ENHANCING ENERGY EFFICIENCY THROUGH ADAPTION OF BIOMIMICRY STRATEGY IN RESORT HOTEL, MAMBILLA PLATEAU.TARABA STATE

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ZARIA, NIGERIA

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POST GRADUATE STUDIES, AHMADU BELLO UNIVERSITY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN ARCHITECTURE

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OCTOBER, 2021

DECLARATION

I declare that the work in the thesis entitled ENHANCING ENERGY EFFICIENCY THROUGH ADAPTION OF BIOMIMICRY STRATEGY IN RESORT HOTEL, MAMBILLA PLATEAU.TARABA STATE. Has been performed by me in the Department of Architecture. The information derived from the literature has duly been acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university or institution.

Anita Kevin _____ _____

Name of Student Student's Signature Date

CERTIFICATION

This thesis entitled ENHANCING ENERGY EFFICIENCY THROUGH ADAPTION OF BIOMIMICRY STRATEGY IN RESORT HOTEL, MAMBILLA PLATEAU.TARABA STATE. By Anita Kevin meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This dissertation is dedicated to the Almighty God and to my mother Mrs. Eglah Kevin whose support and encouragement made this research a success.

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ABSTRACT

Resort facilities use a large amount of energy for its operation; cooling, lighting, heating and the 24hours time frame operation of the facility per day to provide comfort and services for guest (Bohdanowicz, 2009).The demand for energy has been met by fossil fuel for decades increasing the carbon footprint on the planet. the building industry today works towards reducing the carbon footprint. Biomimicry has shown to be effective in enhancing energy performance over the past years. This research is aimed at using biomimicry strategy to achieve energy reduction in Holiday resort hotel in the temperate climate of Mambilla plateau, Taraba. To achieve that, there was exploration of the concept of biomimicry relating to energy reduction in buildings and identify the appropriate biomimicry approach to be used. The study employed a mixed methodology with the use of case studies and computational simulations using quasi-experimental approach. Using the tree trunk mechanism as a strategy and purposely selected a case study of a resort hotel, base case models were created and using Design Builder/Energy plus to perform energy simulation and obtain annual cooling load data for the base case with and without the biomimicry strategy applied. The most optimal insulating material and external skin material is polystyrene and Anodized Aluminium which reduced cooling load by 60.57% in the hot dry climate of Kano. Further application in the temperate climate resulted in a 53.84% reduction in cooling load and 51.85% energy saved, this also indicated an increased heating in the cold months throughout the year. This study recommends that architects and other professionals in the building industry should consider energy efficiency right from the early stage and developing biomimetic building envelope that will lower energy consumption depending on the problem that needs to be solved in the facility.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to Study

Energy is a basic requirement for economic development in almost all major sectors of any economy; agriculture, industry, transport, commercial, and residential. The demand for energy has been met by fossil fuel resource for decades. A consequence of which is a significant climate change and dwindling supply of these fossil fuels. This consequence can be addressed with energy efficiency which is key to ensuring a safe, reliable, affordable and sustainable energy system for the future. The concept of energy efficiency has become a significant consideration in the construction industry, due to its benefits in saving cost and reduction in resource exploitation and environmental degradation

(Iye, 2015). Indeed, one of the key approaches to low-energy design is to; first reduce energy needs by carefully designing the building envelope so that the heating, cooling and lighting loads are reduced. The second is to offset the remaining needs for efficient systems and appliances, and the third aims to make the most of resources, which means free energy that are available in the occupation site (Chayaamor-Heil & Hannachi-Belkadi, 2016).

Study from nature has shown the possibility of optimizing the structure of the building, mechanical system and materials used to improve their energy performance ecologically. One innovative approach is Biomimicry, which is defined as the applied science that derives inspiration for solutions to human problems through the study of natural designs, systems, and process (Radwan & Osama, 2016). Biomimicry design is not only adapting the design from nature, but also considering how to use nature's

effective functions such as heating and cooling system, protecting natural light and ventilation (Rao, 2014).

Biomimicry in architecture finds inspiration in the strategies, technologies and concepts that living organisms use to meet their needs and ensure their survival on earth. The main idea is that, Nature which is imaginative by necessity, has already succeeded to solve many of the problems we are struggling with where we find that animals, plants, and microbes are taking the role of skilful architects and engineers. Nature has figured out what works and what does not, what is appropriate and what is not, and, most important, what continues and lasts on this planet earth (Nessim, 2016). The most common type of biomimicry in architecture is copying surface morphology from nature. There are lots of buildings that take their shapes from nature, from bones to leaves and flowers to shells (Tokuc, Ozkaban, & Cakır, 2018).These buildings adopt the natural form for symbolic or aesthetic reasons, functionality, environmental sustainability and achieving efficiency in the building. This include water efficiency and energy efficiency (Nkandu & Alibaba, 2018).

The tourism industry contains one of the most energy intensive sub-sector known as the accommodation section, with about 50% of the overall energy consumption due to space conditioning. Resorts hotel serve as the primary provider of the guests' experience, often providing services for business and meetings and are characteristically located in vacation-oriented settings. Resort hotel are basically recreational development combining entertainment and accommodation facilities which cater for the leisure aspect of the social context of any society (Iye, 2015). Resorts hotel located in environments such as sea sides, mountains and rocks pose as an attraction to people who need a place of tranquillity and security to relax and ease stress (Arowona, 2016). Since resorts hotel are for recreational and other purposes and are in environments with

good natural features, a preferred approach for maximum use of the surrounding to minimise energy demand within the building should be adopted. The reduction of energy load through energy efficiency can reduce the operational costs of resorts, reduce environmental degradation and contribute to the development of resorts.

1.2 Problem Statement

Resort hotel facilities use a large amount of energy for its operation; cooling, lighting, heating and the 24hours time frame operation of the facility per day to provide comfort and services for guest (Bohdanowicz, 2009). According to Paul (2011), about 50% of this energy expended is due to cooling and heating of spaces.

In Nigeria where there is inadequate power supply, most of this resort pose more threat to the environment based on reliance to other sources of power supply such as fossil fuel. Internationally, the energy used in resort hotel is still predominantly fossil fuel based, even though many of these facilities are in areas with ample access to renewable energy resources (Bohdanowicz, 2009).

Biomimicry has been one approach used in reducing energy demand and mimicking natural strategies in buildings can occur at many levels. For example, creating a building that only mimics form for aesthetics like the Tirau's iconic dog building in New Zealand. A building that mimics a natural form to provide additional functionality like the glass panels of the Waterloo International Terminal mimic the flexible scale arrangement of pangolin which allows the building to respond to changes in air pressure when trains are entering and departing from the terminal (Zari, 2010).

Most of the mimicking outcomes are applied at organism levels such as developing a material or product (Al-Obaidi, Ismail, Hussein, & Abdul Rahman, 2017). Previous studies carried out by Manga, (2013), Nakakana (2012) and Barka (2012) were on

application of biomimicry principles, while Ewa (2018) and Isah (2017) emphasized on thermal comfort.

The focus of this study will be on how to reduce energy demand in the design of a resort hotel through adaptation of biomimicry strategy.

1.3 Justification

With environment pollution, climate change, and global warming, sustainable development becomes a vitally important issue. Nigeria is in an energy demand dilemma and Taraba state is known to be one of the gradually growing state in Nigeria with a problem of unstable power supply throughout the state. Also, it is known to have naturally blessed land like the Gashaka Gumti National Park and the Mambilla Plateau among many more others. The plateau is a resource frontier zone replete with abundant natural resources such as agricultural crops, mineral resources, wildlife, beautiful scenery. Mambilla plateau has far more natural and cultural tourist attraction that could be developed into tourist resort to make the state a world class choice tourist destination for local and international visitors. (Oruonye, Ahmed, & Tukura , 2016)

This study will go a long way in the reduction of energy consumption in the Holiday resort and save cost for energy demand and running the entire facility. This will also reduce Greenhouse emission from this facility to the ozone layer.

1.4 Aim and Objectives

The aim of this research is to design a resort hotel that optimises biomimicry strategy to achieve energy reduction in resort hotel, through the following objectives:

1. Explore the concepts of biomimicry as it relates to energy reduction in buildings.
2. Determine the most appropriate biomimicry approach for achieving energy efficiency in resort design.

3. Demonstrate the findings of these biomimicry approach in the design of a resort.

1.5 Research Questions

This research is expected to provide answers to the following questions;

1. What biomimicry strategies have been applied in building designs?
2. What biomimicry strategy will be suitable for the design of a resort hotel?
3. What kind of building resort hotel design can optimise an identified biomimicry strategy?

1.6 Scope of Study

Form(organism), behavioural, ecosystem mimicry levels have been used to achieve energy efficiency in buildings, this research will identify which biomimicry strategy is most appropriate with respect to the physical and climatic characteristics of the site considering mainly the accommodation part of the resort. The proposed design will be in Taraba state, Nigeria.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Energy Efficiency Concept

Energy efficiency is defined as a reduction in the quantity of energy used to provide a service or product. In buildings, energy is used for several purposes day after day, and it is important to understand when and where energy is being consumed. Studies have shown that energy consumption in a typical commercial building are divided by percentages of the total building energy consumption (Luis, 2013). And it is widely known that approximately 40% of global energy consumption and one-third of global GHG (greenhouse gas) emissions is from buildings (Saint-Gobain, 2018).

2.1.1 Energy Efficiency Strategy

Investing in the buildings form and enclosure (building skin) is one of the key approach taken to have a low-energy building. The second is to offset the remaining needs for efficient systems and appliances, and the third aims to make the most of resources, which means free energy that are available in the occupation site (Chayaamor-Heil & Hannachi-Belkadi,2016).

2.1.1.1 Reduction in Energy Demand

Reduction of energy demand ought to come before renewable energy technology and that energy load reduction should be a requirement to low energy building development. Another suggestion was that Energy efficiency measures should be checked periodically throughout the building's operation to ensure effectiveness. A study stated that energy efficiency improvement in commercial buildings in the US can reduce consumption by 43% on average. buildings with the most potential for reduction in energy demand

through efficiency improvement are the most likely to achieve low energy building status.

The new energy performance building regulation aims to reach low energy consumption for all new building along with bioclimatic design principles, which aim at construction of buildings that are in harmony with the natural surroundings and local climate, ensuring conditions of thermal comfort inside as below

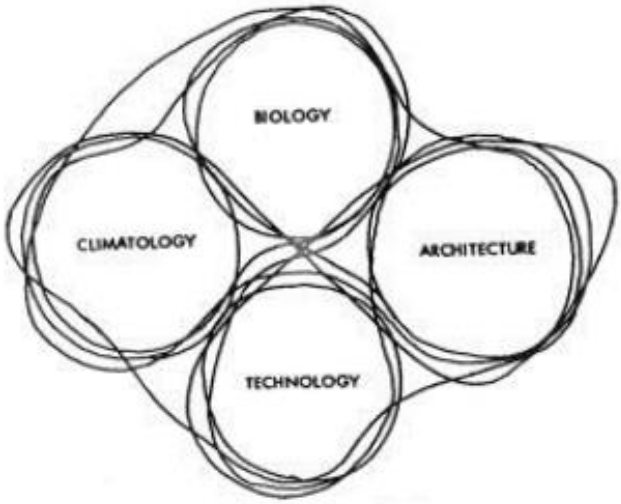


Figure 2.1: Interlocking fields: Bioclimatic Design
Source: Building energy efficiency guide (2015)

However, a significant part of energy consumption can be reduced during the architectural design since this has a direct impact on choosing and sizing the mechanical system of the building which in turn affects the energy consumption of the building during its life time. (Sozer, 2010).Therefore identifying the energy consuming building components is critical from the perspective of the building designers, building owners and utilities to examine the possibilities of reducing building energy consumption, not only through efficient building systems and management, but also with building architectural characteristics.

2.1.1.2 Efficient Heating, Ventilation and Air Conditioning Systems

Anderson (2016) conducted a study which shows that in developed countries, HVAC accounts for half the energy demand in the built environment and 20% of national overall energy demand and due to this increasing demand for energy from the HVAC systems, considerable efficiency measures need to be developed. Once energy requirements are reduced through a bioclimatic design, a choice of high-performance materials (insulation, glazing, etc.) and power systems (HVAC and lighting) will be lower and so it will economize over the long term (investment as consumptions). (Chayaamor-Heil &Hannachi-Belkadi,2016). The system requirement should be reduced to the barest minimum through passive design principles and the HVAC system installed should be energy efficient.

2.1.1.3 Production of Sustainable Energy

After carefully designing buildings with a high-performance envelope, efficient HVAC and lighting systems. It is customary to offer high efficiency power generation systems and promote those using renewable energy (solar panels, heat exchangers, natural wind).

2.1.2 Energy Efficient Buildings

As earlier said energy efficient buildings are designed to use as little energy as possible this can be achieved by using quality building and insulation materials which help prevent heat loss and make the building air tight. Also, The Chartered Institute of Building Service Engineers (2012) described an energy efficient building as one that provides the required indoor environmental conditions with minimum energy through cost effective and environmentally friendly approach. Energy efficient buildings are classified into four categories; Low energy buildings, Passive buildings, zero energy buildings, plus energy building.

2.1.2.1 Low Energy Building

A low building is identified to be the building type that consumes only half of the energy needed in a standard building. Meanwhile a standard building is a building that meets the minimum building standard energy efficiency requirement. They are very often designed without traditional heating systems and without active cooling and the end up saving energy consumption of 70%-90%. (Saint-Gobain, 2018)

2.1.2.2 Passive Building

Passive buildings consume less than a quarter of the energy used by a standard building.it generate energy within itself. The passive buildings can achieve the lowest energy requirements through striking a balance between the heat losses, and the heat gains with respect to the climatic condition of building's location (Omrany & Marsono, 2015)

2.1.2.3 Zero Energy Building

A zero-energy building is a building with zero net energy consumption and zero carbon emissions annually. These buildings can be independent of the energy grid supply (Paroc, 2018).

2.1.2.4 Plus Energy Building

As the name implies this type of energy efficient building have an energy efficiency level of a passive building and additional integrated active energy supply system that exploit solar or wind energy. Plus-energy buildings are currently rare but are likely to become a new building trend soon.

2.1.3 Benefits of energy efficient buildings

Energy efficient buildings have knock-on benefits in social and economic terms as well as environmental benefits as shown below

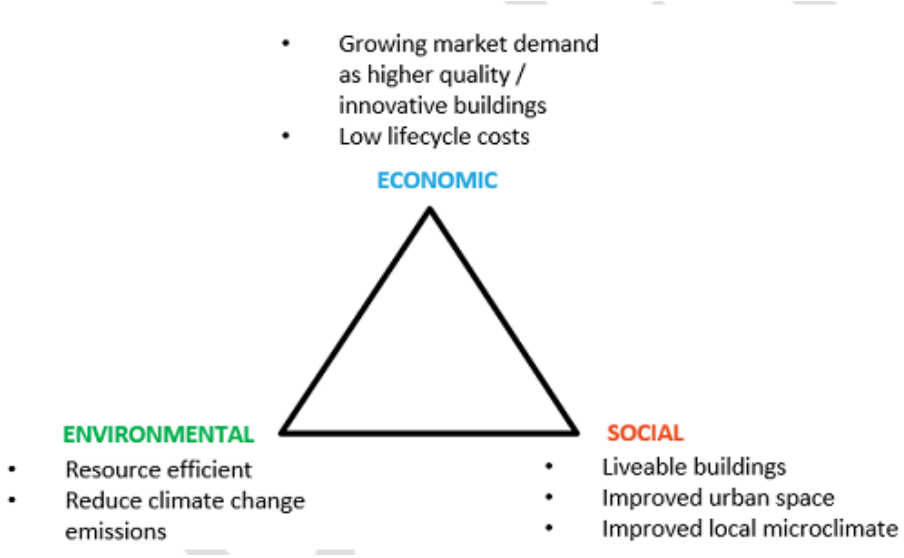


Figure 2.2: Benefits of energy efficient building

Source: Building Energy Efficient Guide Nigeria (2015)

2.1.3 Energy efficiency and Biomimicry

For the design concept of an energy efficient building, building envelope is the first to count on the consumption change, which will allow us to reduce energy needs by careful design of the building envelope. (Chayaamor-Heil &Hannachi-Belkadi,2016). Recently, one of the most development tool for energy management in the building is integrating biomimetic design in building envelope. Nowadays, building envelopes are associated with a wide range of innovative technologies that significantly influence, cases, have a functional role in providing a satisfactory indoor climate for the occupants. (Del Grosso &Basso,2010).

2.2 Biomimicry

Biomimicry, coming from a combination of the Greek words bios (life) and mimesis (imitation), it literally means ‘life imitation’ or the ‘imitation of life’ It is defined as the process of creating sustainable designs and solutions through the study and conscious emulation of natural forms, processes, and ecosystems (Oguntona & Aigbavboa, 2017).

Biomimicry is a new science that studies nature's models and then emulates these forms, process, systems, and strategies to solve human problems sustainably. It uses an ecological standard to judge the sustainability of our innovations also, Biomimicry design is not only adapting the design from the nature but also considering how to use nature's effective functions such as heating and cooling system, protecting natural light and ventilation (Rao, 2014). Biomimicry could be used as a tool for energy-efficient building design, aiming to achieve low energy consumption by innovative design and sustainable energy generation without negatively impacting the natural environment (Chayaamor-Heil & Hannachi-Belkadi,2016).

2.2.1 Biomimicry in Architecture

Biomimicry in architecture finds inspiration in the strategies, technologies and concepts that living organisms use to meet their needs and ensure their survival on earth. Biomimicry in architecture can be defined as a movement in design and construction that using the forms, structures, processes, and functional solutions from nature for technical purposes, creating sustainable and regenerative environment. (Vavan, Milosevic, & Minic, 2019)

2.2.2 Biomimicry Approach

Benyus (2009), mentions two major approaches for the use of biomimicry which are; Design to biology approach (top to bottom) and Biology to design approach (bottom to top)

2.2.2.1 Design-to-biology approach

This approach is used when the design process is originally depended on the scientific knowledge of biologists and scientists instead of human design problems. Innovation starts with the design challenge, identifies the basic function, and concludes with an

analysis of natural principles by which different organisms or ecosystems fulfil this function. The pattern of problem-driven biologically inspired design follows a progression of steps which, in practice, is non-linear and dynamic in the sense that output from later stages frequently influences previous stages, providing iterative feedback and refinement loops. (Michael, Swaroop & Ashok,2009).

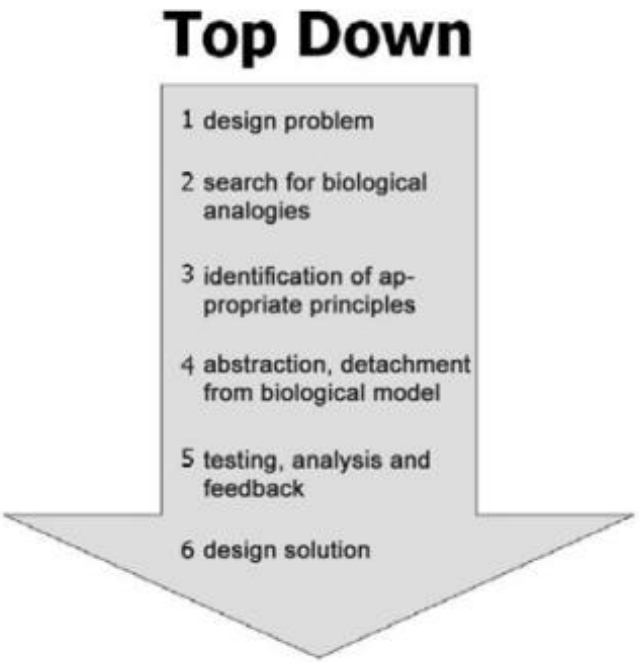


Figure 2.3: Top to bottom Approach

Source: Salma , (2011)

2.2.2.2 Biology-to-design approach

In this approach, the designers search for solutions through identification of the problem and the biological phenomenon suggests new way of solving from identifying an organism that has solved a similar problem.

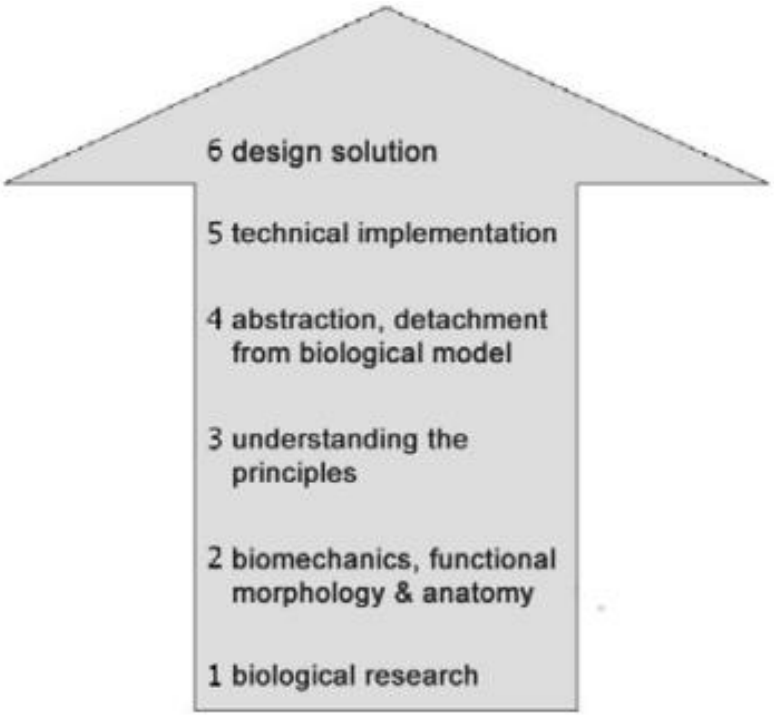


Figure 2.4: Bottom to Top Approach

Source: Salma, (2011)

When biological knowledge influences human design, the collaborative design process is initially dependant on people having knowledge of relevant biological or ecological research rather than on determined human design problems. (Salma , 2011). The advantage of this approach is that biology may influence humans in ways that might be outside a predetermined design problem, resulting in previously unthought-of technologies or systems or even approaches to design solutions.

Benyus (2009) also mentioned that nature can be seen as a model, measure and mentor:

I. **Nature as a Model**: In this view biomimicry uses nature as an inspiration and model for the solution of various problems. A design spirals which uses design as a model consist of five elements which were identified as ; **identify**(development of design solutions for human needs, it is important to identify where is the problem and where will the solution be

applied); **translate** (translation of design into biological functions in order to solve problems in a way that were solved in nature);**discover**(search for biological models that correspond to the subject design);**emulate**(development of solutions and concepts based on biological models, by mimicking the appropriate forms and/or functions from nature) and **evaluate**(comparison of design solutions with life's principles)

II. **Nature as a measure:** This uses ecological standards for assessment of the sustainability and safety of our innovation. And emphasis has to be laid on the importance of applying the life's principles in which nature is presented as a measure to build a sustainable environment.

III. **Nature as a mentor:** Biomimicry is a new way of observing and evaluating the nature. It begins a new era based on what we can learn from nature, and not what we can get from it.

2.2.3 Biomimicry Principles

These principles are common tools through which biomimetic designs, materials, and applications are evaluated for sustainability. Also, these principles are identified as important checklist to be adhered to in ensuring the application of biomimicry resulting in sustainable outcomes.

Barka (2012) mentioned the following to be the principles of Biomimicry

a) Use of natural forms
b) Exploring the application of natural processes
c) Using minimal energy and material
d) Adaption and evolution

e) Learning from ecosystem.

2.2.3.1 Use of natural forms

Using natural forms has to do with adopting and mimicking outward organic forms. A building that can mimic natural processes and can function like an ecosystem in its creation, use and eventual end of life has greater potential to be part of a regenerative built environment. An example of a building that mimic form is the winning elliptical dome for the Chinese national opera house and concert hall, Beijing.



Figure 2.5: The National Centre for the Performing Arts, China
Source: http://www.guardian.co.uk/news/gallery/2007/sep/25/internationalnews2

2.2.3.2 Use of minimal energy and material

Nature always tries to use energy and materials efficiently, successfully minimizing mass and energy use.it recycles everything; the natural skin reacts to changing conditions and influences of air pressure on the surface to perform a process of transpiration in plants

2.2.3.3 Exploring the application of natural processes

The concept of this principles is to displace some of our conventional energy with a renewable source and life over the years, has learnt to harvest energy from the Sun and to transform it for work without creating toxic by -products.

2.2.3.4 Adaptation and evolution

Nature evolves by responding to its environmental needs and finding solutions that work. The regenerative nature describes processes that restore, renew or revitalize their own sources of energy and materials, holistic frameworks that seek to create systems that are waste free. (Barka, 2012)

2.2.3.5 Learning from ecosystem

Nature uses and builds with life friendly processes and systems, considering the immediate environment is not depleted. Natural filtration environment filters out and absorbs components that would otherwise pollute the local ecosystem. (Biomimicry Guild,2008).

2.2.4 Biomimicry level

The form is an obvious component of nature, but a mere imitation of natural shapes in the design misses the point, unless it is not related to the function of the object and its relation to the environment. (Vavan, Milosevic, & Minic, 2019).It is necessary to understand that full imitation of nature involves at least three levels of biomimicry: form, process and ecosystem. And these three levels are the starting point for successful application of biomimicry to solve the existing problems that increases the regenerative capacity of the built environment and the promotion of environmental sustainability (Nakakana,2012). Figure 2.6 below shows a frame work of the 3 Biomimicry Levels

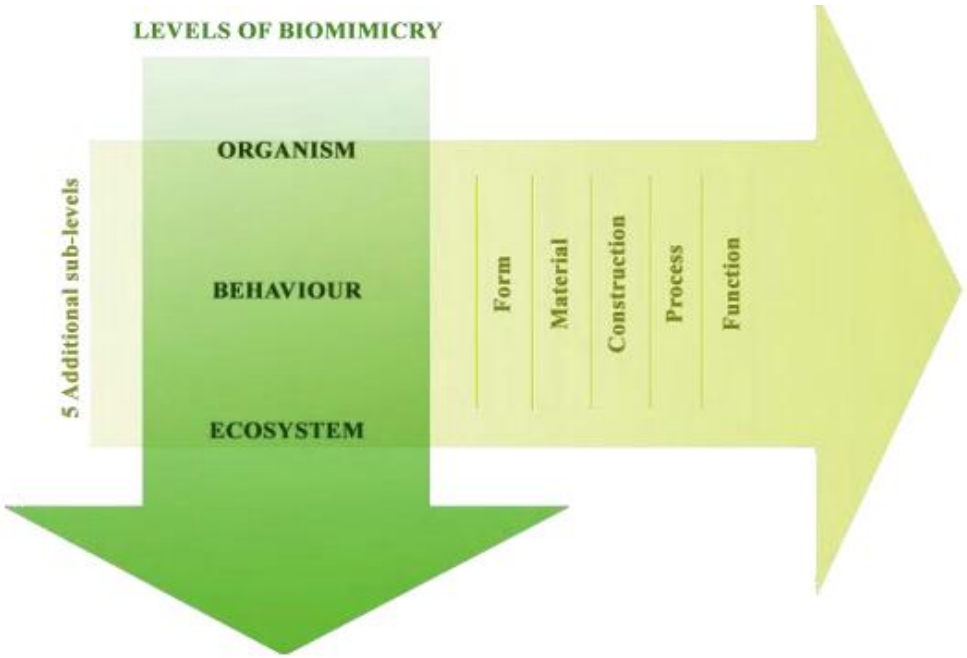


Figure 2.6: Framework of Biomimicry Level

Source: Salma, (2011)

2.2.4.1 Level of form/Organism

On the first level of biomimicry, the shapes and forms from nature or specific organism like a plant or animal are imitated and applied in architectural design. Mimicking an organism alone however without also mimicking how it is able to participate in and contribute to the larger context of the ecosystem it is in, has the potential to produce designs that remain conventional or even below average in terms of environmental impact (Salma , 2011)

2.2.4.2 Level of process/Behaviour

Biomimicry is not a mere imitation of nature, but the observation and analysis of general patterns and processes in nature that are called the Life's Principles. This level includes the transformation, development and application of these principles in sophisticated technological solutions, which results in different relation between object

and environment, i.e. object can respond to changes in the immediate environment an adapt to them to the customers' satisfaction.

2.2.4.3 Level of ecosystem

The third level of biomimicry is the mimicking of natural ecosystem. The technology will enable the future buildings to mimic sophisticated system for energy consumption management and to respond to temperature, intensity of daylight, wind speed and force and other changes in the environment. In the near future, the buildings will imitate the natural systems in order to protect the environment.

2.2.5 Building skin

A new architectural trend is to make an adaptive envelope that is responsive to both exterior and interior variable environments (Armstrong, 2012). A subcategory of biomimicry is building skin which forms the entire exterior envelope of the building. According to Rankouhi (2012), building skin as the boundary through which the buildings interaction with the environment occurs. It consists of layers and filters that interact with the whole world and external factors like sound, heat, light and moisture. The most common feature is the ability to maintain the optimal internal conditions that respond to the functions they carry. The building skin also acts as the identification of the building. It includes façades, roofs, external walls, ceilings and floors, as well as doors and windows. Façades perform under the influence of climate conditions and affect the indoor living conditions; therefore, the first criteria of a sustainable façade are usually defined as material and energy efficiency (Tokuc, Ozkaban, & Cakır, 2018)

Building skin also looks like a filter that controls what to enter like light, air, moisture, sound and heat and what comes out to reduce energy consumption of the building and perfect biomimetic skin to achieve our smart emotional city. (Mohamed, Bakr, &

Hasan, 2019). The design of a façade aims to impart functional characteristics as well as an aesthetic look; in addition, it considers extending the life of the building with more durable materials. Thus, a façade may be designed as an adaptive layer which has a great impact on the energy efficiency and thermal comfort of the whole building. (Tokuc, Ozkaban, & Cakır, 2018).

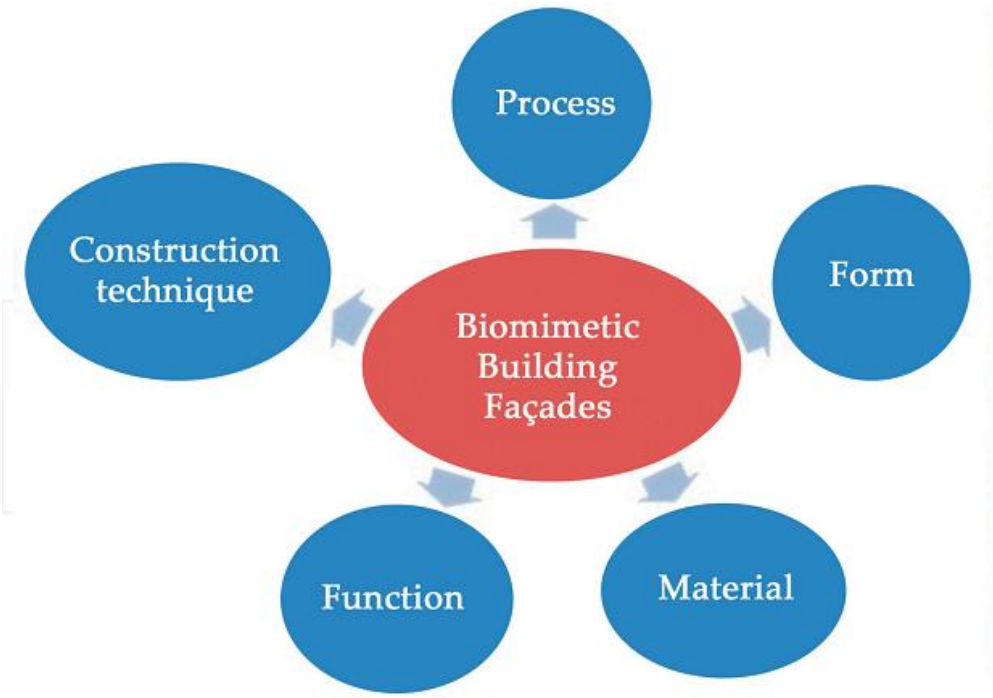


Figure 2.7: Biomimetic technologies for building facade design
Source: (Tokuc, Ozkaban, & Cakır, 2018)

2.2.6 Adaptive building skin

An Adaptive Building Skin System controls light levels, solar gain, and thermal performance that could reduce energy usage, enhance comfort, and increase the flexibility of the built environment (Binus University, 2019). Building skins are generally a complex system that requires the control of many aspects, such as heat, light, humidity and ventilation. Applying adaptivity in building skins requires various elements of the building system, such as sensors, actuators and command wires to be

efficiently correlated with the approach of nature such as metabolism and morphology (Wigginton,2007). The terms smart, responsive and adaptive concepts have been used loosely and interchangeably, which confuse many professionals (Barozzi & Zanelli, 2016).

i. First, smart building skins refer to automated or largely automated self-monitoring systems like building management systems, which deploy integrated instruments within a building (Brooks,2011).
ii. Second, in contrast to manipulate, the term responsive refers to a system moving and responding from the outside based on specific factors, thus allowing interaction with a passive environment (Hasselaar, 2006).
iii. Third, adaptive skin has the ability of a system to adjust by itself in relation to a changing environment. An adaptive system, as in the case of building skins, can adapt the features, behaviour or configuration of the external environment (Dewidar, Mohamed & Ashour, 2013).

The above-mentioned systems can also use smart materials to enhance their performance. In fact, smart materials play an important role in smart, responsive and adaptive building skins due to their intrinsic properties, which include the ability to change physical properties or shape without any energy source. (Al-Obaidi et al, 2017). Many types of smart materials can function in different forms and sense environmental stimuli, where responses can be thermal, radiant, chemical, electrical, magnetic and others. Elattar, (2013) divided smart materials into three different types.

i. Passive smart materials work as a sensor for their inner system and the surrounding environment. All shape memory alloys and fibre optic materials fall into this category. Shape memory alloys respond to temperature by changing

shape without analysing signals, while fibre optics act as sensors but not as actuators or transducers (Kamila,2013).

ii. Active smart materials have similar properties as passive materials; however, active smart materials can also react to stimuli. Example of this active smart material is piezoelectric material use a feedback loop for its actuator circuit to recognise both change and initiation of appropriate response

iii. Intelligent materials adapt their behaviour to circumstance and the have been divided into two groups. First, materials that undergo change in one or more of their properties to respond directly to external stimuli, such as thermochromics and shape memory, as well as photochromic materials that change colour in response to ultraviolet radiation, and second smart materials that transform energy from one form to another (e.g. Thermoelectric, and photovoltaic materials). (Al-Obaidi et al, 2017).

2.2.7 Adaptive materials

2.2.7.1 Temperature reactive materials

As the name implies these materials operate under the influence of change in temperature. Several materials are listed under this type of material. For example, the thermo-bio metal that deforms and curves when heated or cooled based on a specific range of air temperatures.

2.2.7.2 Light reactive material

Light responsive polymers or light-induced shape memory polymers are polymers that undergo light-induced shape changes, which can be deformed and temporarily fixed as a new shape (Jochum,2013). Phosphorescence pigments, such as conductive paints that fabricate passive and active luminous skin, which allow materials to glow in dark

environments. Such materials are applied on surfaces to form conductive surfaces and create capacitance that can detect moving objects (Khoo,2012).

2.2.7.3 Humidity reactive material

Hydrogel is a smart gel that consists of an insoluble network of polymer chains that swell up when water is added; it can store large amounts of water, which is like the functions of natural tissue. Currently, hydrogels are utilised for bio-inspired cooling (Cui, Ahn & Wingert,2016).

2.2.7.4 Carbon dioxide reactive material

An example includes: (1) CO2 responsive polymers, which are divided into two types, namely, carbon dioxide responsive polymers and carbon dioxide polymers for CO2capture (i.e. carbon dioxide is used as a green eco-trigger, and to absorb CO2 directly from air) (Manoranjan, Kim & Woo, 2016).

2.2.8 Mechanism of different adaptive building skin

This section helps to identify that for adaptive skins two responsiveness can be distinguished, which either Active responsiveness (response by the system), or Passive responsiveness (response by material mechanism). Active responsiveness is typically conceived as a technical function enabled by sensing, actuating and regulating devices. Passive responsiveness is achieved by embedding sensing, control, and actuation within the material itself. Below are some examples of some of these mechanism,

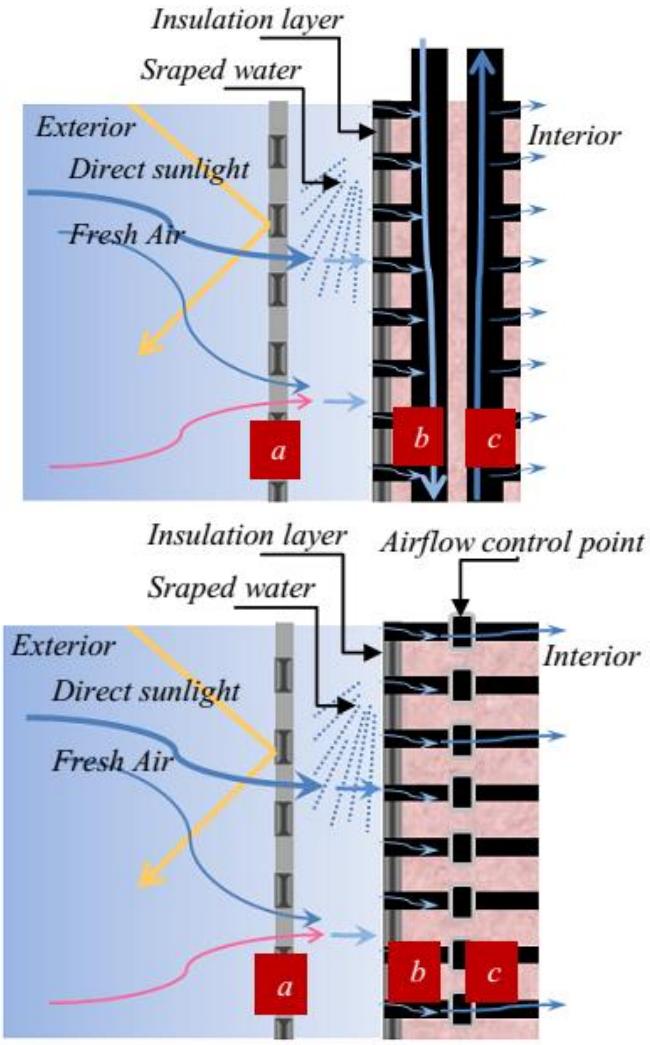


Figure 2.8: Mechanism of breathing wall (thermal adaptive layer).

Source: Mahmoud, (2010)

The Breathing wall shown in figure 2.8 above is aimed at minimizing direct sunlight, allowing airflow to pass and thus cooling the building. (a) exterior layer capable of preventing or filtering direct sunlight while allowing airflow to pass, (b)Middle layer acts as thermal insulation layer, then it cools air temperature by evaporative cooling and receives air flow, (c)Internal layer aims at controlling airflow. (Mahmoud, 2010)

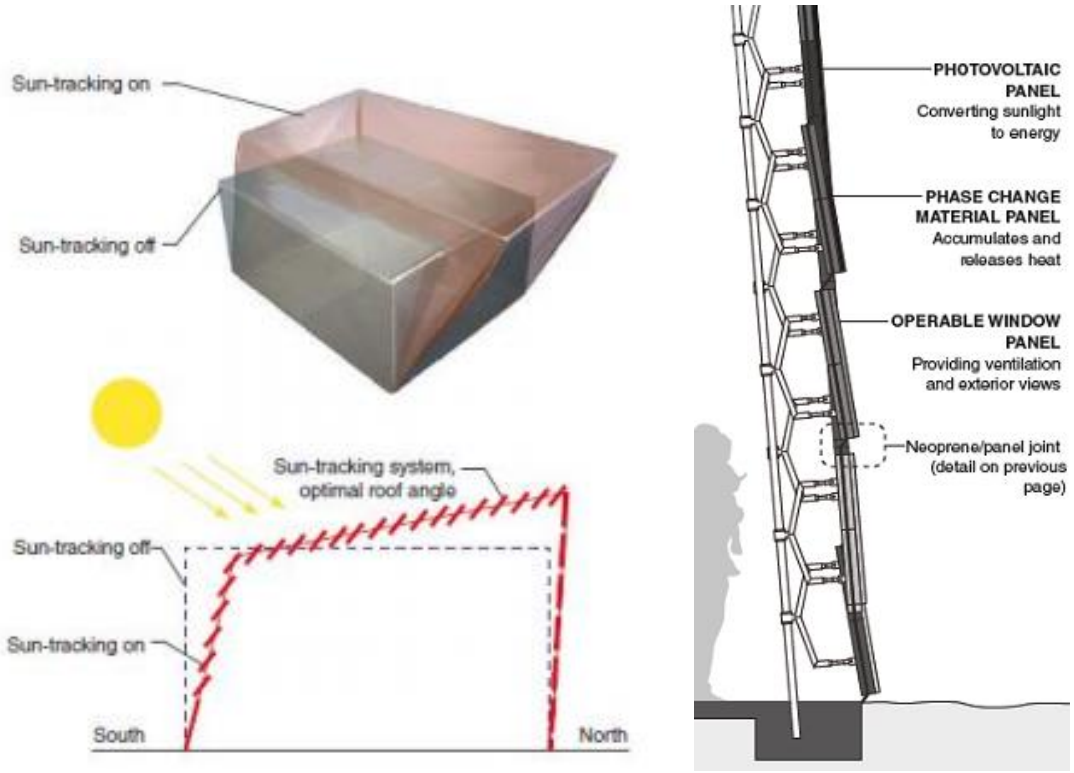


Figure 2.9: Building skin adapted from the skin of Lizard

Source: Mazzoleni (2013)

The building in figure 2.9 above combines the characteristics and behaviours that help the lizard survive in the desert and integrate it in the building envelope. It takes cues from survival skills of the lizard and makes the building, in essence; survive in the desert quite comfortably (Mazzoleni,2013). The south facing wall is composed of three different types of panels: opaque insulative, photovoltaic, and operable window. The insulative panel uses phase change material to allow for a stable interior temperature throughout the day. The heat collected during the day is slowly released and heats the residence at night.

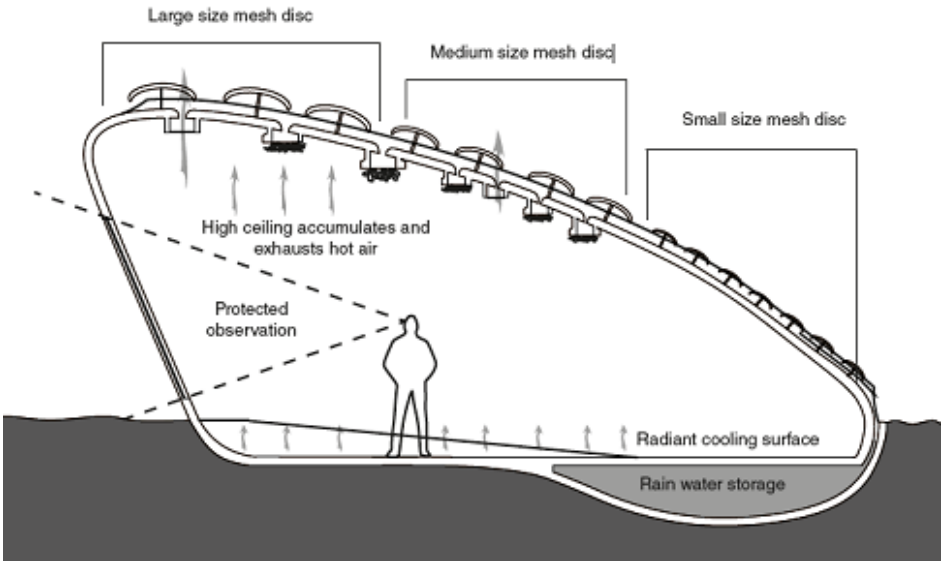


Figure 2.10: Building skin mimicking a beetles' ability to collect water

Source: Mazzoleni (2013)

Figure 2.10 above shows the components of the mesh disc and how it collects water droplets. The schematic building section indicates the exterior positioning and decreasing sizes of the discs as well as delineating the interior space, slightly sunk into the sand to take advantage of its thermal mass. The building envelope uses a series of mesh discs to capture moisture from the morning fog. Each disc is set on a pivot and tilts when enough water has accumulated

2.2.9 Examples of energy conserving buildings using biomimicry concept

This case studies will help to understand the role of building skin in reducing energy consumption through biomimetic approach, an analytical study of different case studies will be done in which the Biomimicry approach has been applied on different levels to understand and analyse the different techniques and strategies applied in building skin and how they have successfully responded to realise an efficient building.

2.2.9.1 Minister of Municipal Affairs & Agriculture building in Doha, Qatar

Climate condition: Extremely hot weather and the intense desert sun

Biomimicry Level: Ecosystem

Elements inspired: the entire building form and function was inspired from the cactus plant as shown in Figure 2.11 due to the climatic condition of the place. The shading system of the building is inspired by the plants capability to shade itself and prevent losing water in the dry weather. One of the strategies of cactus plants is to avoid losing moisture by using its spines or thorn like structures to prevent air exit near the surface skin so it will keep it cool and, they act like shades to protect it from the sun.





Figure 2.11: Cactus plant

Source: Google Image (2019)

Design concept: The building is covered from its top to its bottom with shades that resemble the spines in the cactus plant as shown in the figure 2.12 below. The sun intensity determines the opening and closing of the openings which was inspired by cactus transpiration. Also, the building uses different ecological systems to clean dirty water.





Figure 2.12: concept of the building in form of cactus plant

Source: Google Image (2019)

Energy efficiency technique: The building skin is covered overall with shades which look like spines in cactus. These shades control the amount of sunlight that is entering

the building and keeping it cool. In addition, it helps flooding the rooms with natural light to create a building that is highly energy efficient.

2.2.9.2 Sino steel international plaza

Biomimicry level: Organism

It is high-rise commercial building consisting of a 358-metre-high office tower which is totally made of glass. It is located besides Grayston drive and Rivonia Road in Tinajin China.



Figure 2.13: Sino steel international plaza
Source: Google Image (2019)

Elements inspired: The inspiration of the outer structure of the building is from the bee hive (honey comb). The external structure consists of hexagonal honeycomb windows in five different sizes. They were arranged according to wind and sun direction in its context to regulate the temperature inside the towers as shown in Figure 2.14 below.



Figure 2.14: concept of outer structure from beehive

Source: Google Image (2019)

Design Concept: The form of the buildings is simple; it looks like a rounded box. The façade consists of five different sizes of hexagonal windows which look like a honeycomb. These windows are spread over the building in a random and in a pattern occurring in a natural way: like cells multiplying as shown in Figure 2.15. This pattern gives the building a life and changes the way people look at it. The towers rise from a green hill that acts as the hotel's podium.



Figure 2.15: windows spread at random to allow sun and air enter building

Source: Google Image (2019)

Energy efficiency technique: The pattern which is inspired by the honeycomb lets the building be efficient for energy as it responds to the patterns of sun and wind direction on the building. By mapping the different air flows and solar direction across the site, different sized windows are positioned accordingly, to minimise heat loss in the winter and heat gain in the summer.

2.2.9.3 Esplanade art centre Singapore

Biomimicry level: Organism and Behavioural

It is a cultural centre composed of two giant theatre buildings, outdoor stages, offices and apartments.



Figure 2.16: Esplanade art centre Singapore

Source: Google Image (2019)

Elements Inspired: The shading system of the building was inspired by two elements: the durian fruit, which is a local fruit in Singapore, and the polar bear which is not belong to the place. The durian plant has a thorn such as protrusions all over its skin to protect the seeds inside it from heat and direct sun light. While The polar bear has a white fur, which consists of transparent hair follicles and black skin. When this transparent hair be upright, it allows the light to enter and to be absorbed by the black skin whenever there is sun and return to normal position otherwise.



Figure 2.17: Durian and Polar bear fur

Source: Google Image (2019)

Design Concept: The aluminium shading device in the double curved building envelope looks like the durian fruits thorns which protrude to provide shade and move like the polar bears hair according to sun location and light intensity through photovoltaic sensors thus protecting the inner space of the art centre.



Figure 2.18: The protrusions which resembles thorns in durian fruit and their move via sensors like the polar bear hair

Source: Google Image (2019)

Energy efficiency technique: The external shading system (The aluminium shading devices) provides the interior spaces with shade throughout the day allowing natural daylight and minimal heat and it lowered HVAC level.

The table below show examples of buildings that employed biomimicry strategy on their building envelope with the aim of achieving energy efficiency. This includes the inspiration, reasons, result outcome (percentage of energy efficiency achieved), examples of buildings, and climate.

Table 2.1a Examples of buildings with Biomimicry applications

Inspiration	Reasons	Outcomes	Climate	Buildings

Tree 	Protective skin, Energy Efficiency, Moderate external Climate	Shading for visual comfort, natural lighting and ventilation saved by 65%, maximizes natural ventilation, Energy saved by 80% (Radwan & Osama, 2016)	Tropical climate	Council house 2, Australia
Water bubble 	Surface tension of bubble reduces surface tension, usage of geometric shapes and form.	Energy reduced by 30%, artificial lighting reduced by 55% (Radwan & Osama, 2016)	Cold and temperate	The water bubble, Beijing.
Durian fruit 	Protective spikes against heat. Allow optimum views of bay	Lowered HVAC levels, Protection against heat, energy saved by 30%, natural ventilation and lighting by 45% (Radwan & Osama, 2016)	Tropical rainforest	The Esplande Theatre, Singapore.

Table 2.1b Examples of buildings with Biomimicry applications

Inspiration	Reasons	Outcomes	Climate	Buildings
African reed frog and Hercules beetle	Skin protection against weather, minimize water loss.	Reduction of cooling by 60% (Fecheyr-Lippens & Bhiwapurkar, 2017)	Hot and humid climate	Proposed office building, Chicago.
Tree Bark	self-shading, low-heat loss and maximum reflection.	Energy saved by 34% (Alkhateeb & Taleb, 2015)	Hot and arid desert climate.	Residential building, Dubai.
East gate centre Termite mound 	Self-regulating temperature	Energy reduction in HVAC system by 100% Allows natural ventilation	Tropical	Mixed use building, Zimbabwe

Source: Author, (2019)

2.2.10 Adopted Biomimicry Approach

Inspiration: Tree Bark

Reason: self-shading, low-heat loss and maximum reflection.

Trees have adapted to keep leaves and barks cool in sunshine and can serve as interesting bionic model systems for radiative cooling. (Henrion & Tributsch, 2008). Tree trunks are typically round, which means that they have minimized their surface, this was apparently one strategy towards minimizing heat influx (Wolfgang & Helmut, 2009). It was also mentioned that Barks have in addition evolved numerous morphological strategies to deal with heat and cold, and they consist of quite thick, thermally insulating material layers (e.g. sequoia barks, which can reach a thickness between 30 and 50 cm). the tree bark is involved in defence against herbivory, protects against fire, and provides insulation in cold conditions. The aspect of insulation can be related to energy reduction since the aim of insulation is to prevent heat again and loss in a space.

Some tree barks also peel off like paper to provide thin air gaps between bark sheets for suppressed heat conduction, also another important factor in temperature control will be that the light reaching the bark of trees will typically be filtered by the canopy, which means it will be solar light reflected from vegetation or solar light transmitted through thin leaves in a tree crown.



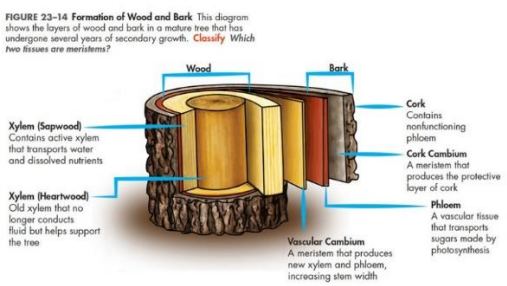


Figure 2.19: Tree bark and cross-section of a tree trunk showing the different layers. Source: Google image (2019)

2.2.10.1 Protection

The bark consists of two main layers, the outer and the inner bark. The outer bark consists of dead cells and forms the first line of protection between the inner bark's vital structure and the surrounding environment. The inner bark or phloem actively contributes to the tree's life processes (Mauseth,2002).

2.2.10.2 Shading

The outer layer of the bark dies causing some barks form peeling crusts, while others react by forming deep cracks. These outcomes contribute to the tree's adaptation towards the sun by providing shade.

2.2.10.3 Reflection

The tree bark has optimal reflecting characteristics which is active due to the Tannius.

2.2.10.4 Insulation

Within the bark, the waxy thick layer of cork plays a very crucial role in preventing water lose in plants.

2.2.10.5 Material conductivity

One function of the inner bark is to transport sugars for the plant, this occurs via conducting tissues that have been produced by the Phloem. This process works under precise procedures to assure completion of the task in the correct manner.

2.2.11. Strategy implementation

Outer layer: An external skin which will serve as shading with high reflectivity value to minimize solar penetration and reduce direct sunlight effect into building. Shading will focus on the east and west side of the building

Waxy layer: light coloured Insulated external wall to keep the desired temperature

Inner layer: Double glazed, solar control windows to minimize heat gain into the building and minimize need for daylight.

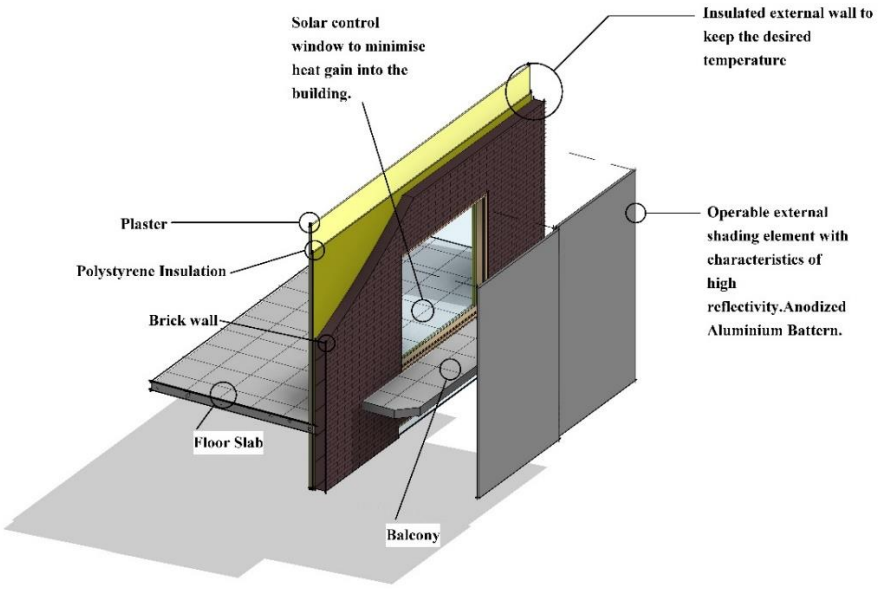


Figure 2.20: Graphic illustration showing the main component of the biomimetic building envelope

Source: Author (2019)

2.3 Resort Hotel

A resort hotel is a full-service lodging facility, intended primarily for vacationers and usually located in places frequented for relaxation or recreation, such as beaches, seashores, scenic, or historic areas, ski parks, spas. (Yahaya, 2012). Resort hotel typically includes entertainment and recreational activities, which sets it apart from smaller-scale city hotels. These hotels may be referred to as major conference centre hotel, flagship hotel, destination hotel.

2.3.1 Energy consumption in Resort Hotel

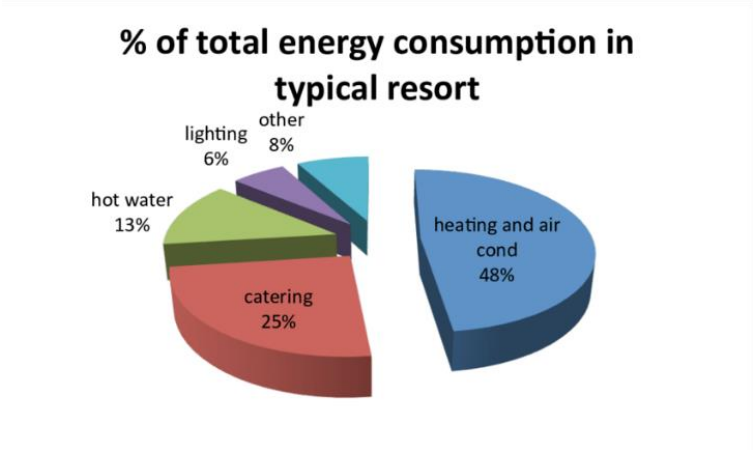


Figure 2.21: Energy consumption in a typical resort hotel

Source: Paul, (2011)

From figure 2.21 above, heating and conditioning of the accommodation takes a larger percentage of the whole energy consumption while lighting takes lesser percentage and other appliances takes a much lesser percentage. This implies that measures must be taken to reduce heating and cooling of spaces.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction

This chapter gives a detailed information on how the research was conducted to achieve the research objectives.to achieving these objectives of the research, quantitative and qualitative research approach were adopted to explore the biomimicry strategy to enhance energy efficiency and identify the relationships between variables

3.2 Research Design

The research adopted a descriptive and quasi-experimental approach in achieving the research objectives. The case study involved interviews, document reviews, direct and participant observation was evaluated qualitatively. This was achieved through the assessment and analysis of selected case studies which reflected application of biomimicry principles. The experimental aspect involved the simulation of data collected from case study which is further analysed with reference to cooling and heating load. The results were analysed in various tables, and graphs through which discussion of findings and conclusions were drawn to ascertain the level of enhancement.

3.2.1 Descriptive approach

For the objective to explore the concept of biomimicry as it related to energy reduction in building, a descriptive approach was adopted, and energy audits conducted on individual case models chosen for the study.

3.2.2 Quasi-experimental approach

Since the adaptation of the tree trunk strategy in Mambilla plateau is relatively a new concept, notable resort hotels are not yet available for real time test and field studies. A scaled miniature real time model is not considered viable for purpose of this research since according to several researchers in the field of this study there are definitive characteristics in dimension that ultimately affect biomimicry and operations.

The assessment of the tree trunk strategy and materials to determine the most effective for energy efficiency is explorative in nature and therefore based on a quasi-experimental approach. By identifying key variables, computer simulations were used to determine their effect on saving energy.

The tree trunk strategy tested by software simulation can therefore best replicate the conditions of an existing building tested close to the real environment.it provides relevant information regarding the thermal performance, computational fluid dynamics, HVAC, wind, lighting and energy consumption of a building.

3.3 Research Variable

The dependent variable, energy efficiency (cooling and heating load) is measured in Watts/Hour.

From the literature review, the independent variables to be examined are the imitation of the tree trunk which is external wall, window type and external skin material.

The different variables were selected based on their function from the imitation of the mechanism of a tree trunk. The window type selected was a solar control window to reduce heat gain into the building which is also the function of the inner layer of the tree trunk.an insulation external wall was selected to prevent heat loss which is the function of the waxy layer in the tree to prevent water loss from the tree. Five different insulating materials with the thickness of 75mm were tested on the wall to see the results (Polystyrene, wood fibre, stone wool, fibre glass and polyurethane foam).

The external skin material was selected based on its reflective characteristics to prevent direct solar effect into the building. The outer layer of the tree trunk performs the same function in preventing the other layers of the tree from the external environment.

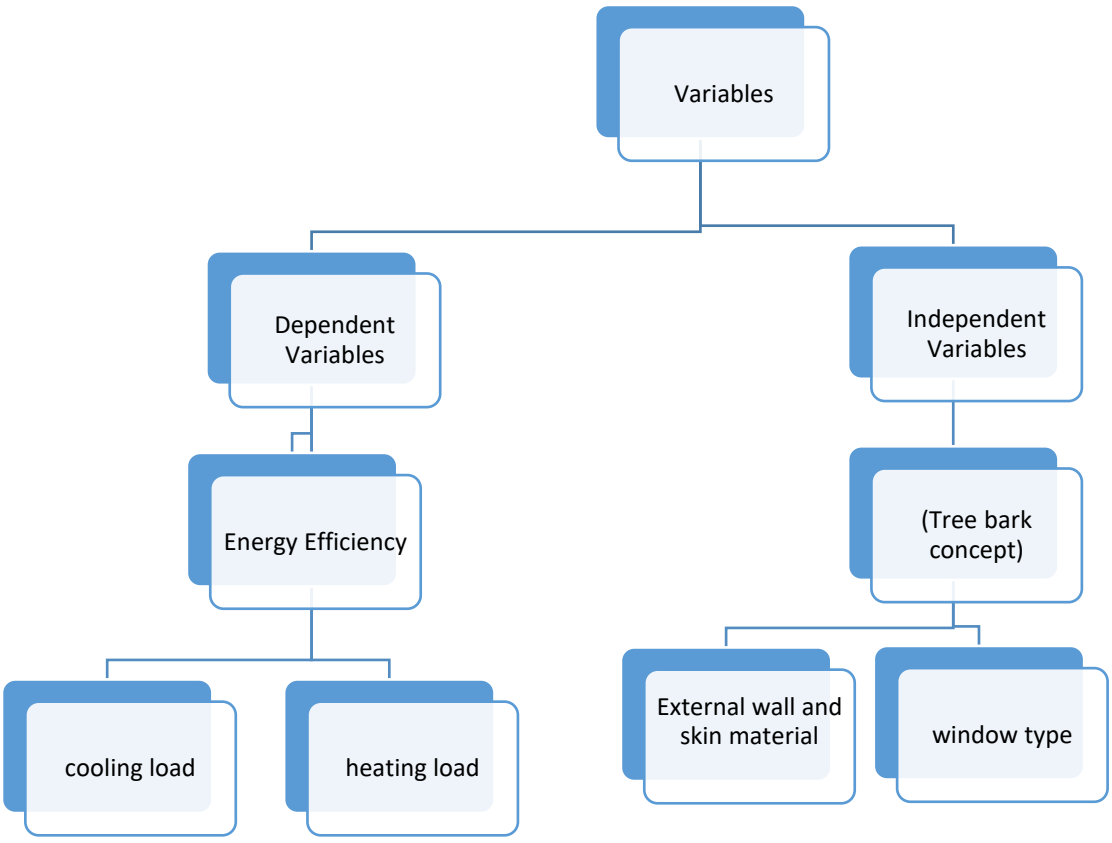


Figure 3.1: Research Variables

Source: Author, 2019

3.4 Population Study

For this research, the population of study basically consists of resort hotels in North-west and South-South of Nigeria with study focus on resort hotels with biomimicry principles applied on them. The case studies selected for the research are;

i. Porto Golf resort (Minjibir resort park), Gezawa-Minjir-kunya road Kano.
ii. Fifth Chukker Polo and Country Club,Kaduna
iii. Le Meridian Ibom Hotel, Akwa Ibom

3.5 Sampling

The purposive sampling method was adopted for this study in selecting cases for this research.

The case studies have been analysed based on the following aspects:

i. A resort in terms of facilities required to operate as a standard resort facility.
ii. Resort or a facility that possess some biomimicry design feature
iii. Availability of energy consumption data; Electricity consumption data of a year period minimally is required as the energy calculations will be performed over an annual period. This is crucial to validate the performance of the building over different seasons.

3.6 Data Collection

A preliminary site visit would be conducted; primary and secondary data would be obtained for analysis. A reference building model of the cases studied would be developed and the energy consumption of the base case models will be determined from both primary and secondary data obtained. The preliminary site visitations would be conducted following a pre-notification of scheduled visits. Energy audits, visual surveys

and observation would be conducted which entails guided tour round the site, taking note of electrical equipment and their power rating.

3.3.1 Primary Data

Primary data collected include building characteristics, physical inventory of all electrical equipment, and observation of building user behaviour. Also, collection of electricity consumption data on-site became unfeasible due to the availability of smart meters provided by the utility company.

3.4.1 Simulation

The case study building will be simulated using Design builder in different stages. A base case model would be first produced in Autodesk Revit as a replica of the case study. The model would then be imported and simulated using weather boundary conditions of Abuja as obtained from Weatherspark, 2019. Cooling loads and lighting load would be measured in kWh. The independent variables which is external wall material and roofing material choice would then be modified and implemented on the base case through which simulations would be performed. For all the simulated cases, the same weather boundary conditions would be adopted.

3.7 Instrument of Data Collection

The method of data acquisition for the case studies in his research would be:

I. Observation

II. Visual survey and checklist

III. Structure interviews and visual survey can be reflected in various formats such as:

   a) Photograph: photographs which would be taken for relevant case studies to ascertain the site and materials used

b) Sketches: sketches would be made from selected case studies. These case studies will show the spatial organisation of the space of the case study

c) Notes: notes will also be made in tabular form outlining the dependent and independent variables relating to resorts. For case studies on this research will be in Nigeria.

3.8 Methods of Data collection

The research being evaluative and quasi-experimental in nature, this study employed visual survey and assessment method (physical measurements and documentation) and energy audit to obtain data.

3.8.1 Energy audit

The energy audit was conducted in two stages, the first stage was a visual survey and observation and the second stage an inventory of appliances using a checklist. The information gathered was used to calculate the end use cooling load required by each building. An inventory of all cooling appliances was collected, and this did not involve lighting and other appliances. The cooling appliances consisted of a list of all fans and air conditioning appliances; their total number in each building with their operational schedule.

3.8.2 Visual survey and Assessment

Information such as the building characteristics such as the total floor area and building envelope characteristics, the number of occupants and hours of occupancy. Through an occupancy schedule, a sketch of the building plan or architectural drawings were obtained. A billing history of energy consumption by the utility company was collected

with alternative power source usage reports (where available) used for the same purpose as the utility bill due to unreliable power supply in the country.

3.8.3 Instrument of data collection

Instruments employed for data collection were camera, check list, note book, and sketch pad and measuring tape. The checklist included information about the variables observed during the survey. Photographs were taken to show existing situation of the cases assessed to support notes taken. Upon gathering relevant data from the case study visual survey, the base case was produced hence data collected via computational simulations.

3.8.4 Checklist

To aid the researcher in collecting data during the fieldwork, checklists attached in the appendix was prepared. The data gathered using the checklist was used to calculate the total cooling load of each building.

3.9 Data Analysis

Data obtained from the case study visual survey, interviews, sketches and photographs was documented, results were presented in form of charts, tables and graphs through which conclusions and recommendations were drawn. The techniques employed for data analysis in this research were; descriptive statistical and parametric analysis.

3.9.1 Descriptive analysis

The descriptive analysis was conducted to describe the existing characteristics and report the energy performance of the building using data collected such as the different energy of end users, materials used, geometry of the building, orientation and annual energy consumption. Statistical analysis will be used to describe relationships between

the variables. Data will be presented in form of descriptions given, photographs, tables and figures.

3.9.2 Parametric analysis

Parametric analysis was used to further analyse the variables. The aim of the parametric analysis was to observe the response following a change in a variable (Batagarawa, 2013). Various double skin cavity depth and external skin materials were simulated in order to identify their impacts on energy performance of the building. The data were presented in tables, graphs and charts.

3.9.3 Simulation process

The simulation was conducted using Design builder in different stages with a base case model was first produced in Autodesk Revit 2019 as a replica of the case study. The model was then imported and simulated using weather boundary conditions of Abuja as obtained from Weatherspark, (2019). Cooling loads were measured in (kilowatt hours) kWh. The independent variables (cavity depth and external skin material choice) were modified and implemented on the base case through which simulations were performed. For all the simulated cases, the same weather boundary conditions were adopted.

3.9.4 Building performance modelling tools

Building performance models are a valuable tool that can be used to evaluate the effects of different building designs, technologies, and control strategies before the construction of a building. It has been determined from literature and similar studies that the most feasible tools for this research are Design Builder and Energy Plus.

3.9.5 Selection of Design Builder simulation software

The selection of the software to use was based on the following criteria:
a. Capability of the software in modelling and energy calculations

b. Cost and researcher's skill of the software

c. Efficiency, availability and reliability of the software

Design Builder has a user-friendly interface which provides advanced modelling tools. Performance indicators such as energy consumption, carbon emissions, thermal comfort, daylight availability and cost can be provided throughout the design process in both naturally ventilated and air-conditioned buildings.

3.9.6 Validation of results

Issues have been raised on the validity of simulations tools, but similar studies have not adequately addressed this in their research which possess a research gap. To validate results from simulations in this study, a two-step approach was applied. Firstly, the case studied were modelled as the base case and simulated to get energy consumption data after which it was compared with data gotten from energy audit. Secondly, a comparative study was conducted to check the validity of the simulation software (Design builder).



Figure 3.2: Summary of the research Methodology

Source: Author, 2019

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 RESULTS/DATA PRESENTATION AND ANALYSIS

This chapter indicates details on how the data collected from cases studies were analysed, to achieve reduction of energy use in the building by minimizing cooling energy consumption through adaption of biomimicry strategy and testing the values derived from case study (energy audit) and simulation. Buildings selected for this case study fall under availability of facilities to categorise it as a resort and different climatic zones.

This section provides information peculiar to each building such as the physical characteristics, gross floor area, building envelope characteristics, window to wall ratio, annual energy consumption, the number of occupants and hours of occupancy through an occupancy schedule, a sketch of the building. The energy audit conducted is to investigate the electricity consumption of the resort accommodation. The total energy use or demand is further classified into cooling load, lighting and appliance load, this is because the research targets to reduce the cooling, thereby increasing energy efficiency.

All information collected from the case study served as the data input for the baseline case model on which various factor affecting building skin were applied and simulated for energy reduction.

4.1 Findings from Case Study One: Porto Golf Resort Minjibir, Kano.

This resort facility is located at Wasai, Minjibir, Kano. It is owned by a private body and situated at the outskirts of Kano State. It comprises of active recreational activities, restaurants, a wide range of green area which include the golf court, a cattle ranch and fresh milk production hall.

4.1.1 Room Types

There 3 main types of accommodation which includes the stable rooms, suites and chalets. The stable accommodation has a total of 28 single rooms,2 suite accommodation consisting of a room and living area,10 blocks of chalets consisting of 2 different apartments in each block and other single rooms. The accommodation sums up to a total of 56rooms.The chalets are hexagonal in shape with two different apartment enclosed in it. which includes a living room, bedroom, kitchenette and a toilet in each section.



Plate I: chalet Accommodation, Porto Golf Resort

Source: Author (2019)



Plate II: Stable Accommodation

Source**:** Author (2019)

4.1.2 Orientation

The building is titled such that the shorter side is facing the north – south axis and the longer side is facing the east-weat axis there by exposing maximum part of the building to solar radiation.



Figure 4.1: Showing the orientation of the building

Source: Author (2019)

4.1.3 Landscape

Buildings are surrounded by different types of soft landscape and evenly disturbed on the site. These trees and shrubs which serve as beatification to the surrounding of the building do not shade the building from solar heat gains.





Plate III: showing both soft scape and hardscape used on the site.

Source: Author (2019)

4.1.4 Building description

The building is a rectangular building that has a total of 28rooms and 2floors, each unit consist of a single room and a bathroom. Plate 1 above shows the space area with the bedroom having a total area of 24meter square, the toilet with an area of 3meter square.

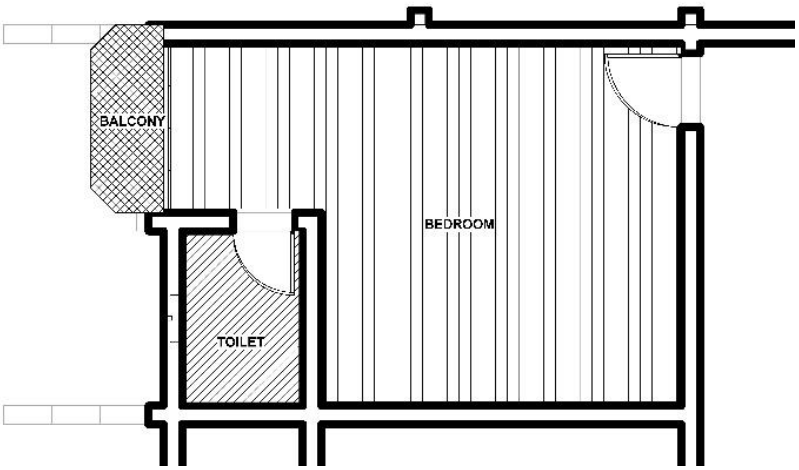


Figure 4.2: Call out of a single room on the first floor
Source: Author's Fieldwork (2019)

4.1.4.1`Walls

The building was made of hollow sandcrete blocks with standard mix proportion of 1:6 cement-sand ratios. The size of the block used is 225 x 225 x 450 mm for both external and internal walls. The walls were then plastered with a thickness of about 25mm on both sides and finished with no paint on the outside and white emulsion paint on the inside. Light colours are known to have low heat absorptivity and high reflexivity Properties. There is no wall insulation in the buildings and it was observed that the building has mechanical cooling using ceiling fan and air conditioner but rely on natural means and infiltration for ventilation.



Plate IV: exterior of the stable accommodation.

Source: Author's Fieldwork (2019)

4.1.4.2 Windows and doors

Windows were about 2100mm* 2400mm openable curtain walls which also served as access to the balcony, and the toilet with a size of 600mm * 600mm with internal curtains in the interior. Doors were aluminium flush doors of 900*2100mm,750*2100 and 1500*2100 for the entrance. The building has a window to wall ratio of 18.17%, and a total of floor area of 756m^2. There are expected to be 28 occupants given an occupancy of 27m^2 per person.

4.1.4.3 Roof

The building was covered with a green coloured 5mm thick long span aluminium hipped roof. The roof has a parapet of 450mm round the building, with a projected fin varying from 300mm to 1800mm long with served as shading.

4.1.4.4 Ceiling

The material used for ceiling cover was plaster of Paris screeded with thin layer of Plaster of Paris (POP) attached to the first-floor slab. A suspended 450x 450mm wide, 20mm thick white gypsum ceiling tiles is used in the first floor.

4.1.4.5 Floor

The floor is finished with 600x600mm glazed ceramic floor tiles laid on a 50mm cement sand screed and floor slabs made up of reinforced concrete slabs.

Table 4.1 Checklist of building skin assessment of energy efficiency

S/N	VARIABLES	FEATURES	REMARK
1	Wall	225*225*450mm hollow sandcrete wall,25mm plaster both internal and external	Use of adequate materials and light-coloured finishes.
2	Window to wall ratio	3mm thick clear single glazed window with aluminium framing	18.17% WWR which is efficient.
3	Window orientation		
4	Wall shading	Wall projection(fins) present	Projection provides minimal shading to the building.
5	Roofing	5mm thick green long span aluminium roofing sheet	Moderate solar reflection
6	Ceiling	Plaster of Paris (POP) finish white emulsion paint	Use of effective insulating material with high thermal mass. Bright and reflective surface prevents trapping of heat.
7	Orientation	The longer side of the building is facing north-south and it properly oriented	Proper orientation reduces heat gain into the building.
8	Landscape	Use of different types of soft landscape which occupies 40% of site.	Use of native plants which is sustainable.

Source: Author (2019)

The table above is a summary of the building assessment based on the checklist. The table indicates the variables, features (material specification) and remarks for the case study.

4.1.5 Energy consumption

The information recorded during the energy audit includes the appliances in the building, their power rating, and estimated hours of usage. The appliances were either used for cooling, lighting, and other functions. The resort solely depends on diesel generator as its source of power, and the hour of usage varies depending on the period. During festive period, the generator operates for 20-24hours while the non-festive periods it operators for 14-16hour.An average of the usage hour was taken to be 19hours which was used in the calculation. The stable accommodation has higher number of rooms in it with a total of 28rooms, the chalet had 4rooms total in each block. The energy consumption was calculated for the two main different types of accommodation (stable and chalet) and the stable accommodation had the highest consumption. Therefore, the information going to be used will from the stable accommodation since it had the highest energy consumption. The data gathered was used to calculate the energy consumption by the building and the total energy consumption is then classified into different end uses. Because the cooling load is based on degree -day analysis, cooling degree days are calculated and for this particular building, the calculated cooling degree days are 365 out of the total 365days.the calculated cooling load is 169,907.5Kwh, the lighting load is 18,031Kwh and other appliances load is 24,589.32Kwh. The total annual energy consumption is 212,527.82kwh which was the sum of all end uses. The source of power is from a 200KVA diesel generator.

The table below shows the summary of the data for energy consumption collected from the building. This includes the window to wall ratio, total floor area, occupancy per person, cooling load, lighting load, other appliance load and the total annual consumption which is the summation of the cooling, lighting and appliance load.

Table 4.2 Summary of Data collected from case study

Data	Stable accommodation
Wall to window ratio %	18.17%
Total floor area (m^2)	756m^2
Occupancy ($m^2/person$)	27m^2
Occupants	28
Cooling load(Kwh)	169,907.5Kwh
Lighting load (Kwh)	18,031Kwh
Other appliances(Kwh)	24,589.32Kwh
Total consumption/yr (Kwh)	212527.82Kwh

Source: Author (2019)

Table 4.3 Reflection of biomimicry principle on Case study one

BIOMIMICRY PRINCIPLE ONE: MIMICKING NATURAL FORM			
Variables	**Features**	**Level of reflection**	**Remarks**
		Abs Low Med High	
Building form (form and flow) exterior.	A symbolic natural form or natural built geometry form adopted to achieve the form.	0	Nil
Buildings relationship to site	Use of indigenous materials.	0	Nil

Source: Author (2019)

Table 4.4 Reflection of biomimicry principle on case study

BIOMIMICRY PRINCIPLE TWO: EXPLORING APPLICATION OF NATURAL PROCESS						
Variables	**Features**	**Level of reflection**				**Remark**
		Abs	**Low**	**Med**	**High**	
Energy/power source	-Integrated photovoltaic, facade system	0				Nil
	-Building integrated wind turbine, wind tunnels and shafts.	0				Nil
Energy conservation	-Automated operable window	0				Nil
	-Low e-glazing or double pane glazing	0				Nil
	-Use of courtyard, garden and pool of water to moderate the micro climate			1		Use swimming pool.
Re-usability of building materials	Use of recyclable or useable materials				2	Use of concrete, steel, wood, stone.
Application of smart materials	Control of solar radiation transmitting through building envelope and control	0				Nil
	of interior heat generation.	0				Nil
	Secondary energy					

	supply systems and optimization of lighting system.				
Environmental response to design features	Day lighting, use of sky light	0			Nil
	Use of natural lighting via stack effect.	0			Nil

Source: Author (2019)

Table 4.5 Reflection of biomimicry principle on case study

BIOMIMICRY PRINCIPLE THREE: LEARNING FROM ECOSYSTEM						
Variables	**Features**	**Level of reflection**				**Remark**
		Abs	**Low**	**Med**	**High**	
Source of water	Source of water is bole drilled on site.			3		Bore hole drilled on site
	Effort at harvesting, processing and recycling rainwater	0				Nil
	Use of on-site storm water treatment and ground water recharge	0				Nil
Working with site topography and native landscape elements	Retention of plants native to location as landscape elements.			3		Most of the native plants were retained
	Construction of building to follow the topography of the site.		1			Minimal cut and fill of the site.
Re generative site and design	Use of natural vegetation to control soil erosion.		1			Nil
	Use of tree to control micro climate of the building			3		Trees present on site.
Water conservation method	Presence of on-site water treatment plant		1			Water recycling is done in on-site treatment plant.

Applying integrated cyclic process &feedback loops	Use of water management and recycling	0	Nil
Minimal alteration of natural hydrological systems.	Minimal cover of site with impervious ground cover like asphalt and concrete walkways to allow for ground water recharge.	2	About 90% of total site are is previous to rain water.

Source: Author (2019)

4.2 Case Study Two: Fifth Chukker Polo and Country Club

The fifth chukker polo and country club is a luxurious 4-star resort strategically located along the Kaduna-Jos road, Kaduna state. It comprises of facilities like the conference Hall, Club House, Swimming pool, Stable and Accommodations.

4.2.1 Room types

The accommodations are basically one bedroom,2 bedrooms,3-bedroom apartment. The one bedroom is circular in shaped with a total of 30types strategically arranged on the site. The 2 bedrooms is rectangular in shaped consisting of two bedrooms with bathrooms each, a living room, kitchenette and has a total of 6 of this type of room and the 3bedroom a total of 2. The accommodation sums up to a total of 50.



Plate V: Single room and double room accommodation

Source: Author (2019)

4.2.2 Orientation



Figure 4.3: Showing orientation of the facility

Source: Author (2019)

4.2.3 Landscape

Buildings are surrounded by different types of soft landscape and evenly disturbed on the site

4.2.4 Building Description

The duplex accommodation is rectangular in shaped, consisting of 3 bedrooms, bathroom in each room, a living room, dining area and kitchen and a sit out area with balcony round the perimeter of the building on the first floor.

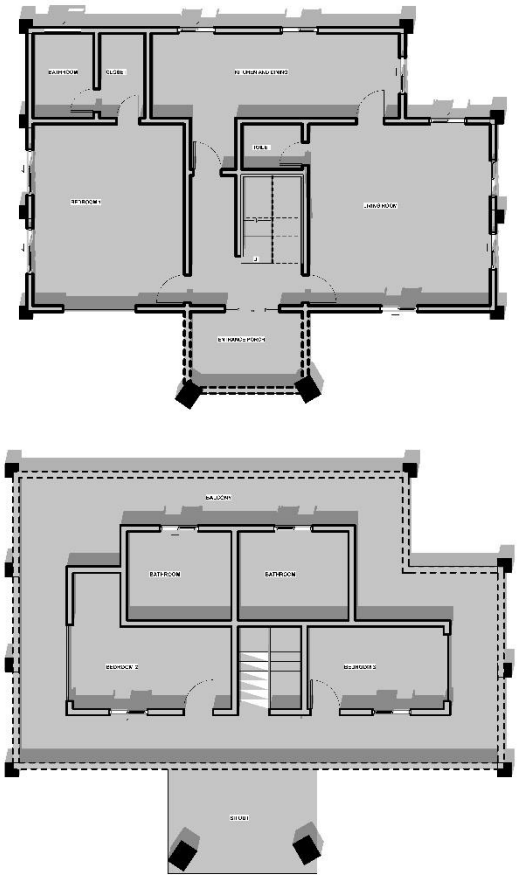


Figure 4.4: Ground and First Floor Plan of the 3bedroom
Source: Author's Fieldwork work (2019)

4.3.2.1 wall

The ground floor of the building was made of stone walls for the exterior part while the partitions were made of 150mm*225mm*450mm hollow sandcrete blocks with

standard mix proportion of 1:6 cement sand ratio. While the first floor was made of 225mm*225mm*450mm hollow sandcrete block. The walls were then plastered with a thickness of about 25mm on both sides except the ground floor exterior and finished with emulsion paint on the inside and outside. There is no wall insulation in the buildings and it was observed that the building has mechanical cooling using and air conditioner but rely on natural means and infiltration for ventilation.



Plate VI: Duplex accommodation
Source: Author (2019)

4.3.2.2 Windows

Windows were about 2100mm* 2400mm curtain walls,1500mm*1200mm,1200mm*1200mm, and the toilet with a size of 1200mm * 600mm with internal curtains in the interior.

4.3.2.3 Roof

The building was covered with brown coloured stepped tile hipped roof. The roof has an eave 600mm round the building with 300mm wooden fascia, with stone columns of about 450mm*450mm.

4.3.2.4 Ceiling

The material used for ceiling cover was plaster of Paris on the upper floor and concrete decking on the ground floor. The building has a window to wall ratio of 10.16%, and a total of floor area of 80m^2.



Plate VII: Interior of 3-bedroom duplex

Source: Author (2019)

4.3.2.5 Floor

The floor is finished with 600x600mm glazed ceramic floor tiles laid on a 50mm cement sand screed and floor slabs made up of reinforced concrete slabs.





Plate VIII: Exterior and Interior of the 3 bedrooms respectively

Source: Author's Fieldwork (2019

Table 4.6 checklist for building skin assessment for energy efficiency

S/N	VARIABLE	FEATURE	REMARK
1	Wall	Masonry wall,225*225*450mm hollow sandcrete wall,25mm plaster both internal and external	Use of adequate and sustainable materials and light-coloured finishes.
2	Window to wall ratio	3mm thick clear single glazed window with aluminium framing	10.16% WWR which is efficient.
3	Window orientation		
4	Wall shading	No wall shading provided	Shading provides minimal shading to the building.
5	Roofing	Brown stepped tile roofing sheet.	Moderate solar reflection
6	Ceiling	Plaster of Paris (POP) finish white emulsion paint	Use of effective insulating material with high thermal mass. Bright and reflective surface prevents trapping of heat.
7	Orientation	The longer side of the building is facing north-south and it properly oriented	Proper orientation reduces heat gain into the building.
8	Landscape	Use of different types of soft landscape which occupies 50% of site.	Use of native plants which is sustainable.

Source: Author (2019)

The table above is a summary of the building assessment based on the checklist. The table indicates the variables, features (material specification) and remarks for the case study.

4.2.5 Energy Consumption

The information recorded during the energy audit includes the appliances in the building, their power rating, and estimated hours of usage. The appliances were either used for cooling, lighting, and other functions. The resort depends on PHCN (power holding company of Nigeria) for a 4-6 hours' electricity supply and diesel generator as its source of power, and the hour of usage varies between 20-24hours.The 3-bedroom accommodation has 3bedrooms with bathrooms, kitchen, dining, living room, a sit out. The energy consumption was calculated for the 3-bedroom accommodation. The data gathered was used to calculate the energy consumption by the building and the total energy consumption is then classified into different end uses. Because the cooling load is based on degree -day analysis, cooling degree days are calculated and for this particular building, the calculated cooling degree days are 365 out of the total 365days.the calculated cooling load is 72,270Kwh, the lighting load is 3416.4Kwh and other appliances load is 8042.41Kwh. The total annual energy consumption is 83,728.81Kwh which was the sum of all end uses. The source of power is from 350KVA or 250KVA diesel generator depending on the population.

Table 4.7 Summary of Data collected from case study

Data	3bedroom accommodation
Wall to window ratio %	10.16%
Total floor area (m^2)	80m^2
Occupancy ($m^2/person$)	26m^2
Occupants	3
Cooling load(Kwh)	72,270Kwh
Lighting load (Kwh)	3,416.4Kwh
Other appliances	8,042.41Kwh

Total consumption/yr (Kwh)	83,728.81Kwh

Source: Author (2019)

Table 4.8 Reflection of biomimicry principle on Case study two

BIOMIMICRY PRINCIPLE ONE: MIMICKING NATURAL FORM			
Variables	Features	Level of reflection Abs Low Med High	Remarks
Building form (form and flow) exterior.	A symbolic natural form or natural built geometry form adopted to achieve the form.	0	Nil
Buildings relationship to site	Use of indigenous materials.	0	Nil

Source: Author (2019)

Table 4.9 Reflection of biomimicry principle on case study

BIOMIMICRY PRINCIPLE TWO: EXPLORING APPLICATION OF NATURAL PROCESS			
Variables	Features	Level of reflection Abs Low Med High	Remark
Energy/power source	-Integrated photovoltaic, facade system	0	Nil
	-Building integrated wind turbine, wind tunnels and shafts.	0	Nil
Energy conservation	-Automated operable window	0	Nil
	-Low e-glazing or double pane glazing	0	Nil
	-Use of courtyard, garden	2	Use of

	and pool of water to moderate the micro climate		gardens.
Re-usability of building materials	Use of recyclable or useable materials	2	Use of concrete, steel, wood, and stone.

Source: Author (2019)

Table 4.10 Reflection of biomimicry principle on case study

BIOMIMICRY PRINCIPLE TWO: EXPLORING APPLICATION OF NATURAL PROCESS			
Variables	Features	Level of reflection Abs Low 0Med High	Remarks
Application of smart materials	Control of solar radiation transmitting through building envelope	0	Nil
	and control of interior heat generation.	0	Nil
	Secondary energy supply systems and optimization of lighting system.		
Environmental response to design features	Day lighting, use of sky light	2	Use of balcony round building
		3	
	Use of natural lighting via stack effect.		Use of operable windows.

Source: Author (2019)

Table 4.11 Reflection of biomimicry principle on case study

BIOMIMICRY PRINCIPLE THREE: LEARNING FROM ECOSYSTEM						
Variables	Features	Level of reflection				Remark
		Abs	Low	Med	High	
Source of water	Source of water is bole drilled on site.				3	Bore hole drilled on site
	Effort at harvesting, processing and recycling rainwater	0				Nil
	Use of on-site storm water treatment and ground water recharge	0				Nil
Working with site topography and native landscape elements	Retention of plants native to location as landscape elements.				3	Most of the native plants were retained
	Construction of building to follow the topography of the site.				3	Minimal cut and fill of the site.
Re generative site and design	Use of natural vegetation to control soil erosion.		1			Nil
	Use of tree to control micro climate of the building				3	Trees present on site.
Water conservation method	Presence of on-site water treatment plant			2		Water recycling is done in on-site treatment plant.
Applying integrated cyclic process &feedback loops	Use of water management and recycling	0				Nil
Minimal alteration of natural	Minimal cover of site with impervious ground		1			About 90% of total site are is

hydrological systems.	cover like gravels to allow for ground water recharge.		previous to rain water.

Source: Author, (2019).

4.3 Case study Three: Le Meridian Ibom Hotel, Akwa Ibom

Le Meridian Ibom Hotel and Golf resort is a 4-star rated hotel opened in December 2007.It is situated in the hilltop ridge, with spectacular views over the surrounding rainforest stretching to the mountains of Cameroon. It is located along Nwanibe Road, uyo Akwa Ibom.The facility is a storey building with a total of 163room and 26suites.Other facilities include fitness and health centre, tropical garden, swimming pool for both adults and children, tennis court, conference hall and restaurants.



Plate IX: Showing entrance to Le meridian hotel

Source: Google (2019)

4.3.1 Building form

The building is rectangular with terraced rooms and suites some overlooking the greenery, while others landscaped courtyard. All spaces are all interconnected making

up the large edifice both in form and structure. The longer side of the building is facing the north-south direction while the shorter parts face the east-west direction. There is no significant local expression attributed to the building in form or structure.



Figure 4.5: showing orientation of the facility

Source: Google earth (2019)



Plate X: showing the sit-out

Source: Google (2019)

4.3.2 Building material

The main building materials used in the facility were hollow sandcrete block, steel and glass, long span aluminium roofing, wood and interior decoration. Bamboos and thatch roofs were used for the gazebos.

4.3.3 Landscaping

Both soft scape and hardscape elements were used in this facility. The soft scape consists of green lawns, shrubs, and trees of different species. The hardscape used were mainly asphalt for road, interlocking concrete block for walk ways.



Figure 4.6: Ariel view showing the landscaping of the site.
Source: Google (2019)

4.3.4 Energy and Energy sources

The main source of electricity to the resort is a diesel generator although electricity from the national grid is supplied to the facility but this source is not reliable.

The main source of water to the facility is an onsite borehole from which water is pumped to the reservoir. There is also an onsite water treatment plant that treats water

collected from the building. A Rain collector scheme strategy is also applied in this building to help water the plants.

Table 4.12 Reflection of biomimicry principle on case study

BIOMIMICRY PRINCIPLE ONE: MIMICKING NATURAL FORM						
Variables	Features	Level of reflection				Remarks
		Abs	Low	Med	High	
Building form (form and flow) exterior.	A symbolic natural form or natural built geometry form adopted to achieve the form.	0				Nil
Buildings relationship to site	Use of indigenous materials.	0				Nil

Source: Author (2019)

Table 4.13a Reflection of biomimicry principle on case study

BIOMIMICRY PRINCIPLE TWO: EXPLORING APPLICATION OF NATURAL PROCESS						
Variables	Features	Level of reflection				Remark
		Abs	Low	Med	High	
Energy/power source	-Integrated photovoltaic, facade system	0				Nil
	-Building integrated wind turbine, wind tunnels and shafts.	0				Nil
Energy conservation	-Automated operable window	0				Nil
	-Low e-glazing or double pane glazing					
	-Use of courtyard garden and pool of water to moderate the micro climate	0		2		Nil Use of courtyard and swimming pool.
Re-usability of building materials	Use of recyclable or useable materials			2		Use of concrete, steel, wood, thatch.
Application of	Control of solar radiation	0				Nil

smart materials	transmitting through building envelope and control of interior heat generation.		
	Secondary energy supply systems and optimization of lighting system.	0	Nil

Source: Author (2019)

Table 4.13b Reflection of biomimicry principle on case study

BIOMIMICRY PRINCIPLE TWO: EXPLORING APPLICATION OF NATURAL PROCESS						
Variables	Features	Level of reflection				Remark
		Abs	Low	Med	High	
Environmental response to design features	Day lighting, use of sky light				3	Use of court-yard systems and gardens
	Use of natural lighting via stack effect.				3	Use of operable windows and provision of fresh air via sky garden.

Source: Author, (2019)

Table 4.14a Reflection of biomimicry principle on case study

BIOMIMICRY PRINCIPLE THREE: LEARNING FROM ECOSYSTEM						
Variables	Features	Level of reflection				Remark
		Abs	Low	Med	High	
Source of water	Source of water is bole drilled on site.				3	Bore hole drilled on site
	Effort at harvesting, processing and recycling rainwater	0				Nil
	Use of on-site storm water treatment and ground water recharge	0				Nil
Working with site topography and	Retention of plants native to location as				3	Most of the native plants

native landscape elements	landscape elements.			were retained
	Construction of building to follow the topography of the site.		3	Minimal cut and fill of the site.
Re generative site and design	Use of natural vegetation to control soil erosion.	1		Nil
	Use of tree to control micro climate of the building		3	Trees present on site.

Source: Author (2019)

Table 4.14b Reflection of biomimicry principle on case study

BIOMIMICRY PRINCIPLE THREE: LEARNING FROM ECOSYSTEM					
Variables	Features	Level of reflection			Remark
		Abs	Low	Med High	
Minimal alteration of natural hydrological systems.	Minimal cover of site with impervious ground cover like asphalt and concrete walkways to allow for ground water recharge.			2	About 90% of total site are is previous to rain water.

Source: Author (2019)

Table 4.15 Case Study rating reflecting biomimicry principle

Principles	Case study one	Case study two	Case three
Mimicking natural form	0	0	0
Exploring application of natural processes	3	9	10
Learning from ecosystem	14	16	18
Total	17	25	28

Source: Author (2019)

4.4 Simulation

Findings from reviewed literature revealed that space conditioning consumptions up to 48% of the total energy expended by a resort thus providing opportunity for significant cut down of cooling load. This section provides relevant information regarding the

variables required to model the base-case. The effect of the variables is analysed parametrically using computer simulation.

The Design builder software was used in this research to carry out the simulation, which served as the graphical interface for the text based internal Energy Plus simulation engine. Energy Plus is a whole building energy simulation program used to parametrically evaluate the thermal and energy performance of the base case models.

4.4.1 Parametric Modelling

Base case model was produced using the Autodesk Revit 2014 software and exported as an energy model after which the model is imported into the Energy Plus Design Builder Simulation software. The location of the building, orientation, building coordinates and the weather data where imputed into the simulation software.

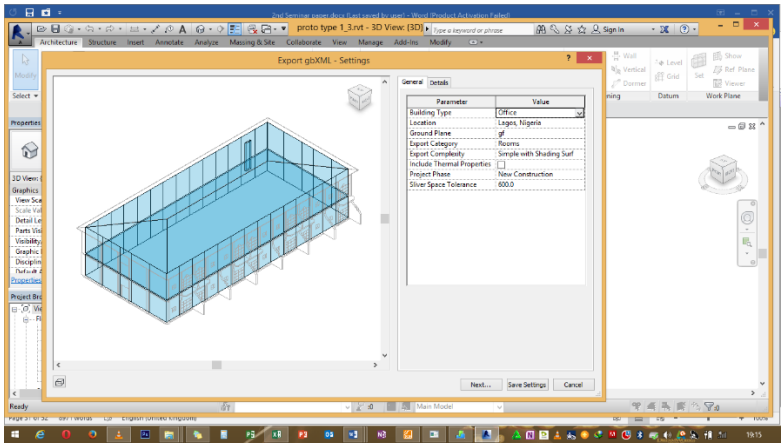


Figure 4.7 Revit14 model of the building as it is with the Energy Zones

Source: Author (2019)

The Model was derived from case study 1 which is a block of 28rooms and 2 floors high. The building as discussed above had the conventional 225* 225* 450mm sandcrete blocks adhered with mortar and plastered on both sides with 25mm sand: cement mixture, used both for external cladding and partitioning. The wall has an

estimated U-value of 1.4 W/m2K. Floors are solid; reinforced concrete slabs laid directly on the soil and finished with ceramic tile. The average U-value of such floors is calculated to be 4.4 W/m2 K. The building also had 3mm clear single glazing with internal curtains and a hipped roof with 0.55mm long span aluminium roofing material, the average U-value of the roof is calculated to be 1.95 W/m2 K. The building has a window to wall ratio of 18.17%, and the Total floor area (TFA) of 756m2. There are 28occupants in the building, giving occupancy of 27m2per person.

A summary of Thermal properties of the individual building components were also imputed as it exists in the building. This also serves as data for calculating the various U-values of materials.

Table 4.16 Thermal properties of the building material used to calculate u-value.

Layers	**Thickness (m)**	**Conductivity, k (W/mK)**	**Resistance,R (m2 K /W)**
External plaster	0.025	0.18	0.14
Sandcrete block	0.225	3.4	0.25
Internal plaster	0.025	0.18	0.14
Wall interior finishing			0.13
Ceramic tiles	0.025	0.8	0.01
Reinforced Concrete	0.15	2	0.15
Floor screed	0.025	0.4	0.06
PVC	0.015	0.6	0.02

A summary of the u-values of the building elements to be simulated is presented in table 4.17

Table 4.17 Summary of U-values for the building components

Building Component	**Model 1 U-value**

Sandcrete wall	1.4 W/m^2K.
Ground floor	4.4 W/m^2 K
First floors	4.2 W/m^2 K
Roof	1.95 W/m2 K
Glazing type	3mm Single, clear
Double glazing, solar control	1.5 W/m2 K
Insulated wall	0.8 W/m2 K
External Skin Material	
Anodized aluminium	W/m^2 K

4.5 Variable to be observed

As mentioned in the methodology, the independent variables to be examine are the external skin materials and their effects on cooling loads measured.

1) External skin materials

   An external skin material that matches the characteristics of the outer layer of TREE BARK(shading) would be tested namely anodized aluminium. This material has a 95% reflectivity and it is light.it is structurally durable, easily flexed and shaped.

2) Wall and window

   The wall and window material will also match the characteristics of the inner layer of the TREE BARK as it is characterized with insulation and material conductivity.

4.5.1 Constant variable

Throughout the simulations, a number of variables were kept constant, namely location and climate (Kano, Nigeria), internal heat gains, building use (Commercial, hotel), density ($20m^2$/person), orientation, window to wall ratio, geometry, schedules, occupancy, roof, ceiling and floors.

4.6 Validation of simulation software

To validate design builder as an efficient tool for the simulation of building skin in Buildings, a step validation process was employed. The information obtained from the stable accommodation building was used as earlier discussed to produce a base case of the building as it is to simulate the total energy consumption of the building and compare it with data gotten from energy audit.

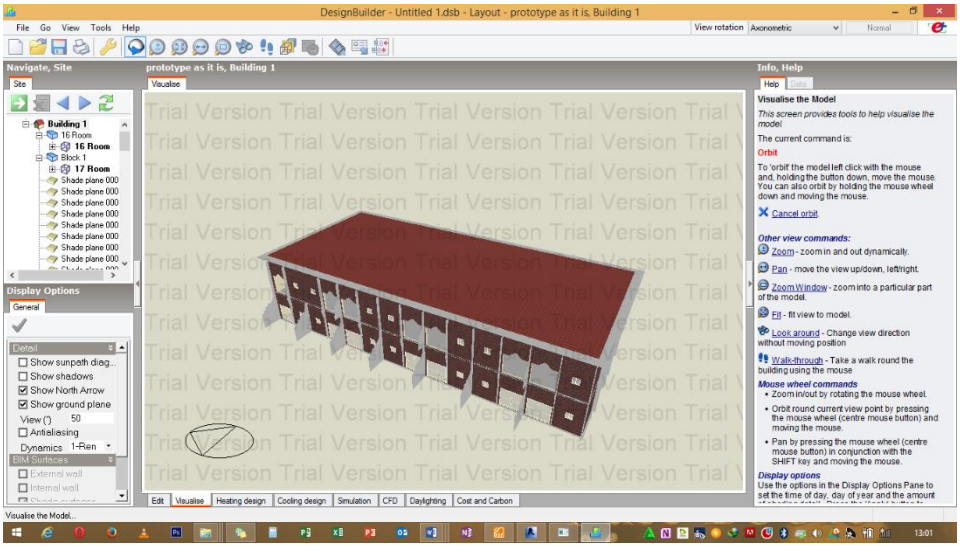


Figure 4.8 Base model in design builder interface as it is.

Source: Design Builder (2019)

These simulations reveal a significantly high percentage for cooling loads indicating the high demand and use of energy for cooling of resort accommodation buildings as earlier also pointed out from literature.

Table 4.18: Monthly and Annual energy load of base case model

Month	Cooling load (Kwh)	Lighting load (Kwh)	Other appliances (Kwh)
January	4282.794	586.9362	714.006
February	4644.585	530.1359	644.9086
March	11584.14	586.9362	714.006
April	21058.18	568.0027	690.9736
May	32196.36	586.9362	714.006

June	31209.13	568.0027	690.9736
July	23651.3	586.9362	714.006
August	13424.43	586.9362	714.006
September	16612.5	568.0027	690.9736
October	15497.42	586.9362	714.006
November	7470.272	568.0027	690.9736
December	4632.758	586.9362	714.006
Total	186263.869	6910.7001	8406.845
	Annual Total consumption		201581.414

Source: Author (2019)

From the simulation, the total energy consumption is 201,581.414Kwh with a total annual cooling load accounts for 186,263Kwh/yr and lighting load accounts for 6910Kwh/yr and other appliances account for 8406.845Kwh/yr. A simulation software is valid given that the result is +15% or -15%, therefore design builder as simulation tool for is valid since the difference in the result is 5.2 %.

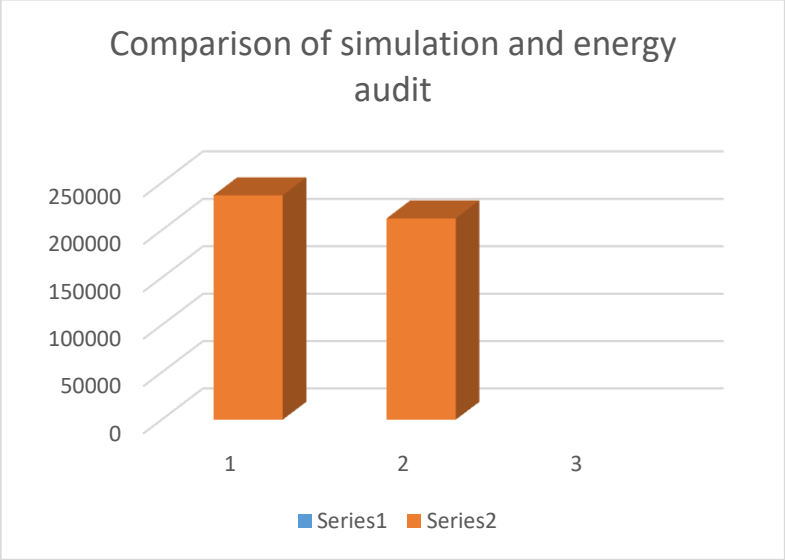


Figure 4.9: Validation of Result of simulation and energy audit respectively

Source: Author (2019)

4.7 Results from Simulation

4.7.1 Base case model

This building was modelled using Revit 2014 and imported into design builder, which is to be used to compare a base case without the biomimicry strategy implemented and a base case with the biomimicry strategy implemented. This is also used to compare results between frequently used simulation engines from similar research to further validate the simulation results.

Energy Plus Design Builder simulation of base case without biomimicry imitation.

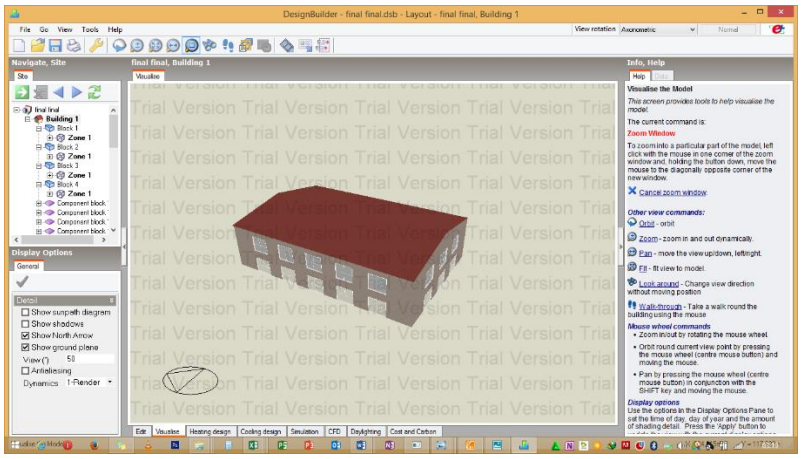


Figure 4.10: Base case model in the DesignBuilder interface without the biomimicry imitation (tree bark).

Source: DesignBuilder (2019)

Analysis was done for the base case model, having the best u-value of building components, orientation of the building with longer side on the east and west axis, which showed from the result that base case without biomimicry imitation (tree bark) consume 69,446.82kwh for cooling. The hottest month are the ones with high energy demand and June has the pick of about 11,319.46kWh. The lowest monthly energy demand is recorded in January with 1,984.032kWh.

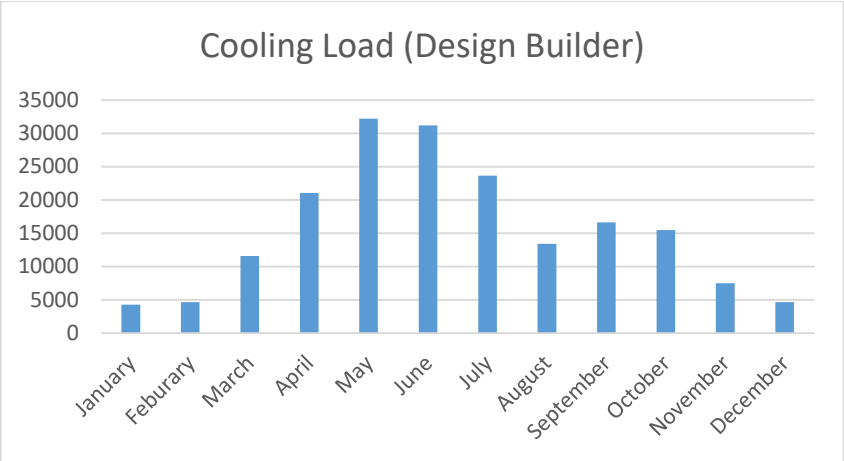


Figure 4.11: Monthly cooling loads for base case without tree bark imitation

Source: Author (2019)

Table 4.19 monthly cooling load of the base case model

Month	Cooling load (Kwh)	Lighting load(Kwh)	Heating load(Kwh)
January	1984.032	837.194	841.1077
February	2966.958	756.1752	212.6622
March	5410.415	837.194	0
April	8007.87	810.1877	0
May	11006.08	837.194	0
June	11319.46	810.1877	0.361411
July	7096.756	837.194	22.44004
August	4012.876	837.194	44.25749
September	6000.199	810.1877	23.88456
October	6435.126	837.194	1.284369
November	3148.732	810.1877	44.00518
December	2058.316	837.194	413.2887
Total	69446.82	9857.284	1603.292

Source: Author (2019)

The base case study simulated with the weather of Jos has a cooling load total of 36465.13kwh annually. June the hottest month has energy demand of 4468.936kwh cooling load while January has the lowest energy demand with a cooling load of 706. 1686kwh.heating load of 841.1077kwh is required in the month of January which

indicates that more heating is required than cooling. December also indicates the same with a cooling load of 1082.72kwh and heating of 413.2887kwh.

4.7.2 Optimal Model (Tree Bark concept)

The building was modelled in the design builder software, anodized aluminium was used for the external skin material due to it high reflectivity, light weight and durability characteristics, the external wall was insulated with polystyrene and gypsum plaster. The windows were double glazed with solar control coating. It was done to observe the effect of the tree bark imitation strategy on the building.5 types of insulation where tested on their ease for shaping and availability while the external skin and glazing remained constant.

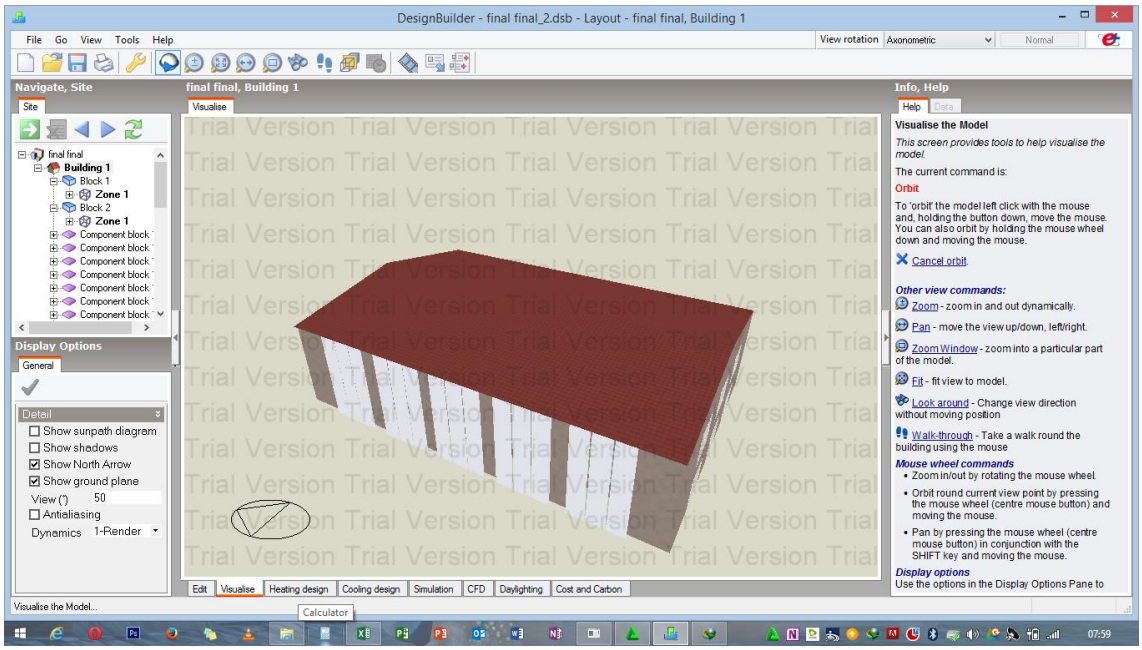


Figure 4.12: Base case model in the DesignBuilder interface with the biomimicry imitation (tree bark).

Source: DesignBuilder (2019)

The optimal model case which was carried out using the same variables as base case1 where settings were still maintained regardless of the size of the base case, though the

first trial was done with the weather file of Kano and later Taraba. Result show a significant difference in the cooling energy consumption in the second model case compared to base case that had no external skin or insulation. The annual cooling energy consumption for the base case was 69,442.82kwh and for optimal model was 27,384.34kwh which showed 60.57% decrease in cooling load using the weather file of Kano.

Table 4.20 Cooling loads with different insulating materials

Month	Base case Model (kwh)	Optimal model without insulation (Kwh)	Optimal model + polyurethane Foam (Kwh)	With fibreglass (Kwh)	With Stone Wool (Kwh)	Wood Fibre (Kwh)	With Polystyrene (Kwh)
Feb	2966.958	1518.187	737.9934	792.8132	778.9183	776.8745	737.9934
Apr	8007.87	5674.265	3733.457	3896.586	3848.365	3868.955	3733.457
May	11006.08	8571.314	5554.689	5797.967	5723.419	5761.213	5554.689
June	11319.46	9016.374	5614.256	5871.915	5792.337	5836.031	5614.256
July	7096.756	5204.288	2968.548	3120.907	3075.458	3095.031	2968.548
Sept	6000.199	3617.095	1903.128	2016.989	1984.552	1995.108	1903.128
Oct	6435.126	4296.352	2437.268	2570.8	2532.362	2543.823	2437.268
Nov	3148.732	1660.589	792.2824	847.1049	833.1012	828.8937	792.2824

Total	69446.82	46675.51	27384.34	28793.91	28383.88	28522.17	27384.34
Percentage Reduction		32%	58%	58.54%	59.13%	58.93%	60.57%

Source: Author (2019)

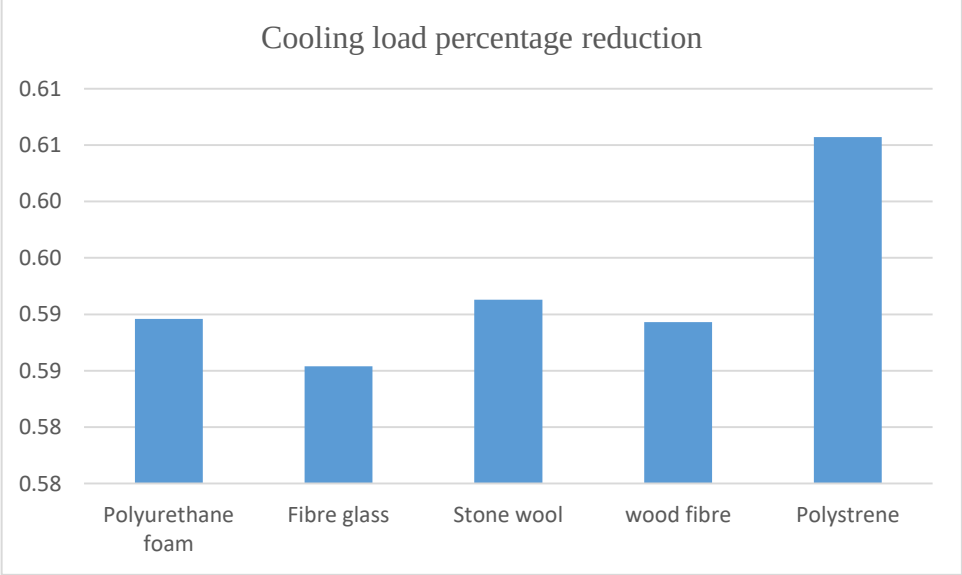


Figure 4.13: Cooling load percentage reduction of different insulation material.

Source: Author (2019)

Table 4.21: Monthly cooling loads for optimal model

Month	Cooling load(Kwh)	Lighting load (Kwh)	Heating load(Kwh)
Jan	336.0903	715.9858	1447.21
Feb	737.9934	646.6968	388.8559
Mar	1950.732	715.9858	6.375265
Apr	3733.457	692.8895	0
May	5554.689	715.9858	0
June	5614.256	692.8895	6.33719
July	2968.548	715.9858	94.09569

Aug	988.486	715.9858	164.3494
Sept	1903.128	692.8895	67.09317
Oct	2437.268	715.9858	19.36544
Nov	792.2824	692.8895	144.8479
Dec	367.4114	715.9858	836.4982
Total	27384.34	8430.155	3175.028

Source: Author (2019)

Optimal model simulated with the weather of Jos has a cooling load total of 16829.31kwh annually. April and June have no demand for heating but is cooled up to 3190.562kwh and 3433. 323kwh.June the hottest month has energy demand of 2101.448kwh cooling load and the lowest heating load of 6.33719kwh. while January has the lowest energy demand with a cooling load of 170kwh and heating load of 1447.21kwh is required in the month of January which indicates that more heating is required than cooling. December also indicates the same with a cooling load of 344kwh and heating of 836.4984kwh.

Table 4.22 Comparison of heating and cooling load in base case model and optimal model

	Energy consumption for base case model		Energy consumption for optimal model	
	Heating load(Kwh)	Cooling load(Kwh)	Heating load(Kwh)	Cooling load(Kwh)
January	841.1077	706.1686	1447.21	170.0965
February	212.6622	1999.128	388.8559	885.2176
March	0	4086.265	6.375265	2128.308
April	0	5679.108	0	3190.562
May	0	6081.944	0	3433.323
June	0.361411	4468.936	6.33719	2101.448
July	22.44004	2876.277	94.09569	1241.785
August	44.25749	1552.49	164.3494	408.1817
September	23.88456	2472.042	67.09317	801.7493
October	1.284369	3335.961	19.36544	1326.656

November	44.00518	2124.086	144.8479	797.9844
December	413.2887	1082.72	836.4982	344
Total	1603.292	36465.13	3175.028	16829.31

Source: Author (2019)

Result show a significant difference in the cooling energy consumption in the second model case compared to base case that had no external skin or insulation. The annual cooling energy consumption for the base case was 36,465.13kwh and for optimal model was 16,829.31kwh which showed 53.84% decrease in cooling load in Jos climate.

4.8 Summary of results for simulation

The method adopted focuses on adopting the tree bark biomimicry techniques which provides minimum energy consumption. Therefore, to evaluate the effects of tree bark on energy efficiency, building form having the same floor area, volume and envelope thermo-physical properties, where considered to achieve lower cooling loads on energy consumption.

Same analysis done for the base case model with Energy Plus Design Builder to compare the cooling loads patterns. This revealed similar but not exact cooling load patterns for each from the result for base case without biomimicry adaptation.

After the simulation of the base case models, it was observed that the biomimicry imitation with polystyrene insulation had the lowest annual energy consumption with a 60.57.0% decrease from the base case without a biomimicry adaptation. 60.57% reduction in energy consumption annually will immensely reduce cost of maintaining a building and reduce operational carbon emission which if not controlled can cause environmental problems.

Finally, it is concluded that:

i. The simulation process is valid and reliable for collection of Data for this study and the Energy Plus Design Builder simulation engine is valid for this research.

ii. With imitation of the tree bark strategy, it is observed that there was a decrease in cooling load by 53.84% compared to base case without biomimicry adaptation which was 34.4% in the cold climate.

iii. With anodized aluminum external skin, polystyrene insulation applied to the wall and Pilkington solar control windows, a total of 51.85% energy was saved.

iv. External skin material Anodized Aluminium with polystyrene insulation applied to the wall and Pilkington solar control window is observed to save 60.57% of total energy consumption compared to base case without biomimicry adaptation.

v External skin material Anodized Aluminium with wood fibre insulation applied to the wall and Pilkington solar control window is observed to save 58.93% of total energy consumption compared to base case without biomimicry adaptation.

vi. External skin material Anodized Aluminium with stone wall insulation applied to the wall and Pilkington solar control window is observed to save 59.13% of total energy consumption compared to base case without biomimicry adaptation.

vii. External skin material Anodized Aluminium with fibre glass insulation applied to the wall and Pilkington solar control window is observed to save 58.54% of total energy consumption compared to base case without biomimicry adaptation.

viii. External skin material Anodized Aluminium with polyurethane insulation applied to the wall and Pilkington solar control window is observed to save 58.96% of total energy consumption compared to base case without biomimicry adaptation.

ix. The study established that during the cold months, increase in heating load is as a result of adaptation of biomimicry strategy.

CHAPTER FIVE

5.0 DESIGN REPORT

5.1 Brief Development

A resort hotel is a facility providing accommodation and service for diverse classes of visitors which is its primary objective. For the design of a resort hotel candid consideration must be taken to adequately cater for the host of design requirement.

Biomimicry strategies aids in solving the high energy consumption and waste production associated with hotel will be considered for this study. A site (study area) must be selected for a design proposal to be complete.

Certain characteristics of each site will suit the project well while others will differ. This set of characteristics used in the analysis is what is termed as “Site Selection Criteria”. The site will be analysed based on climatic, visual, topographic, social, ecological, and cultural aspect of the site as to how best to utilize the site which will influence the design.

5.2 Site selection criteria

The selection of site for resort hotel happens to be an interesting task to carry out as it its takes cognizance of environmental sensitive areas that promote curiosity and interaction with nature. These areas exhibit interesting topographic terrain, excellent views, cool and conducive micro climate etc. The site is to be located in serene area with privacy and tendency for relaxation, therefore this lead to the siting of the proposed site in a mountainous area (Gembu) while exhibiting some of the features below according to the guidelines from Building Technical Manual (1996).

i. The proximity to residential area: the resort is expected to be located far away from town.
ii. Access to basic amenities and services: it should be close to an access road, electricity, water and telephone lines.
iii. Location/ Accessibility: the resort should be in an area which is easily accessible.
iv. Energy resources on-site: the resources should solar energy, wind, rainforest and biomass accumulation on-site.
v. Other on-site natural features: these elements such as rocks, plants, soil structure and gullies.
vi. Suitability of a resort: the site should be attractive and be able to use for recreational activities.
vii. Size of site, possibility of expansion, suitability and availability: site should be large enough to contain all resort facilities, accommodation and space for future expansion.

viii. Visual and aesthetics potential: site has to be visually and aesthetically pleasing and should also have the potentials to allow for use of a good architectural scheme to express the design organically.

ix. Land use compliance: the site most comply with the government land use decree and policy for the area.

5.3 Study Area

The proposed project site is in Gembu range, the headquarter of sarduna local government of Taraba state. Sitting at an average elevation of about 1,348m(4,423ft) above sea level, it is among the high elevated towns in Nigeria. Gembu is divided into three areas; Nguroje axis (adjoining Gashaka-Gumpti park area), Gembu axis where the Emir resides (city centre) and Mbamga axis (border area). it is located on Latitude 6°42’0’’N and Longitude 11°16’0’’E and covers 9.389 square kilometres with its southern and eastern escarpments bordered by the Republic of Cameroon. The surface of the plateau, which has a blend of evergreen low growing grass vegetation, neatly demarcated into ranches and grazing reserves, and the sharply meandering roads with hairpin corners across hills slopes, ravines and deep gorges, make driving to and from the plateau most astounding and interesting to a visitor. Along with the many cattle ranches and farm houses, the Nigerian Beverages Production Company Limited (Kakara Tea Estate), makers of highland Tea, is also located in Kakara on the plateau.



Figure 5.1: The study area Gembu, Taraba State.

Source Google, 2020

5.3 1 Site One

The site is located close to Kusuku settlement, few kilometres away from Karaka town.it has an area of 273,002m2 and a perimeter of 2,086m. it is located on Latitude 6°52’4.38’’N and Longitude 11°8’1.19’’E

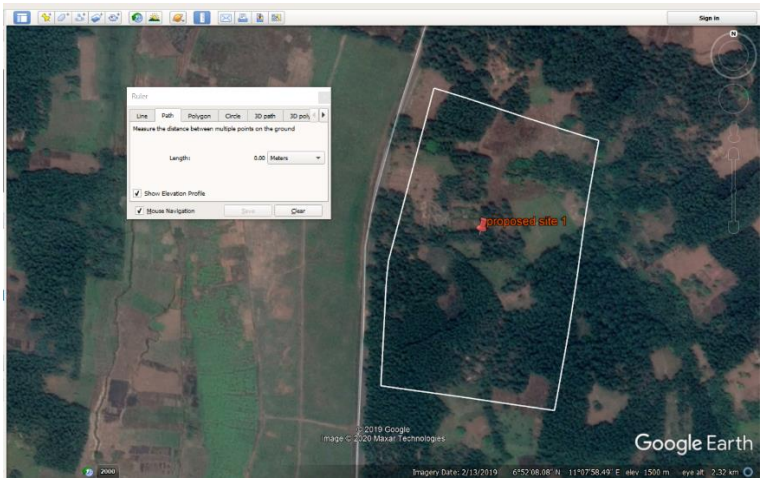


Plate XI: Proposed site one

Source Google earth, 2020

5.3.2 Site Two

This site is located few kilometres away from Kakara along Donga-Gankoi Yeba road. it is located on Latitude 6°48’23.52’’N and Longitude 11°6’39.02’’E with a land area of 65,469m2 and perimeter of 1,016m



Plate XII: Proposed site two

Source: Google earth, 2020.

5.3.3 Site Three

This site is located from Nguroje-Gembu federal road on the north western part of gembu metropolis for proximity and ease of access, this is also for development opportunity.it is located on Latitude 6°52’8.77’’N and Longitude 11°11’35.81’’E and has a land area of 108,906m2 and a perimeter of 1,272m.

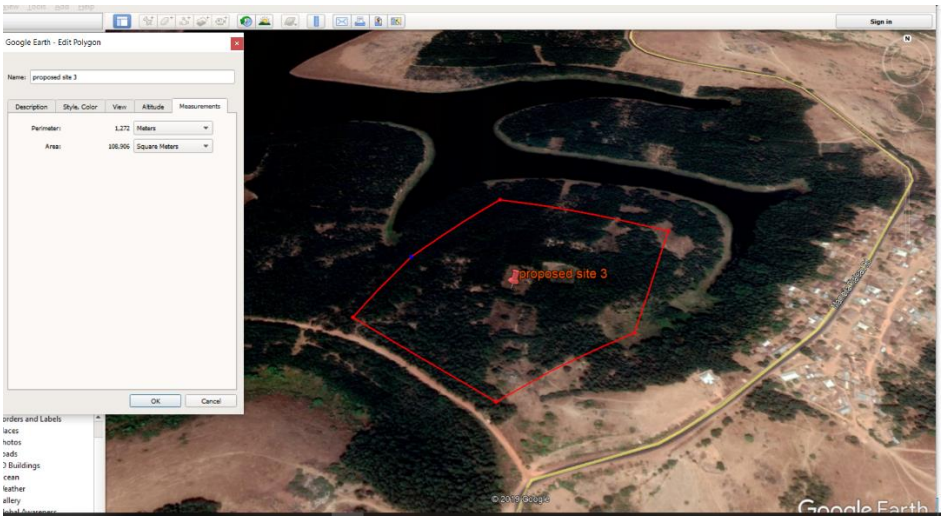


Plate XIII: Proposed site three

Source: Google earth,2020.

5.4 Assessment of Site

The three sites selected will be compared based on the identified criteria listed below and ranked based on a five-point scale. The rating point range for 1=not suitable, 2=suitable, 3=averagely suitable,

Table 5.1 Assessment of site characteristics

S/N	Criteria	Site 1	Site 2	Site 3	Remark
1	Proximity to residential area	4	4	4	All sites are close to a small settlement.
2	Location/accessibility	2	4	4	Two sites are located along main access road expect for site 1.
3	Access to basic amenities and	2	3	3	All site has proximity to amenities expect for site

	services				1
4	On-site energy resources	4	3	4	Site 3 has high vegetation, water body area it.
5	On-site natural elements	4	3	5	All sites have rocks and laterites.
6	Size of site, possibility for expansion	5	3	4	Site 1 shows higher possibility of expansion than others.
7	Suitability for a resort	4	3	5	Site 1and 3 will create a better environment for activities.
8	Land use compliance	4	4	4	
9	Visual aesthetics potential	4	3	5	All sites have aesthetic potential as they can be visually accessible from the road
	Total	**33**	**34**	**38**	

Source: Author (2020).

5.5 Proposed site

Results from table 5.1 above indicates that site 3 is the most suitable site.

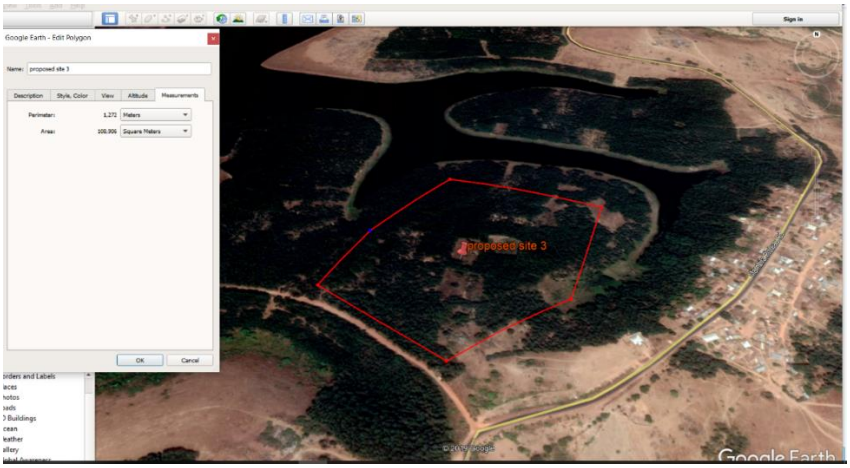


Plate XIV: Selected proposed site

Source: Author (2020)

5.5.1 Site Features

The site is located from Nguroje-Gembu federal road on the north western part of gembu metropolis for proximity and ease of access, this is also for development opportunity.it is located on Latitude 6°52’8.77’’N and Longitude 11°11’35.81’’E and has a land area of 108,906m2 and a perimeter of 1, 272m.the site on the north and west

side is covered with vegetation and water body, an access road by the east of the site with settlement across the road. A secondary access to other settlements around from the south side of the site. Service lines, electricity grid will be tapped from the nearby settlement.

5.5.2 Site analysis

For comprehensive study to be carried out the site is analysed taking into cognizance both natural and man-made features affecting the site.

5.5.2.1 Climate

The climate of the site is same as the general area (Gembu) in which the site is located in.

5.5.2.2 Topography

This depicts the natural drainage pattern in which the site slopes difference between the highest and lowest points being 10m in height, the site naturally drains towards the north western part of the site.

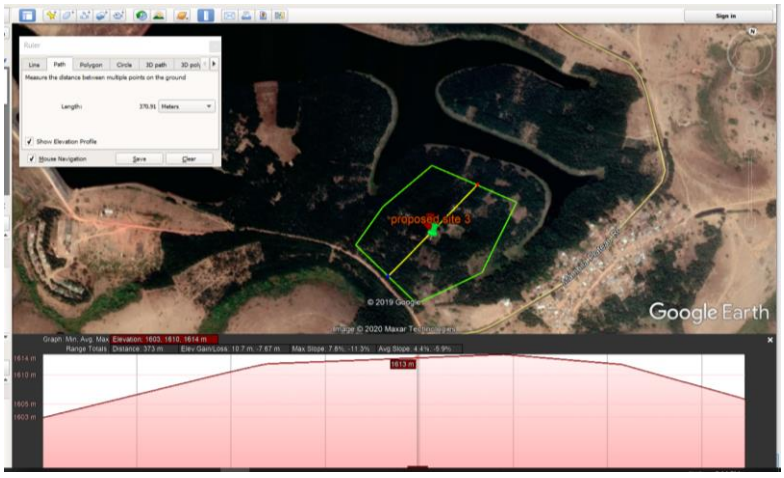


Plate XV: section north-south axis

Source: Google earth, (2020)

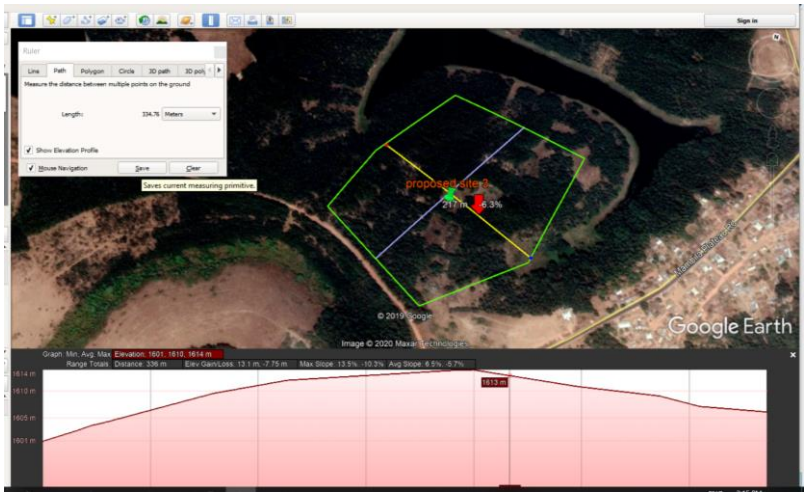


Plate XVI: section east-west axis

Source: Google earth, (2020)

5.5.2.3 Vegetation

The nature of the vegetation on the site is a thick green with part covered in trees, shrubs and grasses, for landscaping purpose most of these will be integrated into the design. A water body is also identified on the north side of the site. These will help the micro climate of the site.

5.5.2.4 Temperature

The plateau is relatively cold with the mean temperature of about 20.1°C with the highest about 27°C and the lowest 11°C recorded during the rainy season in mid-august.

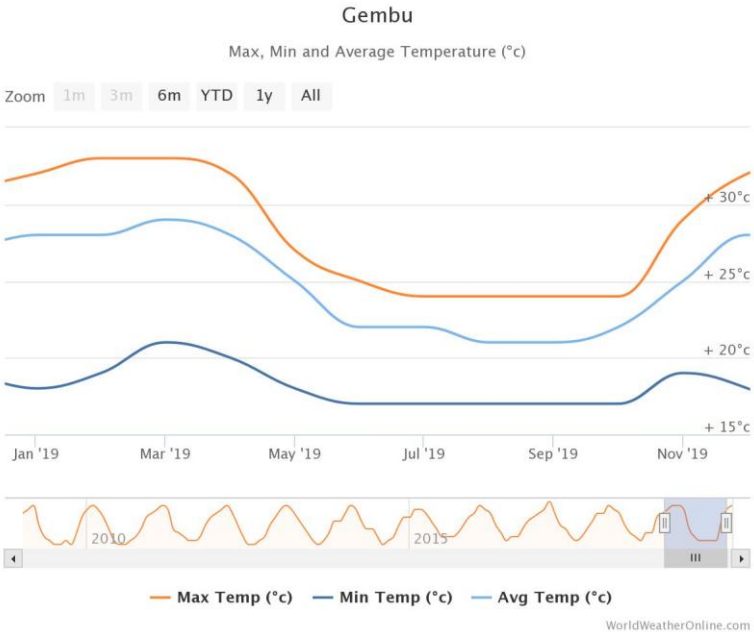
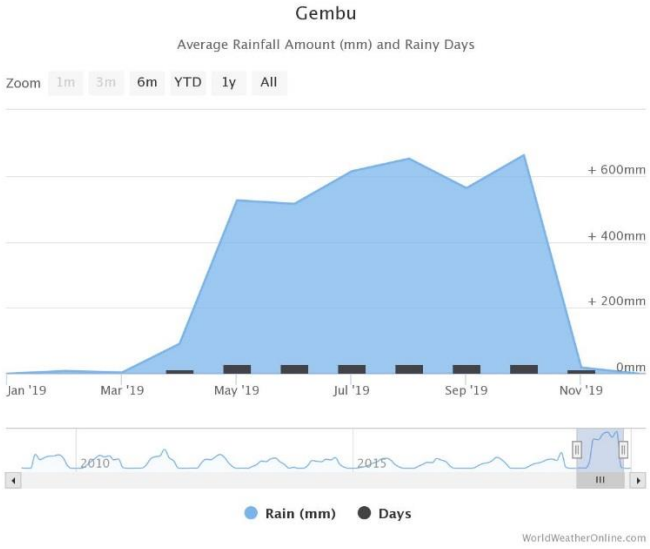


Figure 5.2 Temperature graph of Gembu

Source: worldweatheronline.com, 2020

5.5.2.5 Humidity and Rainfall

Rain is quite long almost all through the year due to the topography with an average annual rainfall of 1766mm, with October having the highest rain of about 1,850mm while February having lower than 100mm of rain.



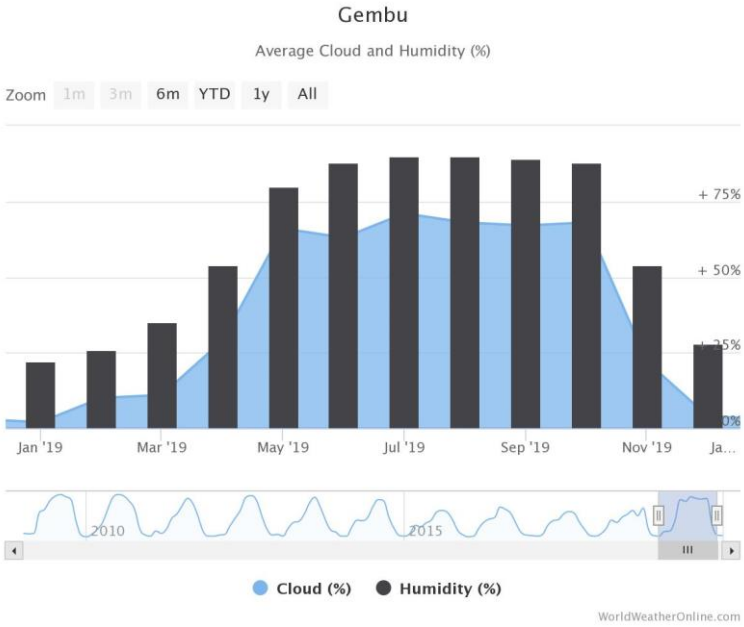


Figure 5.3: Rainfall and Humidity chart

Source: worldweatheronline.com, 2020

5.5.2.6 Wind

Based on the geographic location of the plateau, the winds are predominantly high all through the year especially higher during the day time with 13.6km/hr high during January and 4km/hr low during September as this helps keep the temperature at a relatively low state.

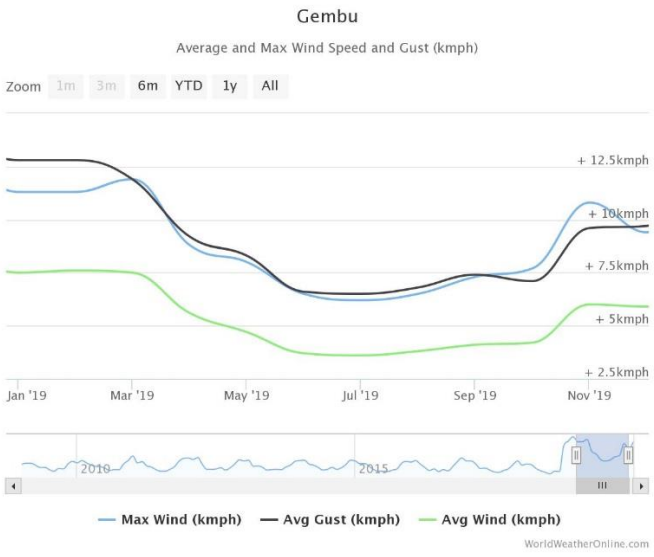


Figure 5.4: Wind speed chart

Source: worldweatheronline.com,2020

5.6 Design Brief

Considering Gembu with its enormous cultural heritage and exceptional topography makes it conducive for attracting tourist of summing to about 10000 visitors annually who come from different parts of the world. They engage in activities such as site seeing, tours, picnics, boating, vacationing, meetings and conferences. Due to the high increase in numbers hence the federal government in collaboration with an NGO (Green world tourism) decided the need for a hotel facility. Based on feasibility studies carried out about 750 visitors flock the Kakara tea plantation with average of 25 visitors daily.

For a hotel to function from literature review is said to have an average of 50% occupancy of the total number of room available. The proposed resort hotel provides services for about 110 rooms which categorised different categories of guest in present and future.

5.7 General and Specific Requirements

Below is the minimum spatial requirement for the proposed hotel;

Reception: the entrance hall provides for security post displaying information for guests, satisfactory circulation space provided to ease movement for crowds at crowning periods. And large lounge (general and private) inclusive of a bar and entertainment area to be provide for guests before room allocation with service such as stairs, lifts, toilets.

Indoor and outdoor Restaurants with joint total capacity to cater for hotel guests with efficient room service, it provides both continental and traditional cuisines.

Total of 2 restaurants of 30-50 capacity to cater for special guests of higher class this is provided at the upper floor with pent house for royal guests. Also, the indoor bar is to provide 24hours services and entertainment for guests and visitors.

Multipurpose and conference halls are adequately provided for meetings and conferences with various seating capacity in mind with multipurpose hall having a flexible stage which could be used for different activities with accurate consideration given to acoustics, seating and safety requirements in conformity with contemporary hall design. These facilities are an 80-capacity conference room, 200-capacity conference including a syndicate room and a 200-capacity multipurpose hall and an outdoor banquet area.

Administrative offices for the facility to run the affairs of the hotel smoothly include the following spaces; General office, facility manager, account office, front desk office, maintenance office, board room and staff lounge.

There is a 60-capacity cinema, badminton court, mini golf course, table tennis, outdoor swimming pool.

The accommodation has the following room types; studio rooms, double suites, executive suite, business suite, penthouse and chalets.

Parking and outdoor services; about 65% of the site is landscaped with vegetation of different species, also this will be in cooperated in the parking area. For parking spaces, a ratio of 1:2 bed spaces for overnight guest, 1:3 daytime visitors excluding the staff and restaurant users.

5.8 Schedule of Accommodation

SCHEDULE OF ACCOMMODATION

SPACES	MINIMUM REQUIREMENT (m2)	NUMBER REQUIRED (m2)	AREA	TOTAL AREA (m2)
ADMINISTRATION				
Reception and waiting area	35	1	90	
Front desk office	27-30	1	50	50
Facility Managers office	27-30	1	45	45
Staff meeting room	1	1	40	40
Staff lounge	2	2	40	80
Laundry and house keeping	27-30	1	30	30
Maintenance office	1	1	30	30
Account office	27-45	1	35	35
General office	27-45	1	45	45
ACCOMMODATION				
Studio room	16-20	72		
Double room	36	38		
Suite 1	42	4		
Suite 2	46-50	4		
Penthouse	60-100	4		
Chalet	60-80	6		

SPACES	MINIMUM REQUIREMENT (m2)	NUMBER REQUIRED (m2)	AREA	TOTAL AREA
BUSINESS FACILITIES				
Conference hall	1.2 per person	2	80-100	336
Banquet hall	1.5	1	250-300	175-385
Meeting room	1.2	2	20	50
Control room	30-37	2	30	60
Laundry	0.9	1	10	10
Restaurants	2per person	2	80-100	160-200
Kitchen	2	2	20	40
Bakery and pastry	1	1	30	30
Changing room	0.8-1.0	1	10	10
Gymnasium	80-100	1	100	100
Spa and sauna	60-80	1	80	80
Lounge and bar				
Lettable spaces	12-30	3	30	90
Coffee shop	45		45	45
RECREATIONAL FACILITIES				
Outdoor swimming pool	16.66*25	609		
Indoor swimming pool				
Outdoor garden				
Indoor garden				
Bush bar				
Indoor games unit				

14

ENHANCING ENERGY EFFICIENCY THROUGH ADAPTION OF BIOMIMICRY STRATEGY IN THE DESIGN OF A HOLIDAY RESORT HOTEL, MAMBILLA PLATEAU.TARABA STATE

P17EVAT8073

KEVIN ANITA
SUPERVISORS
Dr. M.S. BALA
Arc H. O. SALIHU

Figure 6. 1: schedule of accommodation

Source: Author 2021

5.9 Design Consideration

Spatial organisation and design layout and zoning: the positioning and location of the facilities on site is in conformity with site. The pattern of movement on site is such that pedestrian is separated from vehicular circulation.as part of effort to increase human-built environment relationship, guest vehicular is terminated at the front of house, while pedestrian circulation continues round the building with emphasis on interaction with the surrounding nature. Within the building facility, the proper activity zoning is ensured which included clear separation of the back of house from the front of house facilities. Horizontal movement is via lobbies while vertical movement is via stairs and lifts, the building staff areas are secluded from guest areas to avoid interference of the guest experience.

5.9.1 Building materials

The selection of materials for use in the scheme is to emphasize overall sustainability which is the goal of the regenerative architecture. Materials with less negative impact on the environment or having recycle content have been adopted for the entire scheme.

5.9.1.1 Natural Form

Natural stone is employed for use onsite for walkways. This is to embark the shorelines to arrest the effect of rise in water level.it is also used as the material for walkways within pedestrian circulation areas on site.

5.9.1.2 Pilkington solar control windows

Glass in use controls solar radiation into the building and possess several green qualities since it is recyclable.it can be employed as the major element in the buildings permitting daylighting and creating visual contact with the environment.

5.9.1.3 Steel

Steel is exceptionally strong, extremely flexible in design and very cost effective especially when used for the reinforcement of the beams and lintels

5.9.1.4 Concrete

The fluidity of concrete makes it a good construction material for the floors, lintels and beams. Concrete is flexible, especially when used with moulds and reinforcement, however it is quite heavy.

5.9.1.5 Anodized aluminium

It is favourable towards current environment regulations because it is one of the most environmentally friendly industrial processes and is typically not harmful to human health.it is heat resistant to the melting point of aluminium.it can be reclaimed, recycled, and reused.

5.9.1.6 insulated wall

Polystyrene insulation will be laid on concrete wall which will serve as a good thermal insulation for the external wall. It will control heat gain and loss into the building.

5.10 Design Concept

5.10.1 Building Form

The building plan arrangement evolve from the circular nature of the cross section of a tree trunk. The leaf like shaped of the chalet was adapted also as it is part of a tree and helps in supplying nutrients to the tree.so also is the function of the chalet. The roof of the chalet is to serve as rain collector.

The building form concept harnesses; Harmony of building to site and surrounding, in terms of forms and materials, giving it a uniform identity with the site features: the hilly

range. The exploration of the curvilinear, typified by the dominance of curved lines over the straight. Fractal principles applied the textural progressive design of the parking spaces and the self similar shapes of the different buildings.

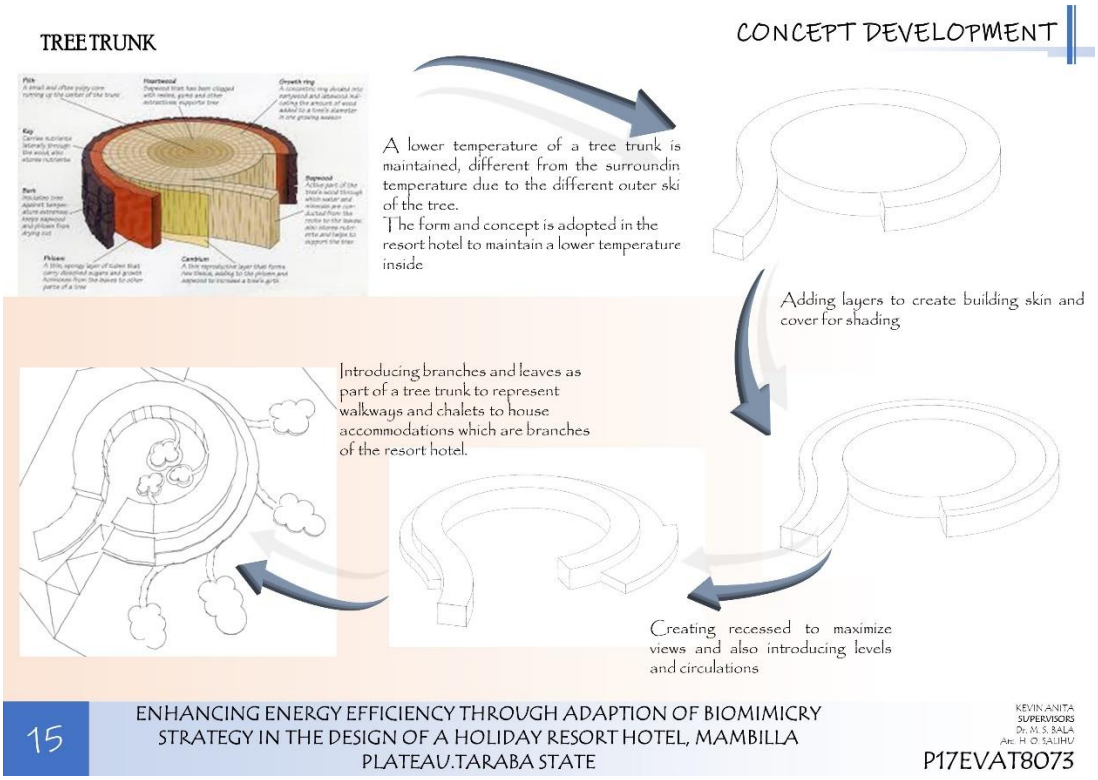


Figure 6.2: Design Concept

Source: Author 2021



Figure 6.3: Elevation

Source: Author, 2021



Figure 6.4: Elevation

Source: Author, 2021

5.10.2 Site Planning and Landscaping

Site planning as an integral part of the design content was put into consideration. Existing

conditions on the site such as rocks, stony soil conditions and steep slopes were considered in the general layout of the site, spatial arrangement and landscaping. The road layout was designed to follow the contours of the site to check for minimal cutting and filing. Stone paving was used for the walkways, to emphasis use of natural materials.



Figure 6.5: Site Plan

Source: Author 2021

5.10.3 Circulation

For the pedestrian and vehicular traffic conscious design efforts was inputted to enable differentiation. The layout of the circulation was designed to allow for guests to drive or walk within the site and experience the scenic views, provides the guest an opportunity to be exposed to nature and the natural scenes of the hills, landscape and water body.

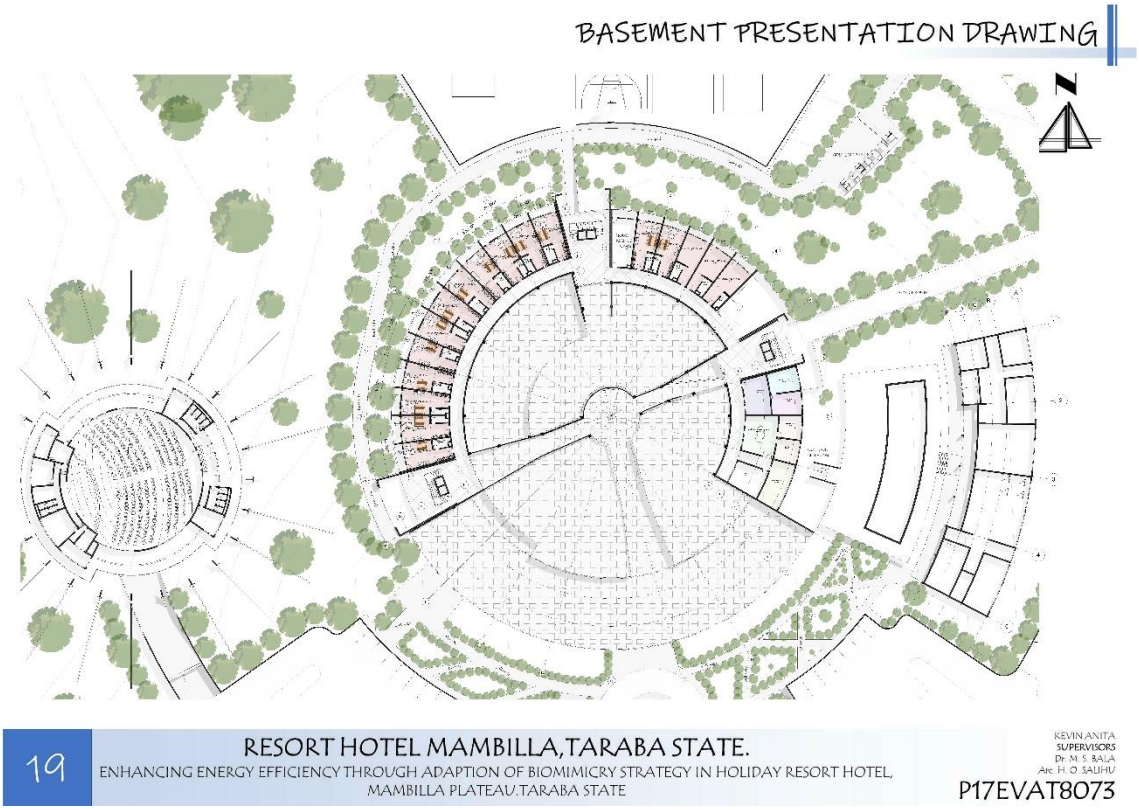


Figure 6.6: Basement Floor plan

Source: Author 2021

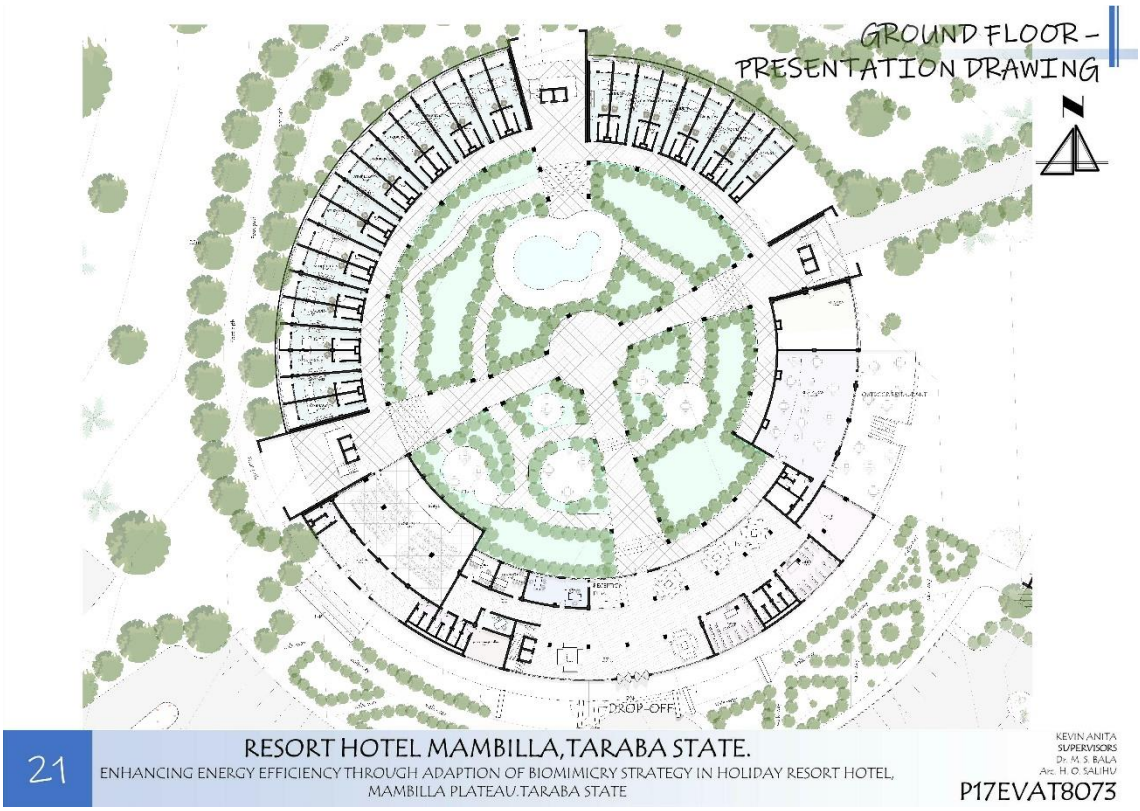


Figure 6.7: Ground floor Plan

Source: Author 2021

5.10.4 Energy Harvest

Building integrated Photovoltaics were used in the roofs of the structures. These are photovoltaic materials that are used to substitute conventional building materials in parts of the building envelope such as the roof. They were being merged into the construction of buildings as a principal or secondary source of electrical power. The benefit of integrated photovoltaics over common non-integrated systems is that the initial cost can be offset by reducing the amount spent on building materials and labour that will normally be used to construct the part of the building that the BIPV modules replace.

5.10.5 Water Harvest

Rainwater harvesting was provided for in the design. Rainwater collected from the roofs of the chalets, can make an important contribution to the availability of water for

domestic

purposes. Roof rainwater collected cannot be of good quality and may require treatment before consumption or domestic usage. It can be useful in flushing toilets, washing clothes, watering the garden and washing cars.

5.10.6 Spatial Organisation

The buildings were fully exposed to cooling winds. To ensure free movement of air through the site, resort buildings were located a fair distance from each other; this also avoids barricading breezes. Another contemplation was the zoning of the facilities according to usage. The public spaces such as the shops, multipurpose halls, and relaxation spots were placed correspondingly as a visitor approaches the resort. Private spaces, basically the relaxing gardens and guest chalets were located deep into the site for control of noise, and to provide privacy to the guests.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

With the need to reduce energy demands in buildings, different alternative ways have been identified to help solve this problem. Building skin, a sub category of Biomimicry is one of the strategy identified. This involves identifying a solution from nature which is like the problem been encountered. This solution could be from animals or animals as the case maybe. The most common type of biomimicry is copying surface morphology.

The concept of energy efficiency has become a significant consideration in the construction industry due to its benefits in saving cost and reduction in resource exploitation and environmental degradation.as the demand for energy increases and the source of this energy is fossil fuel which has a negative effect on the environment at large. Therefore, there is need to get an alternative means of reducing energy demand which is environmental friendly.

Biomimicry in architecture finds inspiration in the strategies, technologies and concepts that living organisms use to meet their needs and ensure their survival on earth. The main idea of biomimicry is copying from nature the solution it has already found for the problems we are struggling from. This solution could be from animals or animals as the case maybe. The most common type of biomimicry is copying surface morphology. These are copied to achieve functionality, aesthetics or efficiency in building. The building skin is a sub-category of biomimicry Chapter one of this research points out problems associated with energy and resort hotels based on literature reviews, highlighted and studied issues of biomimicry, building skin and energy efficient building which led to the discovery of the research gap and hence the research questions

that needed to be answered. Energy consumption through cooling or heating is a major problem affecting deep planned buildings.

6.2 Conclusion

This research has shown that resort hotels have only one source of energy and they have not or do not consider addressing the current challenges of energy demand facing them. No attempt has been made to reduce energy demand from this facility through sustainable means even though they have access to such means. Biomimicry will go a long way to help achieve and solving this problem as it is not all about imitating forms but also imitating mechanisms from nature to help achieve energy efficiency as identified from this research. This research had added to the literature of biomimicry with imitating building skin as an approach to reducing the energy consumption in an energy efficient resort hotel.

6.3 Recommendation

The research makes the following recommendation;

1. Designers should consider energy efficiency from the conceptual stage of the design. Using the appropriate biomimicry strategy will reduce cooling/heating load and optimize natural lighting. This will reduce energy consumption.
2. Since resort hotels are located where there are ample natural resources, biomimicry will be a good approach to addressing energy consumption to not temper which the resources around and make the facility blend with the environment. Depending on the climate region and problem to be solved, different imitating mechanism could be adopted.

3. If cooling/heating is the major issue in the building, the tree trunk concept should be used as it offers a better solution from this operation mechanism and adaptation to the immediate environment,
4. Encouraging the use of biomimicry strategy on buildings in Nigeria will improve energy shortage condition in the country.it is a step towards energy efficient buildings.
5. Other biomimicry mechanisms could be adopted and tested for energy efficiency, in the tropical or temperate climate.
6. Biomimicry does not only address energy efficiency but also spatial organisation, water efficiency, structural stability, this indicates it could be applied in different field.

6.4 Contribution to Knowledge

i. With imitation of the tree bark strategy, it is observed that there will be an approximate decrease in cooling load by 53.84% compared to base case without biomimicry adaptation which was 34.4% in the cold climate.
ii. With anodized aluminum external skin, polystyrene insulation applied to the wall and Pilkington solar control windows, a total of 51.85% energy might be saved.
iii. The study established that during the cold months, increase in heating load is as a result of adaptation of biomimicry strategy.

6.5 Areas of Further Research

This study is conducted mimicking the tree trunk mechanism. The study can be replicated with different choice of materials (external skin, insulation and window type) based on function to establish that the findings is applicable in other climates.as the major factor is identifying the appropriate mechanism to use.

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APPENDIX

Appendix A: Checklist for Energy Audit

Cooling load (Kwh) monthly=

Cost of cooling load monthly=

Lighting load (Kwh) monthly=

Cost of lighting load monthly=

Appliance load (Kwh)=

Cost of appliance load monthly=

	Type of appliance	Quantity	Usage duration (hrs)	Power rating (Kwh)	Total
Cooling					
Lighting					
Other appliances					

Appendix B: Checklist for Building Facilities

Facilities	Present	Not present	Rating based on satisfactory level	Remark
Conference hall				
Reception				
Offices				

Restaurants				
Kitchen				
Spa				
Shop				
Fitness/gymnasium				
Bar				
Outdoor spaces				
Game court				
Staff accommodation				
Store				
Maintenance room				
Parking				

Appendix C: Checklist for Building Envelope Assessment on Energy Efficiency

Key findings;5-Excellent, 4-Very good, 3-Good, 2-Fairl good, 1-Poor

S/N	Variables	Features	Rating	Remark
1	Wall material			
2	Colour of wall material			
3	Window to wall ratio			
4	Window orientation			
5	Wall shading			
6	Roofing material			
7	Colour of roofing material			
8	Ceiling material			
9	Building orientation			
10	Window shading			

Appendix D: Letter of Introduction



DEPARTMENT OF ARCHITECTURE
(Postgraduate Section)
AHMADU BELLO UNIVERSITY, ZARIA
VICE CHANCELLOR: Professor Ibrahim Garba, BSc (Hons) MSc (ABU) PhD (London), DIC, FNMGS, MCOMEG

R/A/2.27

27th August, 2019

The Managing Director,
Nike Lake Resort,
Enugu state.

Dear Sir/Madam,

LETTER OF INTRODUCTION: KEVIN ANITA, M.SC.POSTGRADUATE ARCHITECTURE STUDENT P17EVAT8073.

I wish to request your kind permission to allow the above named M.Sc. Postgraduate Architecture Student of this Department who is currently undertaking her thesis research to use your **Establishment** as a case study for data collection relevant to the research towards a purely academic purpose.

TOPIC: Exploring Biomimicry approach to enhance energy in the design of a resort, Mambilla Plateau, Taraba state.

Yours faithfully,

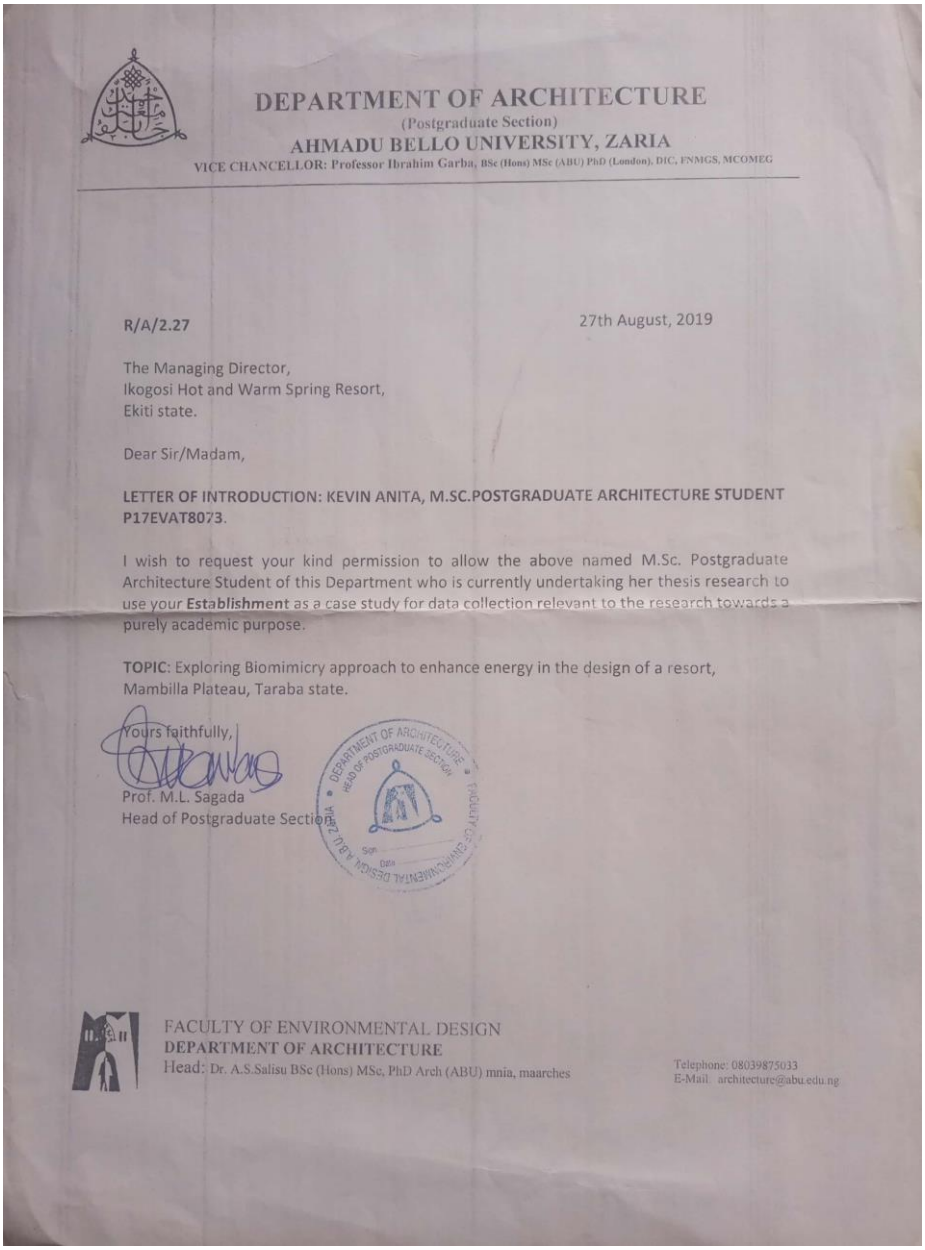
Prof. M.L. Sagada
Head of Postgraduate Section

DEPARTMENT OF ARCHITECTURE • HEAD OF POSTGRADUATE SECTION • FACULTY OF ENVIRONMENTAL DESIGN A.B.U. ZARIA
Sign Date

FACULTY OF ENVIRONMENTAL DESIGN
DEPARTMENT OF ARCHITECTURE
Head: Dr. A.S.Salisu BSc (Hons) MSc, PhD Arch (ABU) mnia, maarches

Telephone: 08039875033
E-Mail: architecture@abu.edu.ng

Appendix E: Letter of Introduction



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27th August, 2019

The Managing Director,
Ikogosi Hot and Warm Spring Resort,
Ekiti state.

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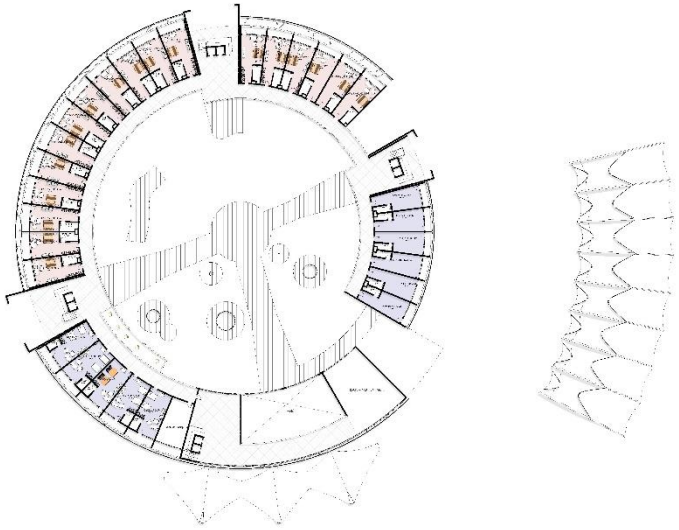
DEPARTMENT OF ARCHITECTURE HEAD OF POSTGRADUATE SECTION FACULTY OF ENVIRONMENTAL DESIGN A.B.U. ZARIA

FACULTY OF ENVIRONMENTAL DESIGN
DEPARTMENT OF ARCHITECTURE
Head: Dr. A.S.Salisu BSc (Hons) MSc, PhD Arch (ABU) mnia, maarches

Telephone: 08039875033
E-Mail: architecture@abu.edu.ng

Appendix F: Presentation Drawings

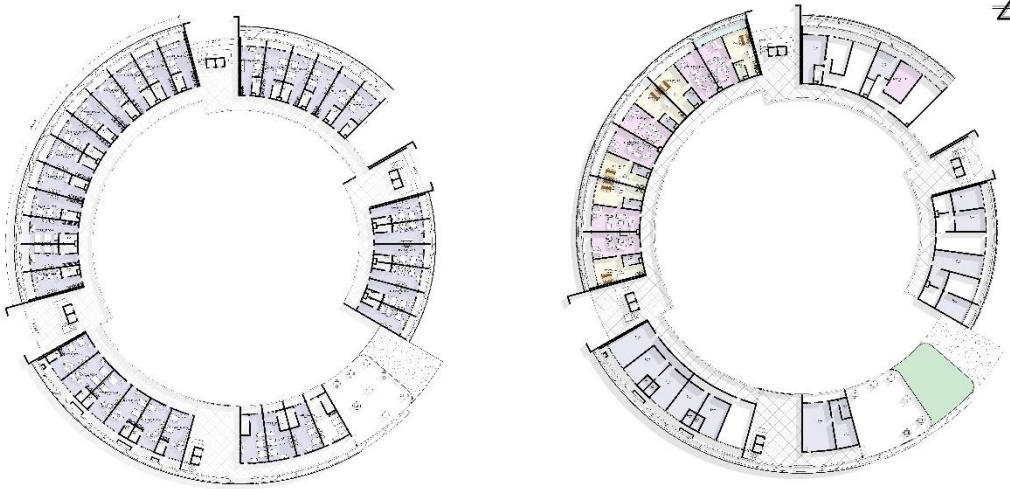
FIRST FLOOR – PRESENTATION DRAWING



23 RESORT HOTEL MAMBILLA,TARABA STATE.
ENHANCING ENERGY EFFICIENCY THROUGH ADAPTION OF BIOMIMICRY STRATEGY IN HOLIDAY RESORT HOTEL, MAMBILLA PLATEAU.TARABA STATE

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Arc. H. O. SALIHU
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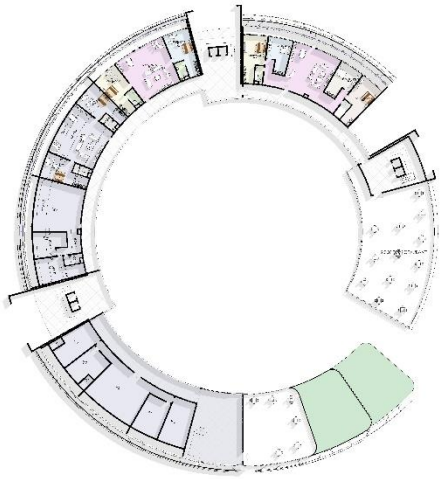
SECOND AND THIRD FLOOR PLAN

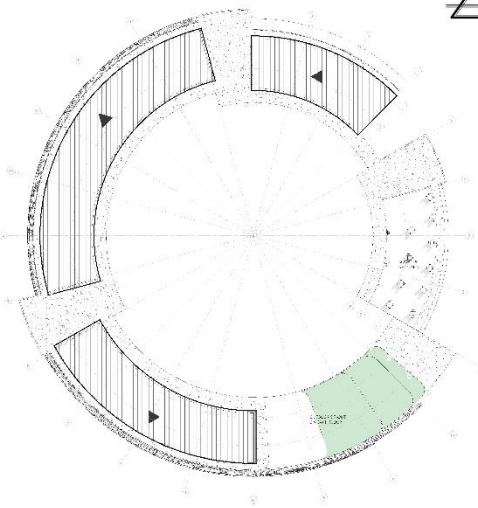


25 RESORT HOTEL MAMBILLA,TARABA STATE.
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FOURTH FLOOR AND ROOF PLAN





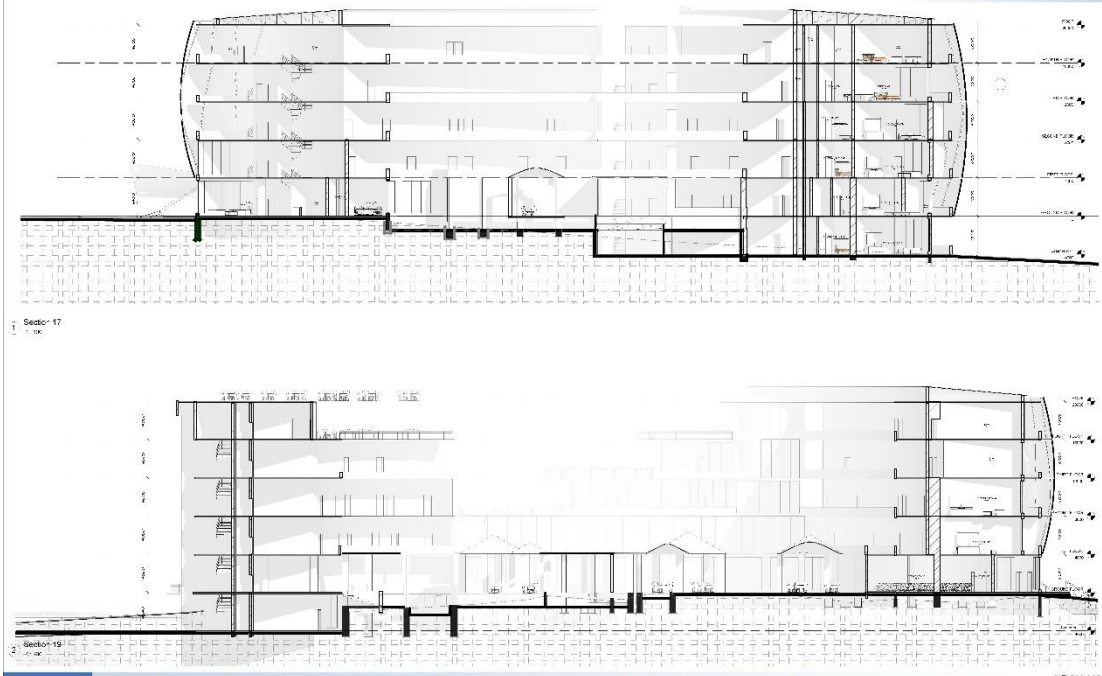
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SECTION

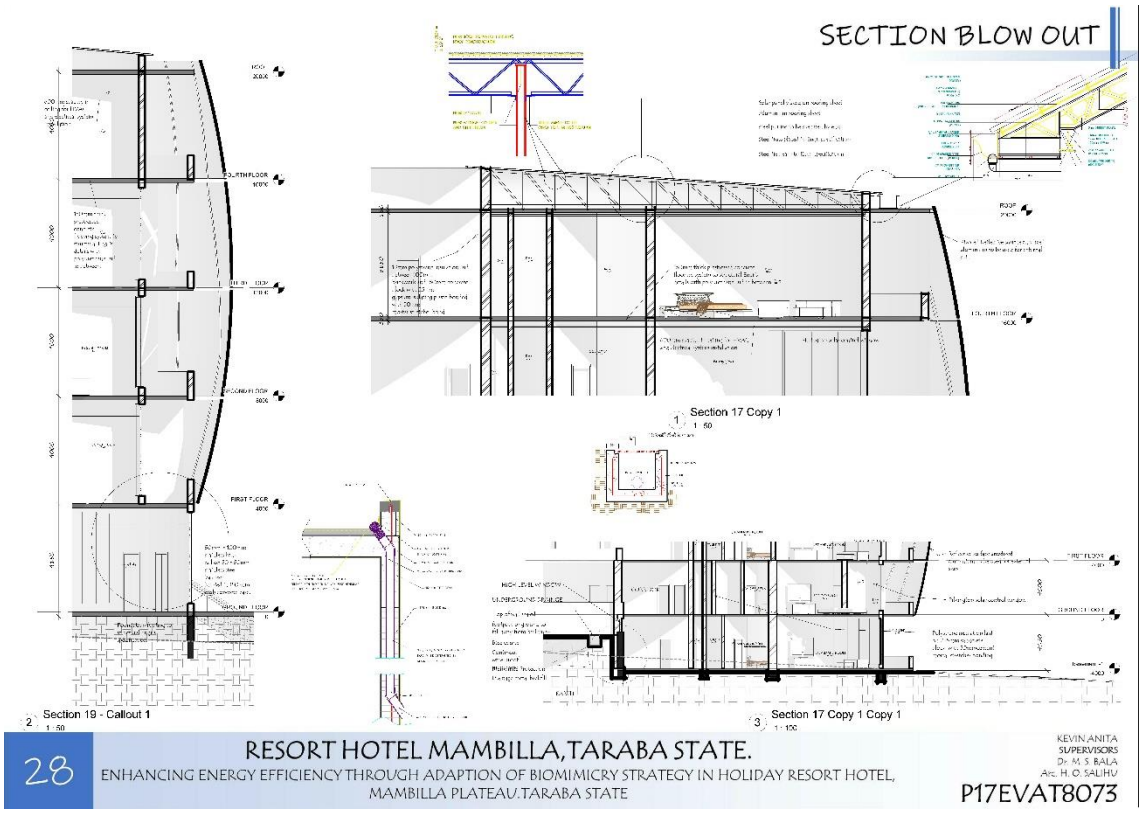


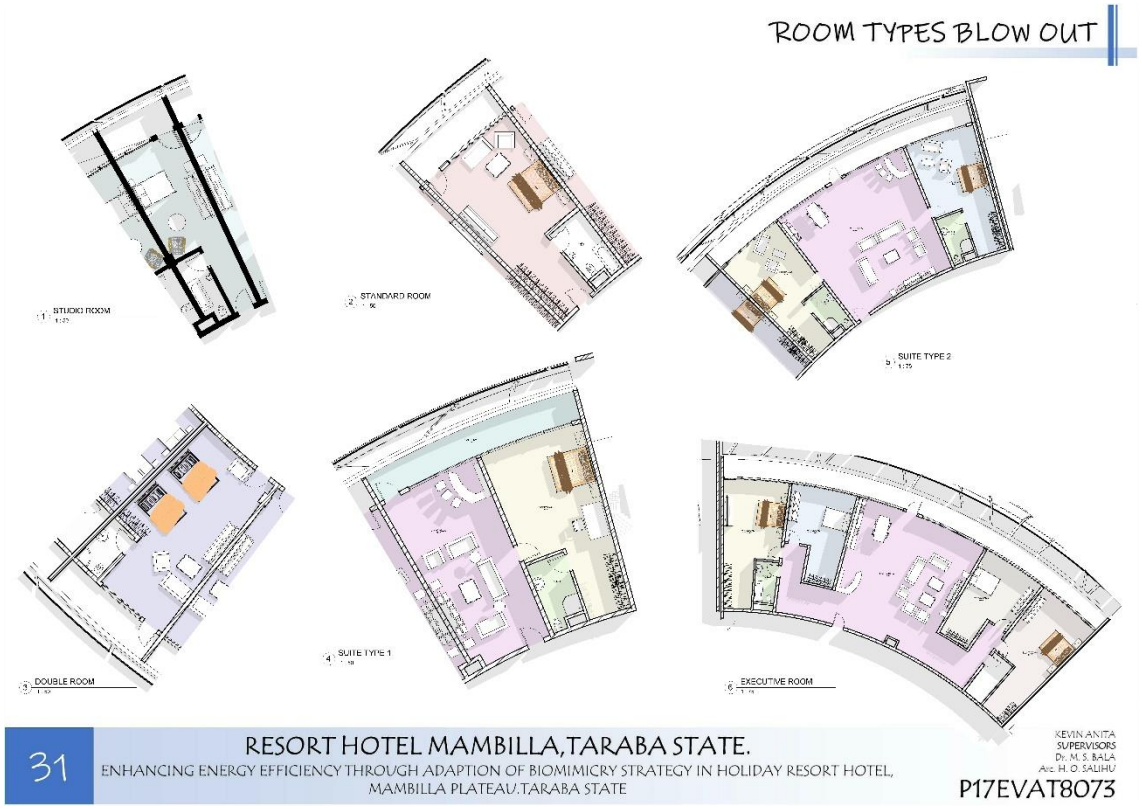
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RESORT HOTEL MAMBILLA,TARABA STATE.

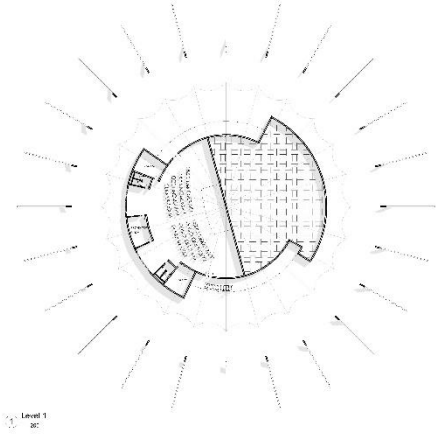
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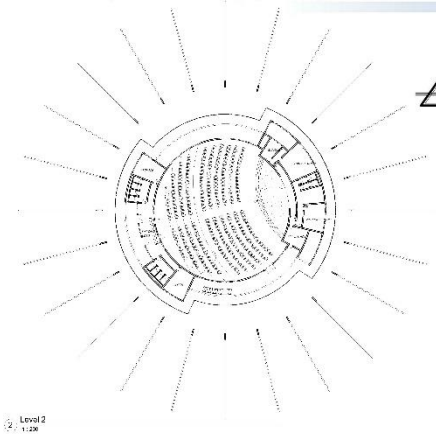
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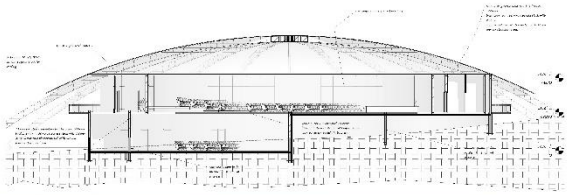

SECTION BLOW OUT
Section 17 Copy 1
Section 19 - Callout 1
Section 17 Copy 1 Copy 1
28
RESORT HOTEL MAMBILLA,TARABA STATE.
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ROOM TYPES BLOW OUT
STUDIO ROOM
STANDARD ROOM
SUITE TYPE 2
DOUBLE ROOM
SUITE TYPE 1
EXECUTIVE ROOM
31
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CONFERENCE HALL FLOOR PLAN







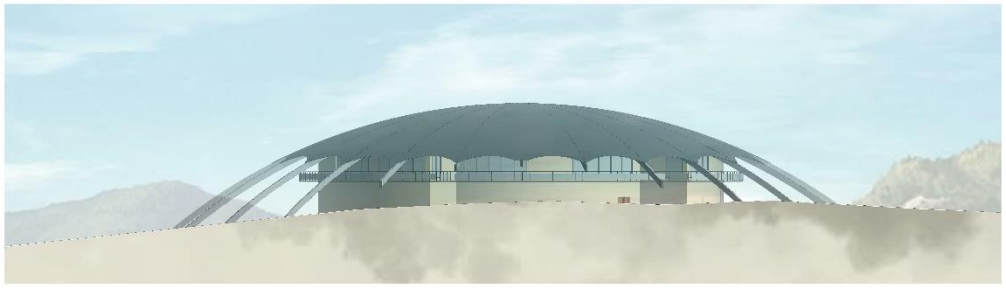
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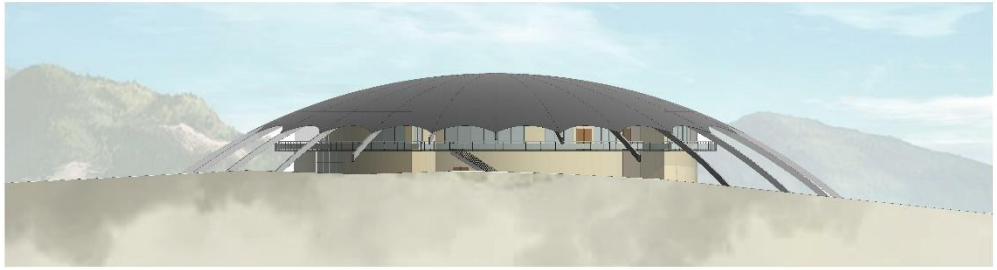
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CONFERENCE HALL ELEVATION





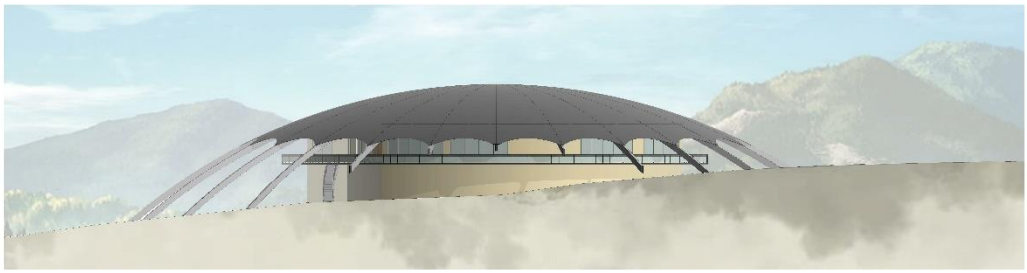
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CONFERENCE HALL ELEVATION

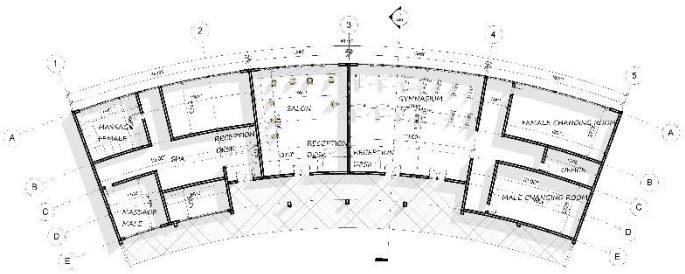


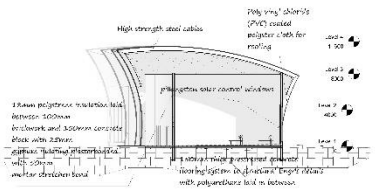


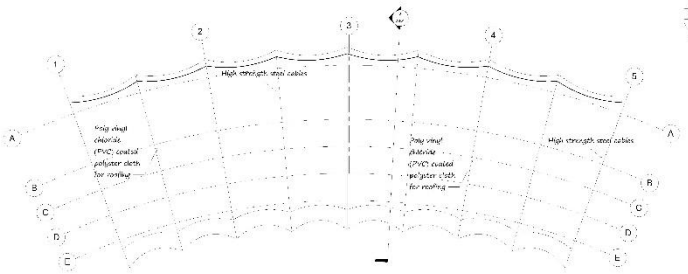
34 RESORT HOTEL MAMBILLA,TARABA STATE.
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GYMNAIUSM – FLOOR PLAN AND ELEVATION







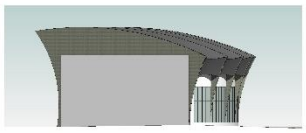
36 RESORT HOTEL MAMBILLA,TARABA STATE.
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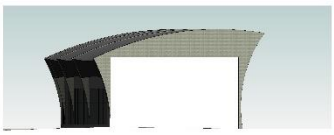
GYMNAIUSM – FLOOR PLAN AND ELEVATION



3 South 1 : 150



1 East 1 : 150



4 West 1 : 150

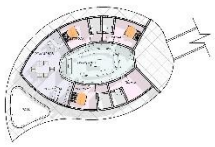


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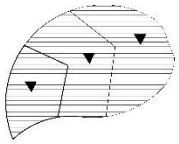
36 RESORT HOTEL MAMBILLA,TARABA STATE.
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CHALET – FLOOR PLAN AND ELEVATION



1 GROUND FLOOR PLAN

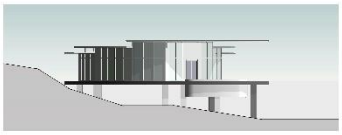


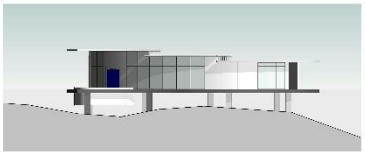
2 ROOF PLAN

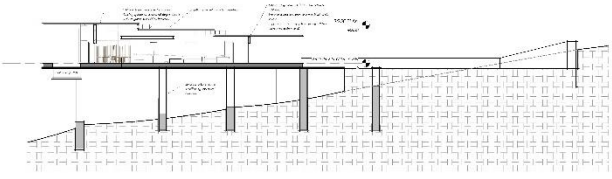




8 3D View 4







3 Section 1



35 RESORT HOTEL MAMBILLA,TARABA STATE.
ENHANCING ENERGY EFFICIENCY THROUGH ADAPTION OF BIOMIMICRY STRATEGY IN HOLIDAY RESORT HOTEL, MAMBILLA PLATEAU.TARABA STATE

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