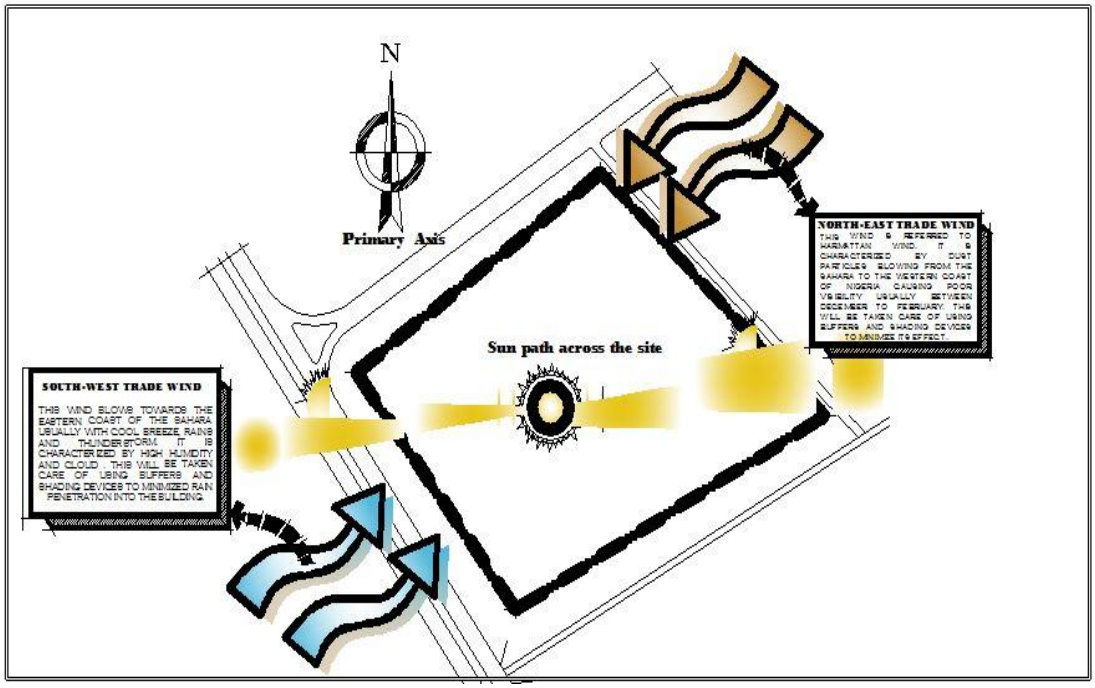


Figure 5.8 Illustration of the movement of the prevailing winds across the site.

5.3.3.4 Wind Flow Pattern

The prevailing winds blows across the site covering almost the entire area. Although the two winds blows with moisture and dust, the trees on the site helps in breaking their intensity and filter the effect of the dust allowing greater part of only bearable portion reaching the surfaces of the site. Figure 5.8 illustrate the movement of the prevailing winds across the site.

5.3.3.5 Soil

The type of soil underlying the site is no different from the soil type of Niger state, which is a light brown and reddish soil. Their suitability for construction purposes varies with depth, texture, run-off potential and drainage. The soil on the site is usually firm.

5.4 Conclusion

This chapter discusses the site features that guide the design of the proposed hotel. It covers the site selection criteria and how the favored site emerged out of the two potential sites. Weather and climatic characteristics of the site with respect the Minna town that influence the decisions made about the building's design and constructionwere also covered.

6 DESIGN REPORT

6.1 Preamble

This chapter covers the architectural design procedure adopted to arrive at the design of the proposed Minna city garden hotel with adequate consideration to principles of passive cooling. The chapter further discuses design brief, bulk schedule of accommodation,concept development and passive cooling consideration.

6.2 Design Brief

Niger State Government have proposed to build three star Minna city garden hotel that will accommodate 200 guest in its effort to minimise environmental pollution caused by backup generators used in hotel operations.

The hotel is aimed at attracting both local and international visitors through its scenic environment, elegant architecture and comfort. The hotel, apart from providing comfortable accommodation, concierge services, catering and recreational services with high level of hospitality, it should also be energy conscious through passive cooling techniques to minimise electricity consumption in its operation. It should also serve as a pioneer in re-orienting hotel designers in the composite of hot-humid/hot-dry climate of Nigeria from the usual mechanically approach to a more energy conscious style.

6.3 Bulk Schedule of Accommodation

To enhance the accessibility to basic amenities, circulation, services, functional relationships and expected interaction among the users of the facilities, the building is planned in such a way that it follows 3 basic groups in the theory of hotel planning. These groups are:

i. Front of the house

ii. Back of the house

iii. Auxiliary services

The breakdown of the spaces in the three categories based on the theory of hotel planning is shown in table 6.1.

6.3.1 Front of the House

The front of the house is the greeting areas. It is usually the places the guest gets in contact with. Table 6.1 and Table 6.2 shows the sections within the front of the house.

Table 6.1 The Sections within the Front of the house

UNIT/SECTION	SPACE	NO	AREA
Greeting area	Entrance hall	1	22
	Front desk	1	28
	Waiting lounge	1	60
	Porters room	1	24
	Lifts	4	32
	Stair cases	5	60
Business unit	Shops	3	24
	Travel agency	1	24
	Restaurant	1	270
	ICT Zone	1	122
	Multipurpose hall	1	270
Accommodation unit	Single rooms	66	2112
	Double rooms	94	4320
	Suites	28	1456
	Wi-Fi Zone/lounge	6	360
Recreational unit	Fitness hall	1	142
	Swimming pool	2	230
	Lawn tennis court	1	260

Table 6.2 Administrative section of the front of the house

UNIT/SECTION	SPACE	NO	AREA
	Badminton court	1	128
	Massage	2	68
	Changing rooms	2	248
Administrative unit	Gen. manager	1	56
	Domestic manager	1	42
	Business manager	1	42
	Secretary	1	42
	Board room	1	118
	Gen. office	1	84

6.3.2 Back of the House

The back of the house is the service areas which help in the effective functioning of the hotel. These spaces are restricted areas for the guest and usually out of the guest vision. Table 6.3 and Table 6.4 shows the units within the Back of the house.

Table 6.3 The Units within the Back of the house

UNIT/SECTION	SPACE	NO	AREA
Catering services unit	Main Kitchen	1	84
	Preparation	1	42
	Pantry	1	32
	Head chef	1	36
	Clock room	1	24
	Staff changing	2	44
Housekeeping/	Laundry	1	42
Laundry unit	Linen store	1	22
	Housekeepers rooms	6	36
	Detergent store	1	18
	Laundry	1	42

Table 6.4 The supply/disposals and the Maintenance units of the back of the house

UNIT/SECTION	SPACE	NO	AREA
Supplies/disposals	Control office		
	Loading/offloading bay	1	40
	Bulk dry store	1	32
	Groceries store	1	32
	Cold room	1	22
	Freezer	1	22
	Refuse room	1	42
Maintenance unit	Elect/Mech.	1	66
	First Aid	1	22
	Tailoring/Furniture	1	42

6.3.3 Auxiliary Services

The auxiliary services are the supporting facilities for the comfort of the guest. Table 6.5 shows the supportingfacilitiesof the Auxiliary services.

Table 6.5 The Supporting Facilities in Auxiliary Services unit

UNIT/SECTION	SPACE	NO	AREA
Supporting facilities	Garden	1	2486
	Parking area	1	2264
	Boiler room	2	64
	Gate house	1	22

6.4 Concept Development

The general hotel design concept is purely functional and it is mainly the integration of the principles of passive cooling with the aim of minimizing energy consumption and form selection with respect to air movement with the appropriate footprint suitable for passive cooling in a composite of hot-humid/hot-dry climate of Nigeria. Figure 6.1 illustrate the concept development by integrating principles of passive cooling.

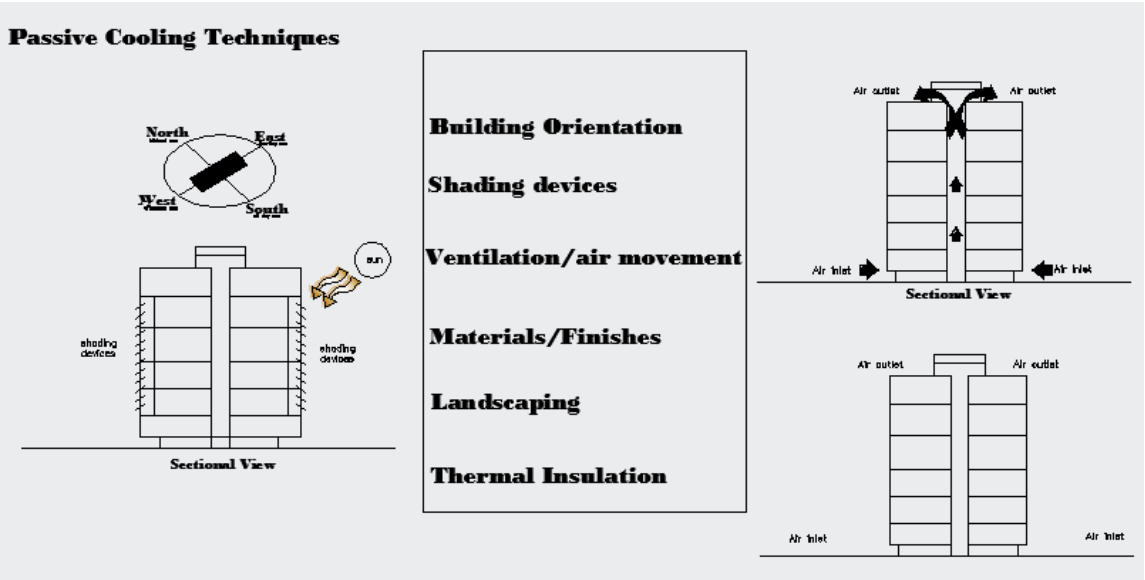


Figure 6.1 Concept Development from passive cooling principles

6.4.1 Site Concept Development

The whole building is designed to rotate around a central core. This makes accessibility easy and quick. There is no longer stretch of the arrangement of the building. The parking lots are arranged on two wings as you approach the building. This arrangement curbs excessive traffic around the buildings. An evenly distributed garden emphasizes the integration of ‘leisure’’ and ’recreation’ in the design.

The proposed Minna city garden hotel is a single block construction with six floors comprising of two hundred and two (202) rooms in the category of executive, deluxe, business and suites. It also consists of a multipurpose hall of sitting capacity of 1200 people. Other facilities include well secured car parks, restaurant and outdoor recreational facilities. All the facilities in the hotel are distributed following the theory of hotel planning. Plate shows the distribution of the various facilities in proposed Minna city garden hotel.

6.4.1.1 Access, Circulation and Parking

Functions have been grouped into noisy, semi-noisy and quiet zones. There is a central pedestrian walkway beside the main entrance access from outside the site leading to the main drop off of the main building and the parking spaces spread out on the larger curve radiating along the axis in a textual progression heading towards west and the east sides of the structure.A service entrance is located along the eastern perimeter of the site leading to the staff parking and service loading and offloading bay. Figure 6.2 show the site access, circulation and parking along with other facilities as sited on the site.

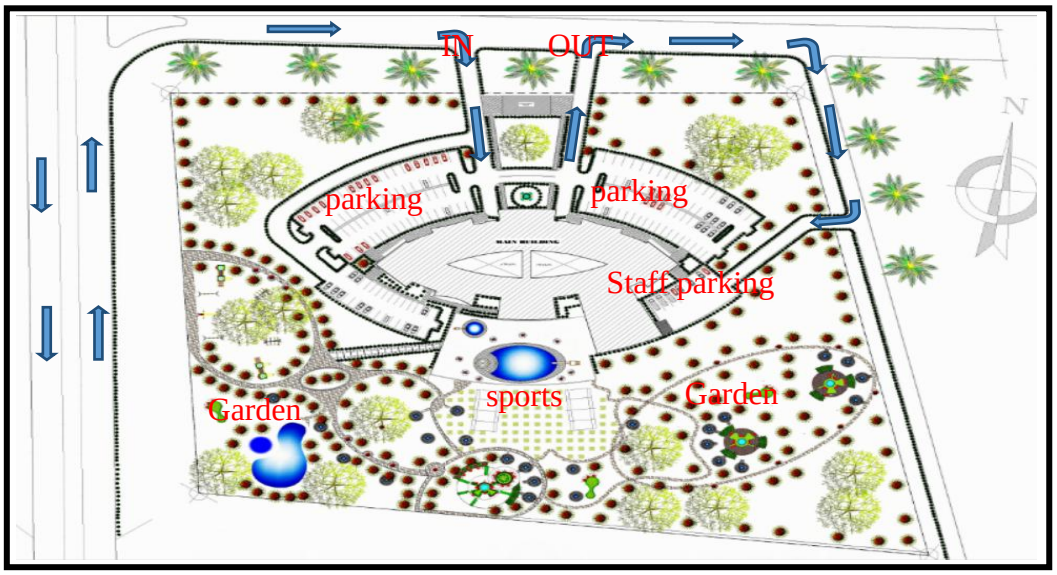


Figure 6.2 Site access, circulation and parking

6.4.2 Form Concept

The building design concept for the proposed Minna city garden hotel has its roots in the tenets stipulated by the principles of passive cooling which includes; Orientation for solar heat gains, Ventilation and air movement, Solar shading, materials and finishes, landscaping and thermal insulation for composite of hot-humid/hot-dry climate.

The form chosen in for the plan in this regard is an elliptical shape because it enhances the following passive cooling features:

i. **Solar Heat gain:**When the shorter sides of a building face the sun path, minimal amount of solar radiation will have access into the building. Hence, the elliptical form has its shorter sides oriented along the sun path and as such less surface area of the building is been exposed to solar radiation. Figure 6.3 shows the solar analysis of various forms of equal volume with elliptical form having advantage over many forms.

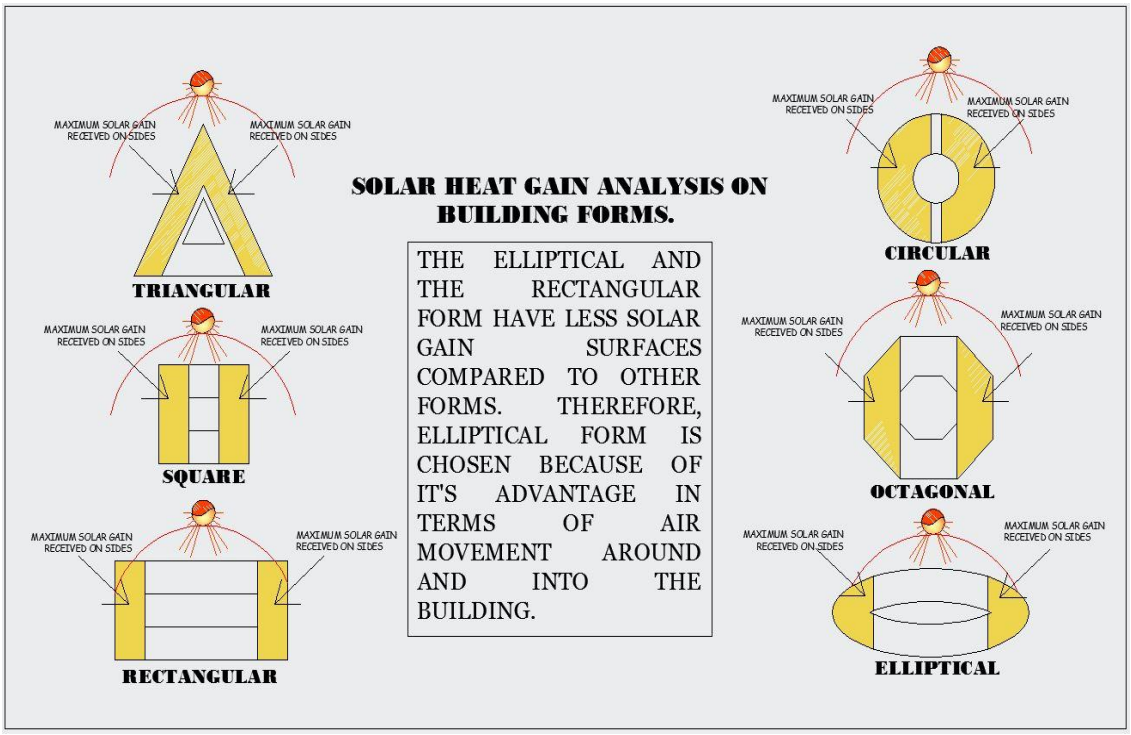


Figure 6.3 solar analysis of various forms of equal volume

ii. **Air Movement**: Elliptical and circular forms are much more compacted than linear forms of equal volume, making them allow more air movement in and around the building. It is also absorbs less heat by reflecting most of the incident radiation incident on its surface during the day and release less heat at night.Figure 6.6 shows the air flow pattern in the proposed hotel design.

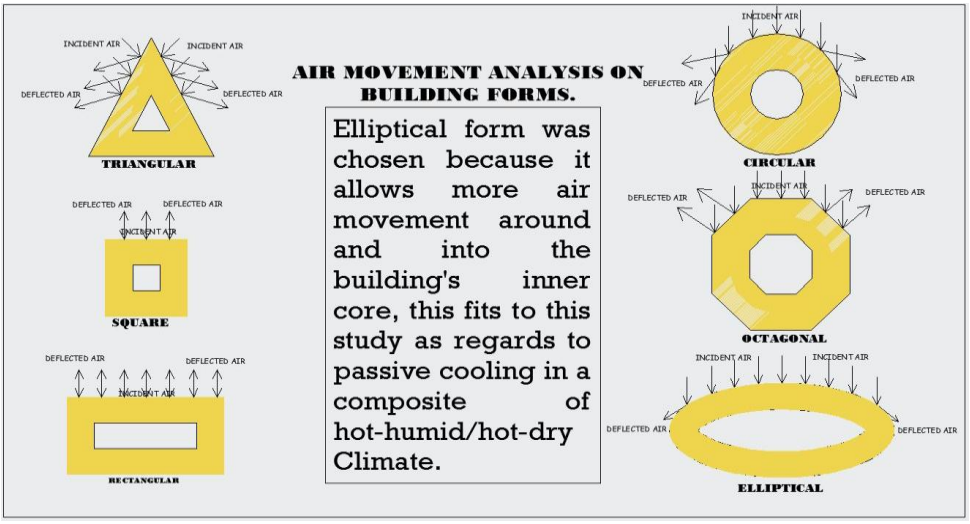


Figure 6.4Air movement analysis of different forms.

iii. **Natural Ventilation:** it is aerodynamic form that enhances natural ventilation. This is because air, being a fluid, is not rigid in nature and would readily assume the shape of the form of the building when it blows around it, thereby easily making its way into the building through the openings to remove internal heat.

6.5 Passive Cooling Consideration

The passive cooling consideration is the principles of passive cooling chosen that are suitable in the composite of hot-humid/hot-dry climate. In each case, the strategies that are employed to achieve passive cooling with the aim of minimising energy consumption are either mean to prevent or minimise heat penetration into the building or to dissipate the heat that finds its

ways into the building. The principles of passive cooling peculiar to composite of hot-humid/hot-dry climate considered in the design are as follows.

i. Building Orientation
ii. Natural ventilation/Air movement
iii. Overhangs/Shading devices
iv. Materials and Construction

6.5.1 Building Orientation/Massing

The building form adopted for the building is elliptical form. Thus, proper orientation has been achieved to a greater extent by placing the longer side on the east-west axis. This is not only to avoid the western sun but also to enable the prevailing wind hit the building at an angle. Figure 6.5shows an optimized orientation on the site with respect to sun path.



Figure 6.5 Building Orientation with respect to Sun Path

6.5.2 Natural Ventilation/Air Movement

The design takes into consideration the peculiar nature of the relatively hot and humid nature of Minna climate in making decisions as it relates to ventilating the spaces.As a result of privacy requirement in hotel design, one side ventilation is adopted with windows placed at the external walls at lower level as inlets of fresh air from outside and smaller windows at higher level to serve as outlets of exhausted air. Following the Principles of stack effect, the indoor air which is warm and dry is lighter in weight is known as vitiated air while the outdoor air is heavier in weight due to moisture content, as a result of an exchange of air from the air intake areas, certainly the outdoor air from the air intake areas will displace indoor air which is vitiated as shown in figure 6.6 in order to maintain human comfort, health and create air movement (feeling of freshness/relief).

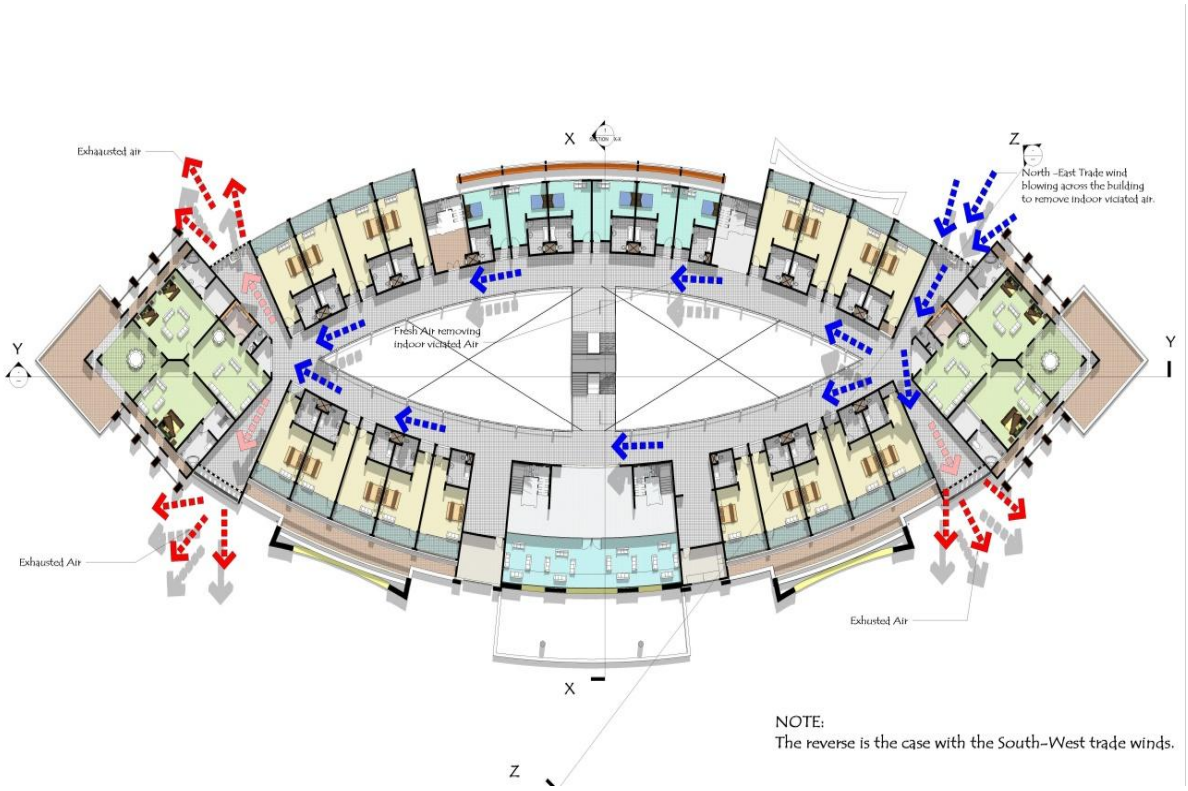


Figure 6.6Natural Ventilation and Air Flow pattern in the proposed hotel

The glazing panels opted for are reflective glass on the exterior façade of the building which have fixed and operable panels. This allow for considerable reduction in heat gain into the building.

A buffer zone of passage ways also contributes to heat reduction. The use of envelope walls around the major wall and the inclusion of Atrium with opening at the roof as shown in Figure 6.7,allow for air flow through the building effectively through stack effect.

The design also allows wind tunnel through the building located along north-east and south-west to take advantage of the prevailing trade winds in flushing out vitiated air.

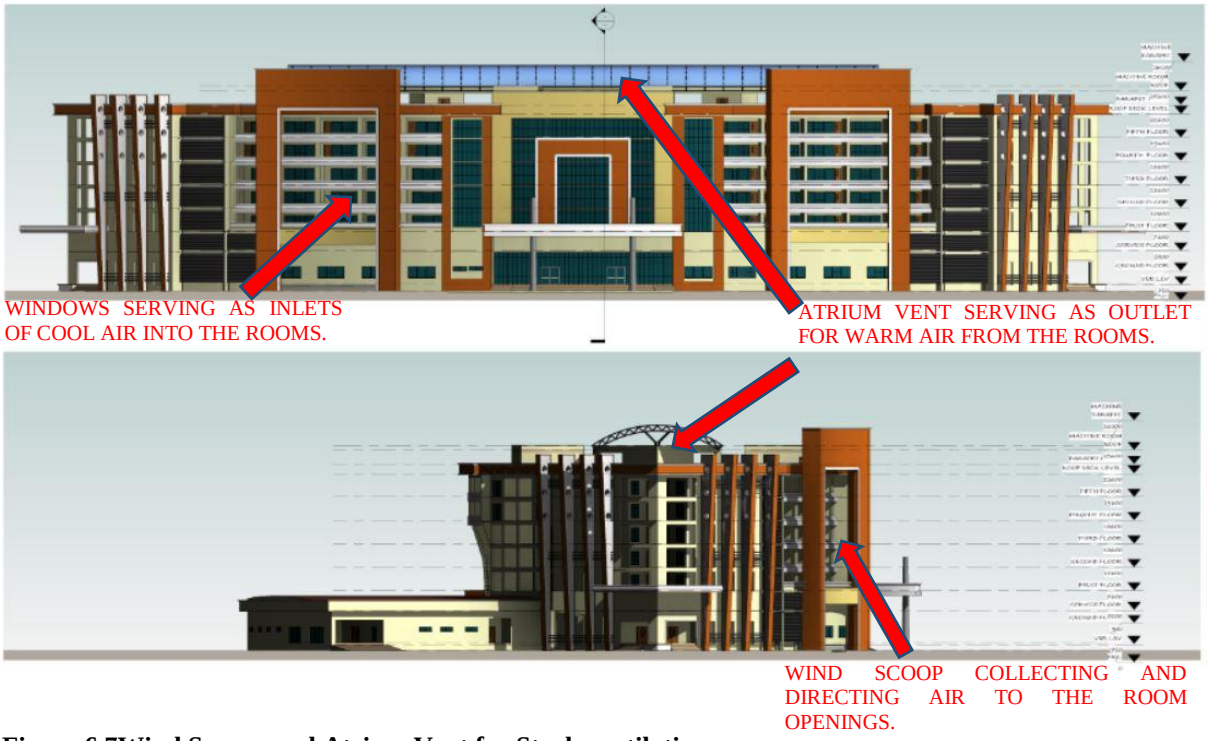


Figure 6.7Wind Scoops and Atrium Vent for Stack ventilation

6.5.3 Overhangs/Shading devices

Both vertical and horizontal shading devices have been employed along the eastern and the western sides of the building to minimise the effects of solar radiation as those sides are the sun path. Similarly, deciduous trees have been planted on the site to serve as shading to

minimise the effect solar radiation and to serve as buffer to filter the effects of dust during the hammattan season.

6.5.4 Material and Construction

The materials used are suitable to the surrounding and climate of the region with the finishes used in relation to the end-users, tackling energy problems.Materials for the floor, wall, ceiling and roof were carefully selected to meet the aim of the design of energy conservation.Sandcrete block was also used in interior walls and partitioning of some interior spaces, meanwhile for interiors where visual access is important such as administrative section glass curtain wall partition was used.

The construction technique to be adopted is frame construction as it has the ease and flexibility of the construction method used suitable for the climate and environment.The construction technique employed is also high thermal construction. As explained in the literature, high thermal construction is most appropriate in areas that experience high diurnal ranges, such as the composite of hot-humid/hot-dry climate of Nigeria. The logic of using them is that during the day, when the external air temperature is above the interior temperature, heat tends to flow into the building, because heat flows from hotter region to cooler region. But the high thermal mass will insulate the building by storing the heat and preventing it from getting into the building. At night, when the sun is not shining, the external air temperature drops lower than the interior temperature. At this time, heat flows from the building interior or from the thermal mass depending on the time-lag of the thermal mass to the exterior space.

Since heat can only penetrate a building through the building envelope, then it follows that the best way to stop this heat is by using high thermal construction for the entire building envelope--including the roof, external walls, glass and floor.

6.5.4.1 Walls

The materials used for the external walls is InnoVida Fiber-Composite panels made of a polyurethane insulation foam core that is sandwiched between two composite structural skins bonded together with InnoVida Resin of high thermal mass, having high time-lag capable of storing heat for a long time.

The superior insulation significantly of the Inno Vida fiber-Composite panels reduces the amount of energy needed to heat and/or cool the structure and provides excellent noise reduction through their high structural and insulationperformance.

The InnoVida as building blocks for the new generation possess the following advantages such as durable, affordable, energy efficient, and sustainable. The panels have an R-value of 5.88 per inch, with a total tested wall R-value of 14.6 for a 2.5-inch panel, or 23.7 for a 4-inch panel. “R-24 gives it an insulating factor greater than a refrigerator, whereas a regular wall has an R-value of 6 to 9.” (Greeanbuildingtalk, 2010). Figure 6.8 is a typical example of InnoVida building block.

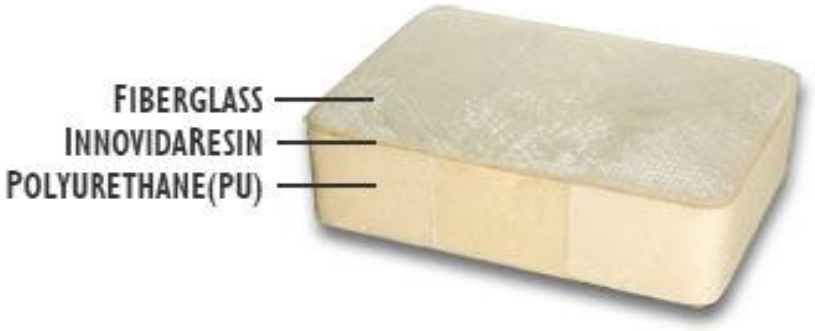


Figure 6.8 Typical InnoVida Building block
Source: Green building talk, 2010

6.5.4.2 Roof

The roof is considered to be the main absorber of heat, due to unobstructed exposure to the sun. For this reason, green roof system (roof garden) is used in this design to counteract the effect of solar radiation. The Green roof system consists of a concrete slab as the outer and inner roof respectively.

The green roof is also used primarily to repel the effect of the intense solar radiation. This is because plants will humidify the air in contact with the roof, thereby keeping the interior space cool. Other benefits offered by the green roof are: increasing the life span of the concrete slab below, improving the microclimate and filtering dust from the north-east trade wind. Figure 6.9 is a typical detail of an Extensive green roof used at the roof deck.

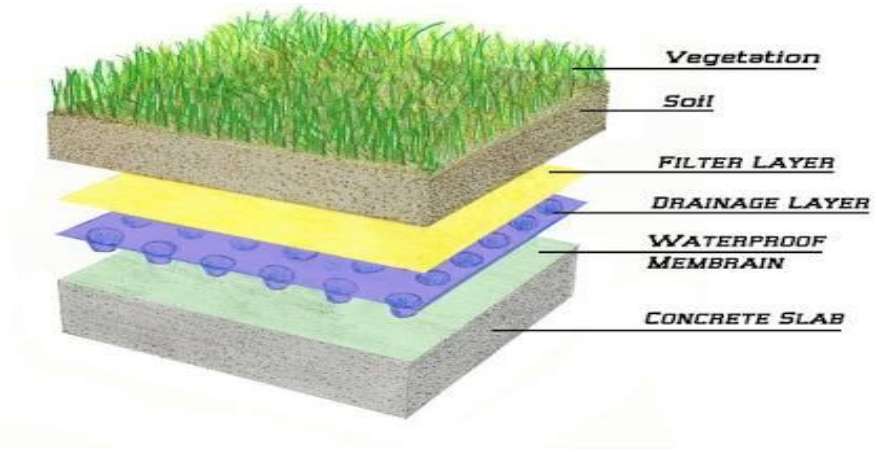


Figure 6.9 Extensive green roof at the roof deck
Source: Greenbuildingdesigntoolkit, (2008)

6.5.5 Landscaping

The form of landscaping used in this design is mainly formal landscaping which is integrated to the site's natural landscape. Soft landscape elements in form of flower beds, hedges and trees were used around the building. The soft elements are particularly used at wind direction

to filter dust from the air and also help blow cool air into the building. The soft landscape elements are also meant to absorb excessive solar radiation incident onto the building envelope. Furthermore, plants are known to absorb water vapour to dehumidify the air, are planted around the building environment. Hard landscape elements were also used for walkways and parking spaces.

6.6 Fire Safety and Exits

Safety measures such as exit points and routes have been provided in the design with fire and smoke detectors placed at strategic points in ceilings while fire extinguishers and buckets of sand and horse reels were provided on verandahs and corridors to help prevent fire outbreak. Provision was also made for access to fire service vehicles into the site in case of emergencies with fire hydrants placed along drainage channels along the service road within the site.

6.7 Site drainage

The drainage channels were designed to follow pedestrian routes and drained through existing drainage channels at the northern and eastern sides of the site.

6.8 Conclusion

This chapter is the design report. It covers the architectural design procedure adopted to arrive at the design of the proposed Minna city garden hotel.The chapter also discusses the design brief, bulk schedule of accommodation, concept development and passive cooling consideration. It further gives the principles of passive cooling consideration that are adopted in the design to help minimises energy consumption.

7 SUMMARY, CONCLUSION AND RECOMMENDATION

7.1 Summary

The aim of this research, as explicitly stated in chapter one of this write-up, is to evaluate the principle passive cooling that are most suitable in reducing energy consumption in hotel buildings in a composite of hot-humid/hot-dry climate of Nigeria; the objectives to this aim were also stated. The incessant exploitation of non-renewable energy, and its negative impact on sustainable development, led to the development of the problem statement, which prompted the author to embark on this research. Other features of chapter one include the research questions, background, justification and scope, which are all meant to give the reader an insight of what the research is all about.

Chapter two contains the review of relevant literature on the research area and the design. To this effect, various principles of passive cooling were studied. In a bid to suit the needs of the climatic region, these principles were then condensed to only five and these include, Orientation, Materials and Finishes, Sun Shading devices, Natural Ventilation/Air movement Techniques and Landscaping. The other aspect of the literature review is information on the Hotel Standard requirement, and was sourced from the World Tourism Organization.

The research methodology involves case studies on purposely selected buildings, which were assessed on the field using energy audit and the aforementioned passive cooling principles/elements as variables. The advantage of the case study is that it enables the use of multiple data collection techniques such as observation, visual survey and checklist. Thus, the qualitative data collected from the case study were in form of field notes, images and sketches. The quantitative data collected is the Energy Audit and computer simulation as a quasi-experiment.

Chapter four is on data presentation, analysis and discussion. The case studies were selected based on buildings that are located within the composite climate of hot-humid/hot-dry climate.The selected hotels in the composite of hot-humid/hot-dry climate were analyzed using the research variables. The findings were discussed by comparison with the secondary data, and then conclusions were made, in order to form a conceptual framework for designing a three star hotel which is simulated using Autodesk Ecotect software to validate the Computational Fluid Dynamics (CFD) software's (Ecotect) and its user's ability to simulate passive cooling as means of Energy Conservation in hotel buildings.

Chapter five elucidated on the site characteristics. The site was selected based on site selection criteria and its topography and climate were discussed and analysed so as to take advantage of the favourable features while avoiding the unfavourable conditions.

Chapter six is the design report of the proposed Minna city garden hotel. The design concept was developed in consideration of the passive cooling elements, as well as the design requirements of a three star hotel. The next part of this chapter listed all the research variables and then explained where and why they were applied on the hotel design.

The final chapter is a summary of the research pointing out the findings and recommendations. It further highlighted on contribution to knowledge and areas of further studies that needs to be researched on.

7.2 Conclusion

The study is able to conclude that the principles of passive cooling, when applied on a building, will greatly enhance its thermal efficiency by reducing energy consumption; that climatic condition of a region determines the choice of passive cooling strategies for

buildings in that region; that the five principles identified can be applied on any hotel design, so long as they are to be sited within the composite of hot-humid/ hot-dry climatic region.

7.3 Recommendation

The outcome of this study could have several applications. To this end, the following recommendations are made for further studies.

1. The design developed from the study can be used to guide future hotel design, and so could serve as a framework to help inform design decisions for passive cooling in garden hotels in a composite of hot-humid/hot-dry climate during the design process with the aim of minimising energy consumption.
2. The use of principles of passive cooling to determine the outcome of this research goes a long way to reveal that;
    i. Conceptual design for buildings should go beyond abstracting artifact or artworks and natural forms to applying the principles of passive cooling.
    ii. The Nigerian tourism cooperation should encourage designers to accommodate principles of passive cooling in hotel design. It is only then we can conveniently say that a design is truly passive when it appropriately meets the social needs of the guest with minimal energy consumption.
    iii. Schools of architecture should encourage more research into principles of passive design, and related areas to adequately explore the potential therein.

7.4 Contribution to knowledge

- This research has disaggregated energy demand in hotels into cooling, lighting and other appliances with cooling accounting for the highest demand of an average of 57% then followed by appliances with an average of 30% and Lighting with an average of 13% of the total electricity demand.

- The research also establishes that targeting the cooling end-use in hotel design will provide a potential energy savings in energy consumption of up to 45%.
- The research has also establishedthat energy consumption per m2 in hotel buildings in a composite of hot-humid/hot-dry climate of Nigeria is 157kWh/m².

7.5 Areas of further studies

This research work, recommends the need for further similar studies be conducted in hotels all around Nigeria to help benchmark the average energy consumption in hotel buildings in tandem with international best practice. Further research should also be conducted expanding to other passive cooling strategies in other climates.

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8 APPENDICES

Appendix I: Joint Paper on Energy Consumption

Proceedings of the Architects Colloquium 2015Architect and the National Development Agenda VIII: Sustainable Architectural Education and Practice in the 21st century.

AN ASSESSMENT OF ENERGY CONSUMPTION IN HOTEL BUILDINGS IN NORTHERN NIGERIA.

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ABSTRACT

This paper present findings of energy use in hotel buildings in Northern Nigeria. The study is conducted in six hotel buildings to examine the demand and supply of electricity consumption in the six selected hotels.

An energy audit is employed to collect data on electricity consumption which is broken down into; electricity demand, electricity supply and the disaggregation into end-use.

Result of the findings show the average electricity consumed per meter square (m^2) is approximately 303KWh within the range of 172kWh to 360kWh. Cooling, lighting and appliances loads account for approximately 51%, 13% and 36% respectively. In addition, the cooling load is substantially greater than the lighting and appliances load. Consequently,

targeting this end use provides a significant scope for considerable energy savings in hotel buildings.

Similarly, the total estimated annual energy supply and the normalized values indicates that Building 1 has the highest annual normalized supply of 378kWh/m2 followed by Building 6 with 312kWh/m2, closely followed by Building 5 with an average annual supply of 299kWh/m2. Building 3 has annual average of 251kWh/m2, Building 2 has an average of 172kWh/m2 while Building 4 is the lowest with annual average of 164kWh/m2 this gives a range of 164kWh/m2 to 378kWh/m2.

Therefore, the difference in the efficiency between the minimums and the maximums is an indication of a potential of energy conservation.

Appendix II:ATBU, Bauchi Journal Paper on the effect of Ventilated Cavity Wall

AN ASSESSMENT OF THE EFFECT OF VENTILATED CAVITY WALL FOR PASSIVE COOLING IN HOT DRY CLIMATE, A CASE STUDY OF BIRNIN KEBBI CITY, NORTHERN NIGERIA

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ABSTRACT

In Nigeria 51% of energy consumed in hotel buildings is used in cooling due to high temperature. The problem of overheating and high solar gain in hot dry climate of Nigeria is increasing due to climate change.

Since building envelope function as an environmental filter which control the impact of outdoor on indoor temperature, new design strategy and techniques for hotel building envelope in hot dry climate is adopted.

The study analyzed the thermal performance of ventilated cavity wall and compared with dominant building material – Hollow Sandcrete block, using Ecotect analysis software.

The design strategy is a ventilated cavity wall, and adopts the guidelines of BS ISO 6946 for ventilated air layers.

The results shows that there is considerable difference when a ventilated cavity wall is used with up to 53% savings compared with single leaf Sandcrete walls in either of the two common block sizes.

On the other hand thermal comfort can be increased and reducing the energy consumption for cooling is of great importance towards adopting building to severe weather condition caused by climate change.

Appendix III: Energy Audit Questionnaire

1. GENERAL INFORMATION.

1.1 Hotel

Name			
Address			
Web Site			
Contact Person		E-Mail	

1.2 Location(Please Tick the Appropriate Option)

City centre { } Suburb { }

Close to the shore { } others { }

1.3 Class of Hotel(Please Tick the Appropriate Option)

5*	4*	3*	2*	1*	No Star

1.4 Building Materials/Construction

i.	Exterior Wall:	Blocks	Bricks	Concrete	Glass	Timber	others
ii.	Interior Wall:	Blocks	Bricks	Concrete	Glass	Timber	others
iii.	Roof Material	Concrete	Aluminium	Zinc	Slate Tiles	Asbestos	others
iv.	Ceiling Material	Concrete	POP	PVC	Asbestos	Celotex	others

v.	Window Types	Casement	Sliding	Louvers	Projected	Folded	others
vi.	Doors Types	Panel Doors	Sliding Doors	Projected Doors	Roller Shutter	Folded Doors	others
vii.	Floor Finish	Floor Tiles	Floor Screed	Terrazzo Finish	Timber finish	PVC Tiles	others
viii.	Wall Finish	Emulsion Paint	Text coat Paint	Oil Paint	Wall Paper	PVC finish	others

1.5 Building Characteristics

Year of construction	No of Floors	No of Rooms/Beds	Average Room Area (m2)	Average Window Area in Rooms (m2)	Total floor Area of the Building (m2)
Main Building					
Building 2					
Building 3					

TOTAL

1.5.1 What are the Classes of bedrooms available?

1	**2**	**3**	**4**	**5**	**6**

1.5.2 Energy Consuming Equipment/Facilities in the Bedroom

Equipment	Number Available (No.)	Capacity (kW)	Average time of usage/day (h)	Electricity Consumption (kW/h)

1.6 Auxiliary facilities

i. Number of Restaurants ☐

ii. Energy Consuming Equipment/facilities in the Restaurants

Equipment	Number Available (No.)	Capacity (kW)	Average time of usage/day (h)	Electricity Consumption (kW/h)

iii. Swimming Pool

Yes	No

Pool1	Closed	Open Air
Area (m2)/Volume (m3)		
Time of Use	From To	From To
Heated Water (Yes/No)		
Heater Capacity (kW)		

Pool2	Closed	Open Air
Area (m2)/Volume (m3)		
Time of Use	From To	From To
Heated Water (Yes/No)		
Heater Capacity (kW)		

iv. Sport Facilities

Sauna { } Fitness { } Others { }

v. Laundry

Installed power of Laundry machine (kW) [ ]

Average operation time (h/day) [ ]

vi. Elevators

Number of Elevators	
Weight Limit (Kg)	
Average occupancy (h/day)	

2.0 ENERGY CONSUMPTION

Months	1	2	3	4	5	6	7	8	9	10	11	12	Total
Electricity Consumption (kWh)													
Purchased Power (kW)													
Cost (VAT inclusive)													

2.1 Backup System of Electricity

Diesel generators { } Petrol generators { }

Solar inverters { } others { }

Months	1	2	3	4	5	6	7	8	9	10	11	12	Total
Petrol (m3)													
Diesel (litres)													
Solar(kW)													
Others (specify)													

3.0 COOLING SYSTEM

i. Is the building mechanically cooled? Yes { } No { }

ii. Energy used by the cooling system

Electricity { } Gasoline { } Solar { } others { }

iii. What mechanical ventilation system is available?

Fan { } HVAC { } Trickle vent { } Exhaust { } others { }

4.0 DATA ON LIGHTING POINTS IN THE BUILDING

S/N	SPACE	LIGHTING TYPE	RATING	QUANTITY

5.0 ELECTRICAL WORKSHEET

Metre description (Entire facility, Area, Equipment, etc.)…….……

Service – Phase(s) …….. Voltage …….

Utility Company Name ……..

Year …… Number of Months …… First Month ……..

(A - Adjusted, R - Reading, E – Estimated, V – Verified, M – Manual Estimate)

S/N	Month/Year (metre reading)	Rate /Unit	Electrical consumption (kWh)	Total cost (₦)	Reading type (A, R, E, V, M)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
Total					

6.0BULK FUEL WORKSHEET

Fuel company name …….

Fuel type ……. Fuel Delivery unit (litres, tones, others, etc.) ……

Fuel use (Entire facility, Area, Equipment, etc.) ……..

Year …… Number of Months …….. First Month ……...

S/N	Month/Year (Fuel delivered)	Monthly Fuel consumption (Litres, tones, etc.)	Total cost (₦)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
Total			

Appendix IV: World Tourism Organisation (WTO) Hotel Standards.

S/N	PHYSICAL REQUIREMENTS	1 STAR	2 STAR	3 STAR	4 STAR	5 STAR
1	Bedrooms	Minimum of 10 letting bedrooms				
Single Double Triple		8 10 12	8 10 12	10 12 14	12 14 16	13 16 19
2	Suites	Some Suites available independent or of connecting rooms of different types and to make temporary connecting rooms suites.				
3	Single bed size Double bed size	1900mmx800mm 1900mmx1900	Ditto 1 star Ditto 1 star	2000mmx800mm 2000mmx2000mm	Ditto 3 star Ditto 3 star	Ditto 3 star Ditto 3 star
4	Entrance	1 independent entrance	Ditto 1 star	1 independent entrance and a service entrance	Ditto 3 star	Ditto 3 star

				for kitchen		
5	Staircase	To comply with legal requirement	Ditto 1 star	Staircases should include separate service staircase	Ditto 3 star	Ditto 3 star
6	Furniture, Fittings and Equipment	Moderate cost, simple, durable and of standard design	Ditto 1 star	Medium cost construction and of custom made	High cost construction and of custom made	Top cost and of individualized décor
7	Emergency power supply	Emergency light source	Ditto 1 star	Stand by gen. to supply basic lighting and power up to 24 hrs	Stand by gen for lighting, lifts, cooking and refrigeration	Ditto 4 star

S/N	PHYSICAL REQUIREMENTS	1 STAR	2 STAR	3 STAR	4 STAR	5 STAR
8	Cooling and heating	Cooling or fan heating when necessary	Central cooling and comfort cooling seasonally available	Individual cooling control in bedrooms and temperature maintained between 18°C and 25°C	Individual air conditioning control in all rooms with high quality equipment of very low noise emission	Ditto 4 star
9	Lift(s) to match rooms capacity	Where more than 3 upper floors	When more than 2 upper floors	Ditto 2 star	When more than 1 upper floor	Ditto 4 star
	Service lifts	No service lift	Ditto 1 star	Ditto 1 star	Separate from main guest lifts	Ditto 4 star
10	In room	Call bell	Internal	Telephone connected	Direct dial telephone	Direct dial for

	communication		telephone only	through hotel switch board	to other rooms and for national calls	national and international calls in bedroom and toilets
11	Bathrooms	Adequate for free, comfortable and safe movement				
	Availability	Wash basin with mirror, light, shelf towels, soap and electric socket	At least 25% of rooms with private bathrooms	All rooms should have private bathrooms	Ditto 3 star	Spacious bathrooms and separate toilet
12	Public toilets	Separate for each sex with hot and cold water running and separate cubicle for disabled with appropriate fittings and suitably sited near public areas with interior screens from view.				
13	Corridors	Well lit 24 hours a day by natural and/or artificial light and adequately ventilated and at the same time free from obstacles or hazards, suitably signposted with emergency exits clearly indicated.				

S/N	PHYSICAL REQUIREMENTS	1 STAR	2 STAR	3 STAR	4 STAR	5 STAR
14	Lounge	Area with lounge seating, music and /or television service	Area with lounge seating, music and /or television service, newspapers and magazines	Lounge area seating at least one-third of hotel bed capacity in combination with reception area.	Choice of lounges as 3 star, plus service of drinks and refreshments	Choice of lounges as 3 star, plus 24 hrs lounge service of drinks and refreshments
15	Restaurant	nil	Restaurant or cafeteria for meals	Restaurant or coffee shop for meals with seating not less than half	Main restaurant or choice of restaurants serving variety of meals, private dining	Ditto 4 star

				of hotel bed capacity	or function rooms with total seating not less than hotel bed capacity	
16	Bar	nil	nil	Separate bar	Separate bar(s) and cocktail lounge, meeting and conference rooms with appropriate facilities	Ditto 4 star
17	Recreation	nil	nil	nil	Sauna or swimming pool or health club and indoor and outdoor games	Sauna, gymnasium, health club, swimming pool or jet pool and indoor and outdoor games

S/N	PHYSICAL REQUIREMENTS	1 STAR	2 STAR	3 STAR	4 STAR	5 STAR
18	Reception service	Reception desk manned throughout the day. Night bell, guest luggage handling on request	Ditto 1 star	Permanent reception service 24 hrs check-in with hall porters, luggage handling and doorman	Ditto 3 star	Ditto 3 star
19	Laundry service	Laundry only	Laundry and dry cleaning	Laundry and dry cleaning	Express laundry including washing, ironing and dry cleaning	Ditto 4 star
20	Internet service	nil	nil	A standard internet café	A standard internet	A standard internet

					café and wireless access (Wifi)	café and wireless access (Wifi) in every bedroom
21	Tourist and travel service	Taxi on call	Ditto 1 star	Ditto 1 star	Taxi service	Taxi service and rent-a-car service
22	Parking	Free access by car with some reserved parking spaces	Ditto 1 star	Parking space reserved for average number of car using guests	Exclusive parking to accommodate all hotel guest and casual visitors with 24 hrs security	Ditto 4 star
23	Green area				Some garden area or terrace with plants	Green area for guest use, terrace with plants, roof gardens

Appendix V: Proposed Minna City Garden Hotel Design.





3D VIEW 3



REAR 3D VIEW



PARKING AREA 3D VIEW



SWIMMING POOL AREA 3D VIEW

SCALE : NTS

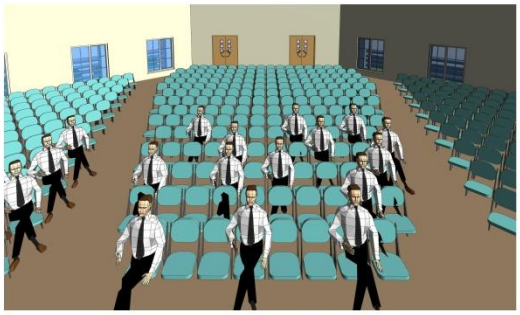
PROPOSED MINNA CITY GARDEN HOTEL
INTEGRATING PRINCIPLES OF PASSIVE COOLING IN THE DESIGN OF FIVE STAR HOTEL, MINNA.

MSC/ENV-DES/41168/2012-13
MOHAMMED ABDULLAHI LAWAL
DR. AMINA BATAGARAWA
ARC. M. H. MUKHTAR

INTERIOR PERSPECTIVE



RECEPTION HALL



MULTI-PURPOSE HALL

SCALE NTS

PROPOSED MINNA CITY GARDEN HOTEL
INTEGRATING PRINCIPLES OF PASSIVE COOLING IN THE DESIGN OF FIVE STAR HOTEL, MINNA.

MSC/ENV-DES/41168/2012-13
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DR. AMINA BATAGARAWA
ARC. M. H. MUKHTAR

SITE PLAN

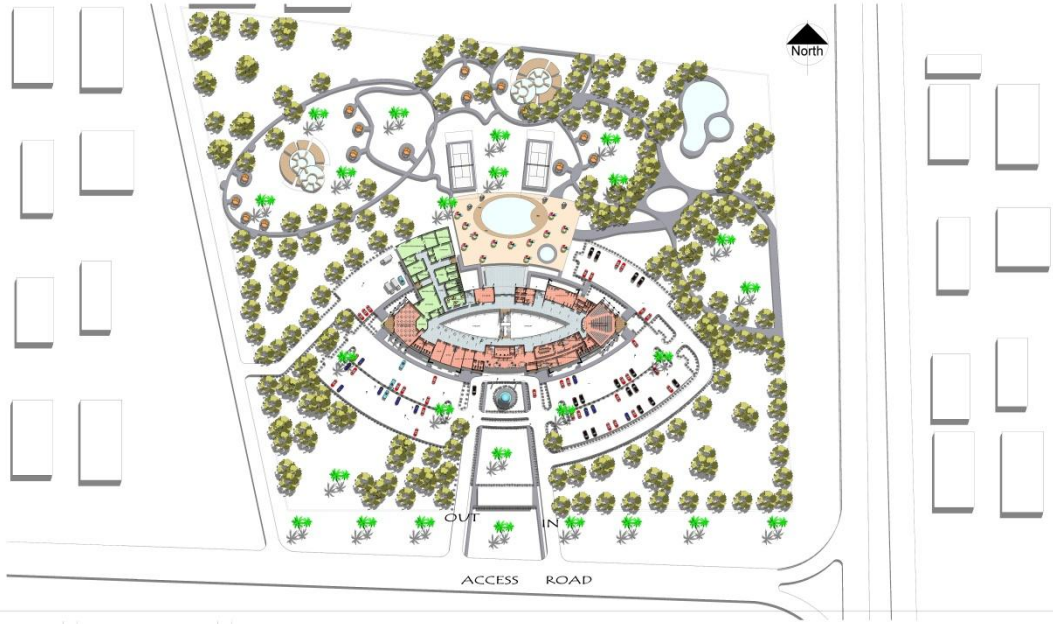


SCALE 1:750

PROPOSED MINNA CITY GARDEN HOTEL
INTEGRATING PRINCIPLES OF PASSIVE COOLING IN THE DESIGN OF FIVE STAR HOTEL, MINNA.

MSC/ENV-DES/41168/2012-13
MOHAMMED ABDULLAHI LAWAL
DR. AMINA BATAGARAWA
ARC. M. H. MUKHTAR
01

PLAN ON SITE

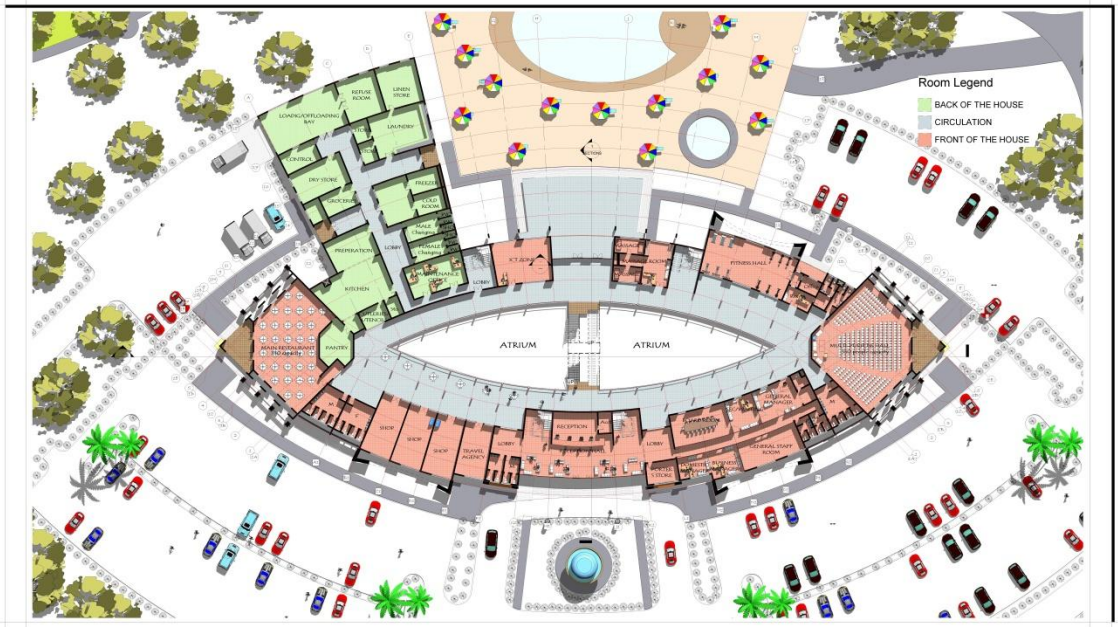


SCALE 1:750

PROPOSED MINNA CITY GARDEN HOTEL
INTEGRATING PRINCIPLES OF PASSIVE COOLING IN THE DESIGN OF FIVE STAR HOTEL, MINNA.

MSC/ENV-DES/41168/2012-13
MOHAMMED ABDULLAHI LAWAL
DR. AMINA BATAGARAWA
ARC. M. H. MUKHTAR
02

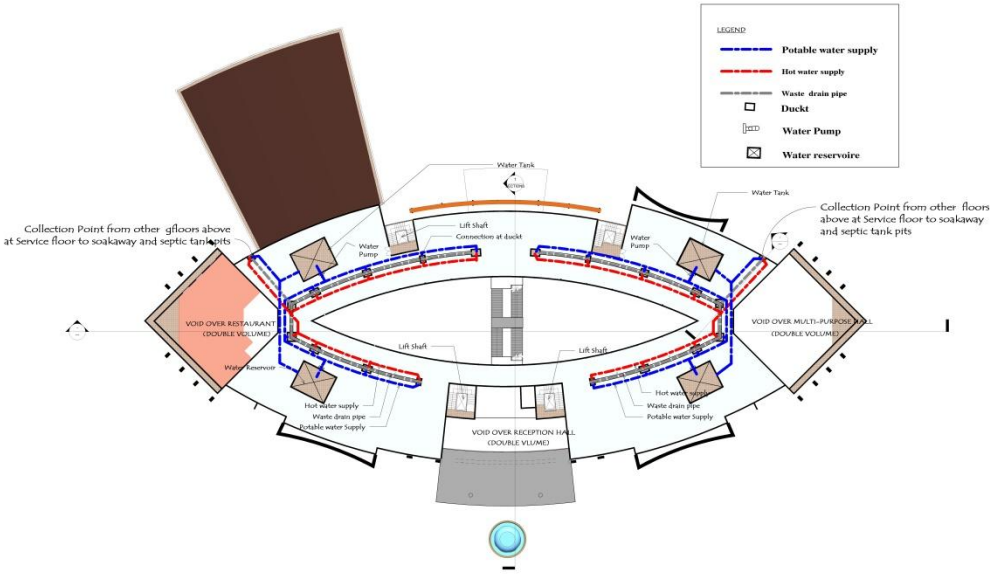
GROUND FLOOR PLAN



PROPOSED MINNA CITY GARDEN HOTEL
INTEGRATING PRINCIPLES OF PASSIVE COOLING IN THE DESIGN OF FIVE STAR HOTEL, MINNA.

MSC/ENV-DES/41168/2012-13
MOHAMMED ABDULLAHI LAWAL
DR. AMINA BATAGARAWA
ARC. M. H. MUKHTAR
03

SERVICE FLOOR PLAN

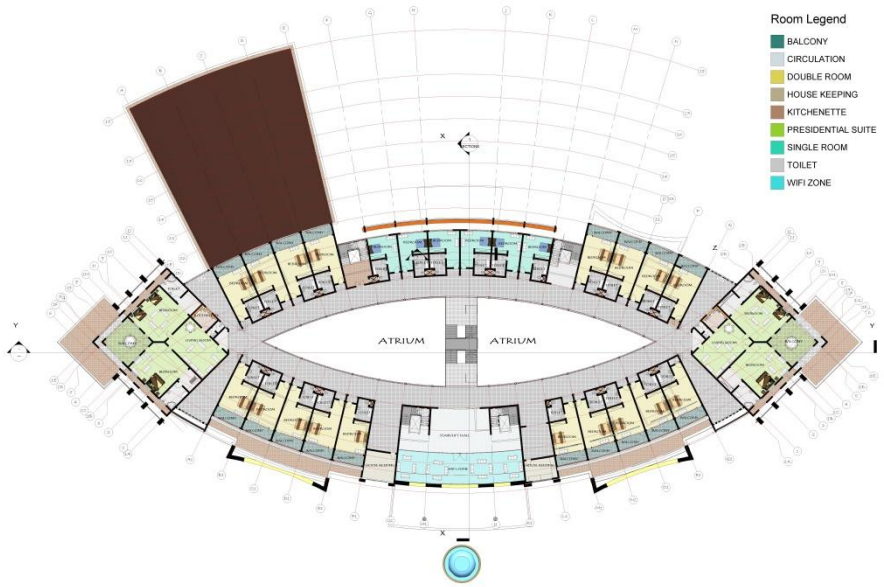


SCALE 1:200

PROPOSED MINNA CITY GARDEN HOTEL
INTEGRATING PRINCIPLES OF PASSIVE COOLING IN THE DESIGN OF FIVE STAR HOTEL, MINNA.

MSC/ENV-DES/41168/2012-13
MOHAMMED ABDULLAHI LAWAL
DR. AMINA BATAGARAWA
ARC. M. H. MUKHTAR
04

1ST, 2ND AND 3RD FLOOR PLAN



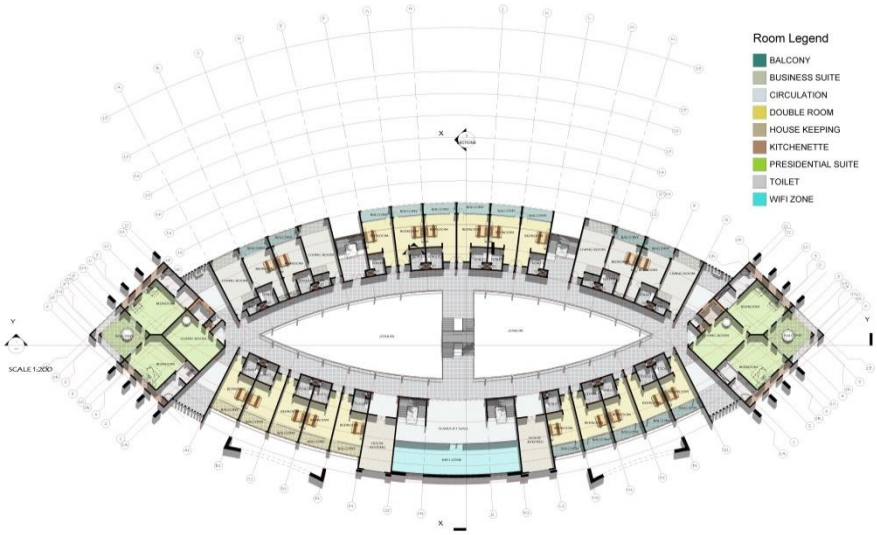
SCALE 1:200

PROPOSED MINNA CITY GARDEN HOTEL

INTEGRATING PRINCIPLES OF PASSIVE COOLING IN THE DESIGN OF FIVE STAR HOTEL, MINNA.

MSC/ENV-DES/41168/2012-13
MOHAMMED ABDULLAHI LAWAL
DR. AMINA BATAGARAWA
ARC. M. H. MUKHTAR

4TH AND 5TH FLOOR PLANS

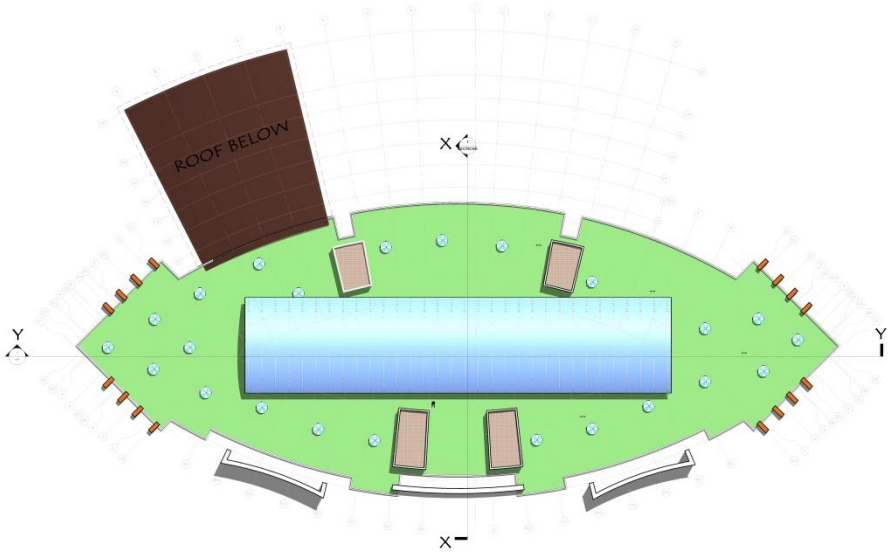


PROPOSED MINNA CITY GARDEN HOTEL

INTEGRATING PRINCIPLES OF PASSIVE COOLING IN THE DESIGN OF FIVE STAR HOTEL, MINNA.

MSC/ENV-DES/41168/2012-13
MOHAMMED ABDULLAHI LAWAL
DR. AMINA BATAGARAWA
ARC. M. H. MUKHTAR

ROOF PLAN

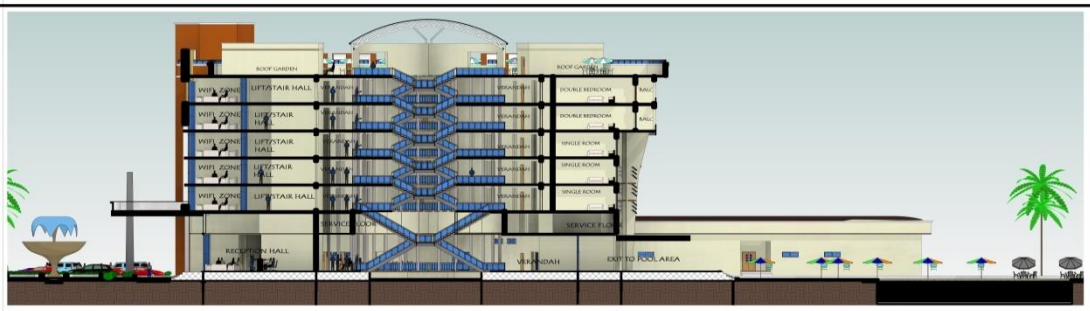


SCALE 1:200

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SECTIONS



SECTION X–X



SECTION Y–Y

SCALE 1:200

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ELEVATIONS



SOUTH ELEVATION



WEST ELEVATION

SCALE 1:200

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ELEVATIONS.



NORTH ELEVATION



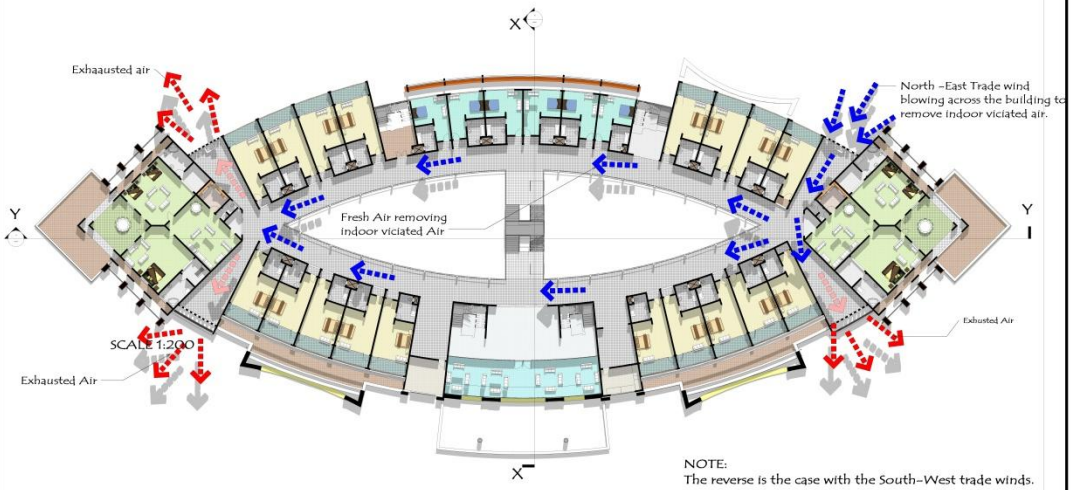
EAST ELEVATION

SCALE 1:200

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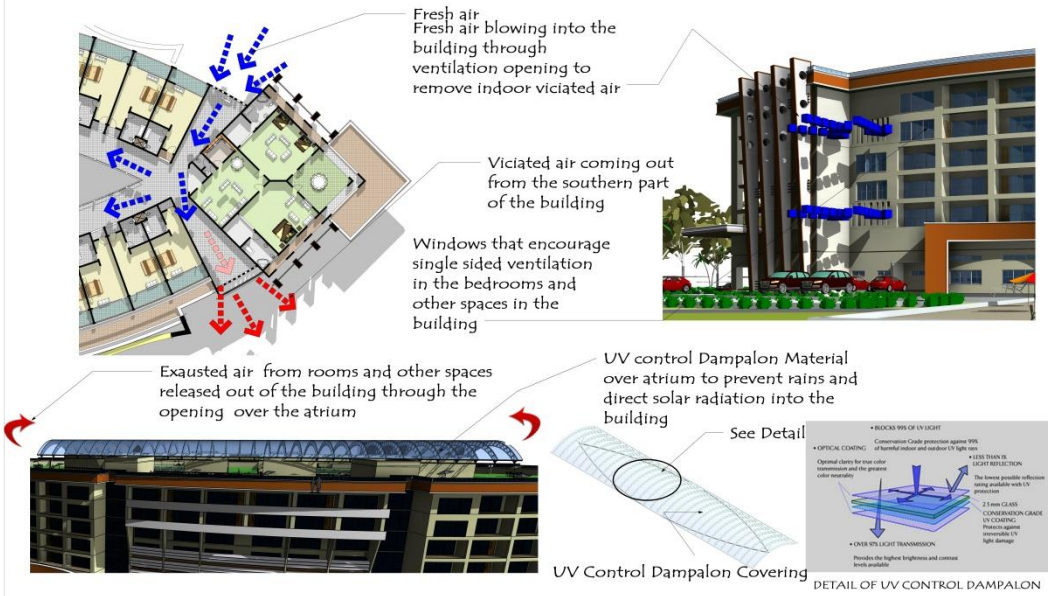
AIR FLOW PATTERN



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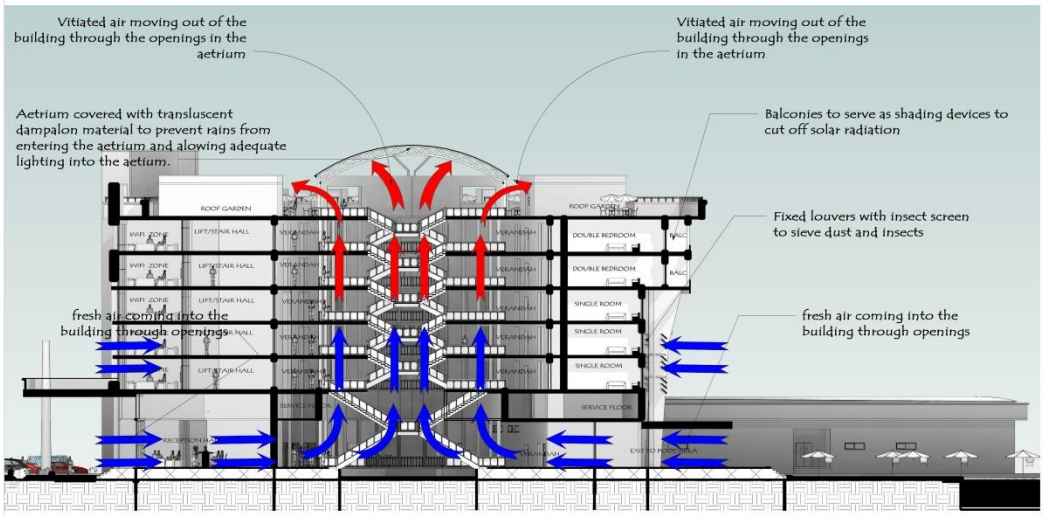
VENTILATION DETAILS



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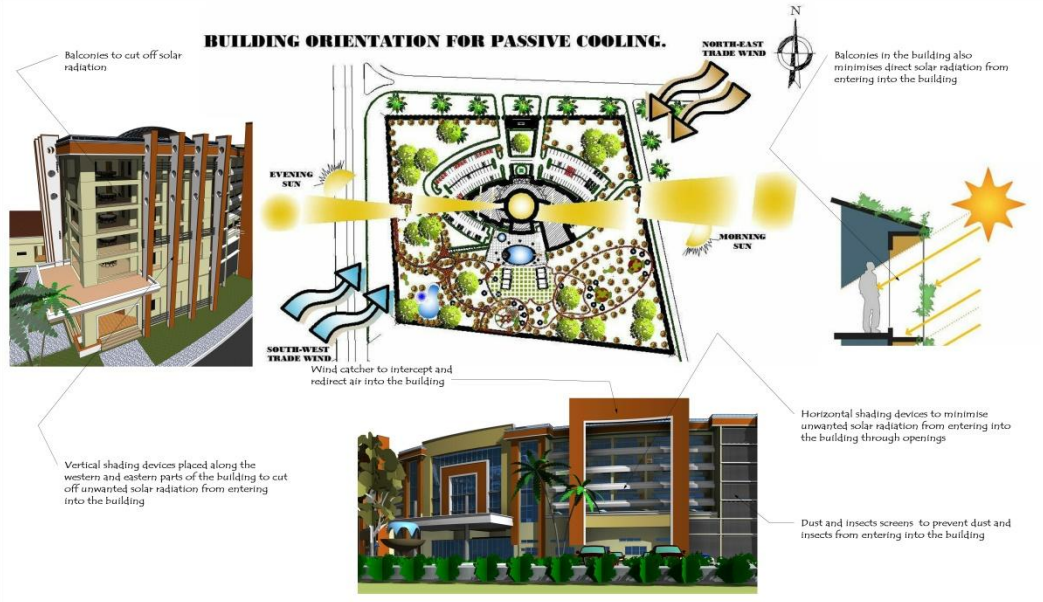
VENTILATION DETAIL OF FRESH AIR AND VITIATED AIR



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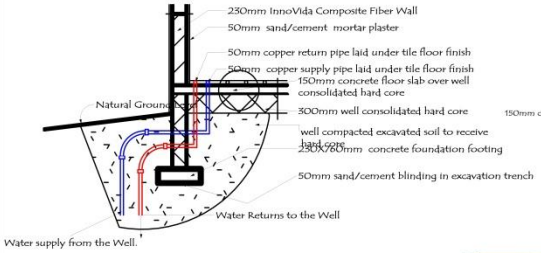
ORIENTATION AND SHADING DEVICES DETAILS

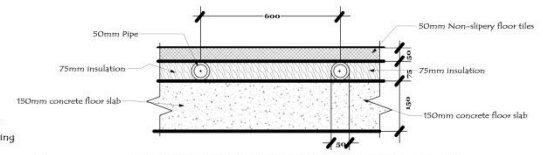


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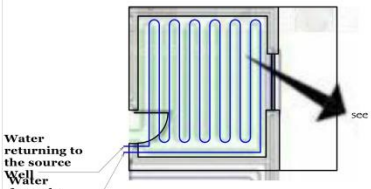
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UNDERFLOOR COOLING BY EARTH COUPLING DETAIL

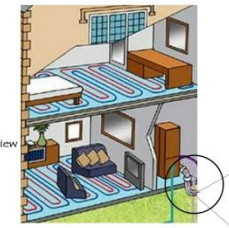




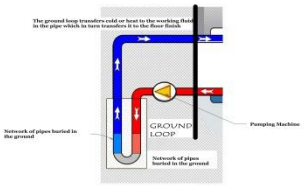
PIPING DETAILS IN FLOOR SLAB



TYPICAL ROOM PIPING LAYOUT



3D VIEW OF TYPICAL ROOM PIPING LAYOUT



Water from the source Well in blue colour

Water returning to the source Well in red colour

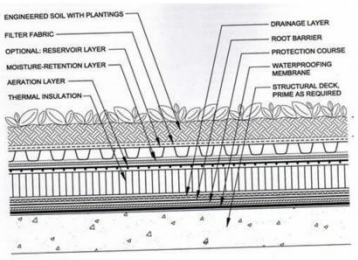
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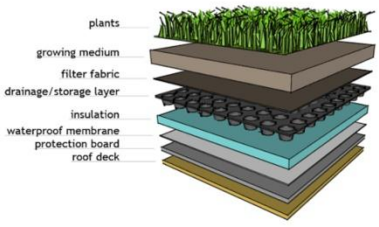
EXTENSIVE GREEN ROOF DETAILS



GREEN ROOF AT THE ROOF GARDEN



SECTION OF AN EXTENSIVE GREEN ROOF



FUNCTIONAL LAYERS OF AN EXTENSIVE GREEN ROOF



3-DIMENSIONAL VIEW OF AN EXTENSIVE GREEN ROOF

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