INTEGRATION OF ENERGY CONSERVATION MEASURES IN MIXED USE BUILDING DESIGN FOR AKURE, ONDO STATE

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ABSTRACT

Mixed-use buildings are characterized by their live-work-play concept ensuring that most activities are achieved within a particular site. Despite their numerous benefits, they experience a wide range of problems including high energy consumption, it is therefore vital that energy conservation measures are employed in such buildings. This study investigated the integration of energy conservation measures in mixed-use building design in Akure, Ondo state. Data was collected through the exploration of academic research repositories using the key terms: energy conservation, sustainable design and mixed-use buildings, this data formed a part of the variables that the researcher termed as “general measures of energy conservation”, the researcher then employed the use of energy calculation software; Climate consultant, to generate specific measures for energy conservation in the study area and termed the data “specific measures of energy conservation”, these two data types formed the variables that were used in this research. Data was also collected with the use of observation schedule, checklist, and audio-visual aids by the researcher from the field after a sample size of 5 mixed-use buildings were carefully selected in Akure, Ondo state. The data was analysed using content analysis after careful documentation. The findings of the research showed that 100% of the samples observed integrated energy conservation measures in some degree in their building design, however, specific energy conservation measures were only integrated in 1/5 (20%) of the buildings at a moderate level of adoption (55%), general energy conservation measures were more predominant and were adopted by 4/5 (80%) of the samples on an average of 30%. Therefore, it was evident that even though the structures had some degree of energy conservation measures integrated, they were minimal and not specific for the climate the buildings were located. The paper suggests the use of energy calculation software by architects to aid in the design of energy conservative buildings and the establishment of laws and standards on the sustainable design of buildings to aid in promoting the construction of more buildings integrated with energy conservation measures.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

A mixed-use building combines multiple facilities, either in a single building (vertically or horizontally) or various buildings of varying uses within a designated site (Niemira, 2007). It is also referred to as developing a modern city block or building structure that functionally and physically combines varying services in the exact location (Narvaez & Penn, 2016). Mixed-used buildings were the norm in early development days before the onset of zoning brought about a break in the facilities for several functions in 1910-1950. However, in the 1960s, a need for urban revitalisation came up, and mixed-use development was the tool used to achieve it. Mixed-used buildings are identified by two or more revenue-generating facilities, Functional interaction of its components, Physical integration, and Conformance to a wholistic plan (Narvaez & Penn, 2016).

Energy conservation is the act of reducing the rate of energy consumption by the reduction in the usage of an energy source or service (Ramya, 2015). Energy-sage (2021), says that energy conservation is the practice of using less energy in order to lower costs and reduce environmental impact. There are basic measures that have been established to conserve energy in all building forms and varying climates. However, for efficiency, energy conservative practices must be streamlined to building types, use and regions. 40% of the global energy use comes from buildings, and this is mainly generated by fossil fuels and comes from the residential sector, closely followed by the commercial sector. Therefore, if the energy requirement and use in buildings are not reduced, the implications will be disastrous (Kujur, 2016).

Mixed-use buildings are often characterised with a live-work-play model, having a combination of residential apartments and shopping complexes as one of the primary functions, with others serving as additional facilities (Anunobi *et al*., 2015). Mixed-use buildings, therefore, consume more energy than single-use buildings as it integrates the leading facilities responsible for the bulk of energy consumed in the building sector. Thus, there is a need to reduce the amount of energy consumed by them. The potential conservation of energy within the built-up industry will substantially add to a decrease in the amount of energy consumed worldwide (Kujur, 2016).

1.2 Justification of Research

The Organization for Economic Cooperation and Development (OECD) (2007), states that, unless the present movements in the world are not transformed, by 2030, the rate of the world's energy Use will undoubtedly surge by 53%, having 80% of this energy been generated by fossil fuels, which will, in turn, increase CO^2 productions. Nigeria, a developing country, uses more energy than developed countries that already have checks to ensure proper energy use. The current scene in Nigeria sees not up to half of the population (45%) having access to electricity which has been singled out as the primary source of energy consumption in residential units; 80% of this energy is produced through fossil fuels while the remaining part (20%) is gotten via hydroelectricity. However, 45% of the population with access to electricity constitutes the group that uses the most energy in the county (Index-mundi, 2018).

The importance of communal facilities within a neighbourhood cannot be overemphasised. Apart from meeting several needs, it helps to reduce the need to travel for residents living within such communities that have been integrated with these facilities. There is a need for communal facilities to be an integral part of urban developments. Additionally, a mixed-use building design seeks to integrate several functions within one building to achieve a live, work and play balance. This balance brings about the communal facilities necessary for neighbourhoods; however, these facilities combine various sectors responsible for significant energy consumption in a single facility, leading to high energy consumption. As the urbanisation of the country calls for the promotion of mixed-use facilities to promote maximisation of resources and comfort, there is also a need to ensure these facilities conserve energy to ensure that they do not create problems while trying to provide solutions (Fakere & Ayeni, 2013).

1.3 Statement of the Research Problem

The residential sector in Nigeria uses the most energy produced through fossil fuels, which is closely followed by the commercial sector (Energypedia, 2012). However, mixed-use buildings combine these facilities with other uses, thereby increasing their energy consumption rate. Pahuja (2017), confirms this by stating that mixed-used facilities increase the pressure on the infrastructure such as water, electricity, and sewage, thereby using large amounts of energy. Therefore because of this level of energy consumption, it is necessary to develop sustainable energy conservation practices in mixed-use buildings to ensure a comfortable life for the inhabitants of those buildings and a sustainable environment.

1.4 Aim and Objectives

1.4.1 Aim

This research aims at integrating energy conservation measures in the design of a mixed-use building for sustainable development.

1.4.2 Objectives

The objective of this study is to:

i. Identify various energy conservation measures that can be used to achieve energy efficiency.
ii. Identify appropriate energy conservation measures to be used in the selected study area.
iii. Evaluate the use of energy conservation measures in existing mixed-use buildings.
iv. Propose an appropriate design in Akure that applies the established energy conservation measures needed in the study area.

1.5 Study Area

The city of Akure is recognised as the capital of Ondo state, a state in the southwestern part of the country. It has a population of 691,000 people (Macro-trends, 2021). It lies in the tropical rainforest zone of the country, and it is known as a trade centre for several farm produce, the layout of the state is shown in Figure 1.1. Varying densities characterise the city; some areas have over 200 persons per hectare while others have between 60-100 people. The city is a commercial hub with several people flocking in to trade daily.

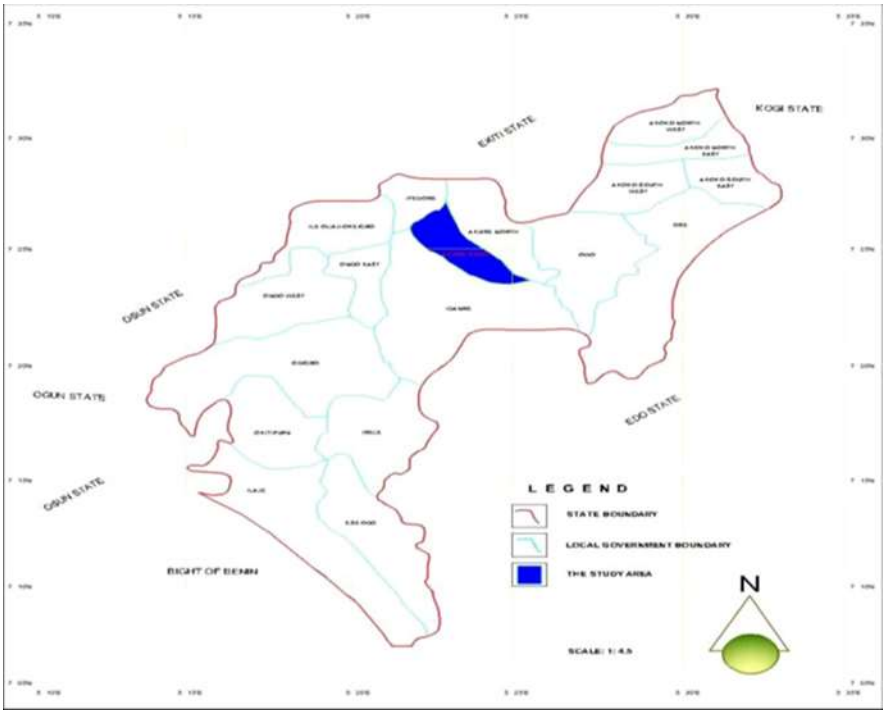


Figure 1.1 Map of Ondo State showing Akure shaded
Source: Olugbamila (2018)

The population of Akure has tripled over the years owing to several factors like it becoming the state's administrative headquarters in 1976, development of establishments such as ministries and multiple building estates, and so much more. Due to the influx of people into the state, several construction projects commenced randomly, rendering the master plan created in 1980 useless. To prevent this, vertical building types, i.e., story buildings and skyscrapers, compact cities and the adoption of smart growth, should be adopted as they aid in reducing indiscriminate land uses and increase the aesthetic appeal of the built environment (Owoeye & Ibitoye, 2016).

1.6 Scope of Research Work

The research emphasises the study of energy conservation through space and form related to the design of a mixed-use building for Akure, Ondo state. Other building forms would have been considered, but the researcher believes the current need for compact designs will demand more Mixed-use buildings. All three types of mixed-use building design were considered during this research to allow for easy adaptability. The research work carefully analyses several ways energy conservation can be achieved through various ways. The ones regarding the use of space and form were carefully selected because they relate directly to the researcher's field of study, architecture. Other methods such as using modern technology to produce Smart buildings were not considered. The researcher felt a seasoned researcher in that field could further expand on them. The space and form selection of energy conservation measures was only made with secondary data from previous academic repositories.

The qualitative method was used alone for the research due to the nature of data that was to be obtained which was majorly existing data that can be physically observed in the building structure. The design will be based on research carried out, and political and economic constraints are omitted. The type of facilities will be limited to Residential, Recreational, and commercial.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Mixed-use Buildings

Mixed-use buildings have dated back to market squares in medieval times and the Greek agora; the building type is not an invention brought about by modernity. In medieval times walking was the primary mode of transportation, and so people had to "live, work and play" within a vicinity. Also, the concept of mixed-use development has been ascribed as a critical influence in several planning theories such as smart growth and compact cities, transit-oriented facilities and new urbanism (Huston & Mateo, 2013).

The concept of mixed-use design is commonly referred to as the development of an urban block, a street, or a building, which functionally and physically integrates different uses in the exact location, thereby enabling a space to connect individuals, living, working and moving together. The concept of mixed-use buildings has been promoted as a tool to achieve sustainable growth in neighbourhoods; strict zoning regulations are now passed over in favour of mixed-use urban spaces, allowing the integration of several social and cultural qualities (Narvaez & Penn, 2016).

2.2 Types of Mixed-use Buildings

A mixed-use building may have multiple uses in a single structure or exist as a mixed-use complex having separate individual entities. There must, however, be a clear distinction in facilities and public and private spaces with the use of passive and active elements; no facility is expected to overshadow the other, as this will defeat the whole aim of mixed-use development and the process by which the mixing of uses occurs is essential. Therefore, entrances, mutual collaboration, and integration of public and private spaces should be focused on (Narvaez & Penn, 2016).

2.2.1 Vertical mixed-use buildings

These are structures that combine various facilities in one structure. The lower-level floors are generally used for general/public functions and the higher-level floors for exclusive/ private functions. In city centres, to achieve compact designs, vertical mixed-use buildings are often used. They can support the lack of urban lands, encourage efficient land use, diversify services, and reduce automobile traffic congestion and commuting (Huston & Mateo, 2013).

There are several vertical mixed-use buildings, including the SAPETRO tower in Lagos state. It is a 13-story building belonging to South Atlantic Petroleum (SAPETRO), an oil and gas production and exploration company located in Nigeria and aimed at creating value in Africa. The building is located on Victoria Island, Lagos, at number 7, Adeola Odeku Street. The building has been home to many firms and companies in Nigeria; after it was completed in an astonishing two years, it became a landmark in Lagos State in 2002. It offers office and residential spaces: 24, 3-bedroom flats and office spaces of $9452m^2$ floor area, an open office design with curtain walls (double glazed) and exterior cladding. The residential units are done in concrete and finished with emulsion paint internally and textured paint externally. The ground floor is a parking structure that accommodates 190 cars. The ground floor also holds a sewage and water treatment plant, generator house and an underground water tank. The façade of the structure is shown in Figure 2.1.

Figure 2.1 Exterior view of SAPETRO Towers
Source: Akinjole and Orji (2020)

2.2.2 Horizontal mixed-use sites

Horizontal mixed-use sites include a collection of single facilities within a development project spread out horizontally on the site. They are sited to spaces that can give some degree of severance amongst the varying facilities. It has several rewards, including easy access to several facilities and segregation of incompatible uses within minimum distances.

An example of horizontal mixed-use buildings is the Jakarta central park project. This park is also known as Pomodoro city, and it is named after a lead developer. It sits adjacent to several notable apartment towers such as the Royal Garden Residences. The total park area is 720,000 square meters, and it sits on land with 9 hectares dedicated to green spaces and landscaping. It comprises 42 office towers, 420 guest rooms, 50 apartment towers, 12 floors for parking, 13 floors for hotels, 2 basements and a large garden on the ground floor (Wijanto *et al.,* 2011). A side elevation of the façade is shown in Figure 2.2.

Figure 2.2 Exterior view of central park Jakarta
Source: Wijanto *et al.* (2011)

2.2.3 Mixed-use walkable areas

This mixed-use building combines horizontal and vertical mixes in an area or space within 10-minute walking to core activities or facilities. It provides more efficient use of land and infrastructure and encourages shared parking; additionally, residential apartments can help reduce drastically or stop the vandalism of the commercial areas. It has also been defined as a pedestrian-friendly development that blends two or more services to create a compact/wholistic environment. in essence; a mixed-use walkable area makes a mini-community where most or all of the occupant's basic needs are met (Kujur, 2016).

According to Douglas-County (2019), mixed-use walkable areas are currently in low supply, causing an increase in the prices of the existing few; their demand stems from the several health and commercial benefits they bring. The health department is of the notion that the neighbourhood's design can go a long way in positively affecting the lives and livelihood of individuals.

The Urban Sustainability Directors Network (USDN) (2020), believes that the provision of mixed-use walkable areas allows users to access services or purchase goods they want or need while eliminating the need for automobile transportation. In turn, this reduces greenhouse gas emissions (GHGs), facilitates more interactions among neighbours aiding the cultivation of social relationships, leads to more housing variations with the inclusion of low-cost residential homes that reduce the overall lifecycle emissions of greenhouse gasses.

2.3 Characteristics of Mixed-use Buildings

Mixed-use buildings have been characterised by having three important core qualities: multiple significant revenue-generating facilities that are mutually supporting, a practical and physical mixing of their Facilities (producing a tight and exhaustive utilisation of the site), continual walkways, it is developed using a plan that shows the type of uses, scale, densities, and other essential details (Hoskere, 2016). Mixing uses requires an appropriate combination of multiple functions inside a single building or within a neighbourhood with a reasonable walkable distance from each facility. The concept of mixing facilities and functions includes providing various living activities that support each other near residents (Narvaez & Penn, 2016).

Hoskere (2016), believes that mixed-use buildings can be viewed from different perspectives by several stakeholders of the building industry, as seen in Figure 2.3. And that it's the architect's role to strongly advocate for functional, social and ecologic benefits of mixed-use developments as cities are gradually moving from being viewed as mechanisms to being viewed as organisms.

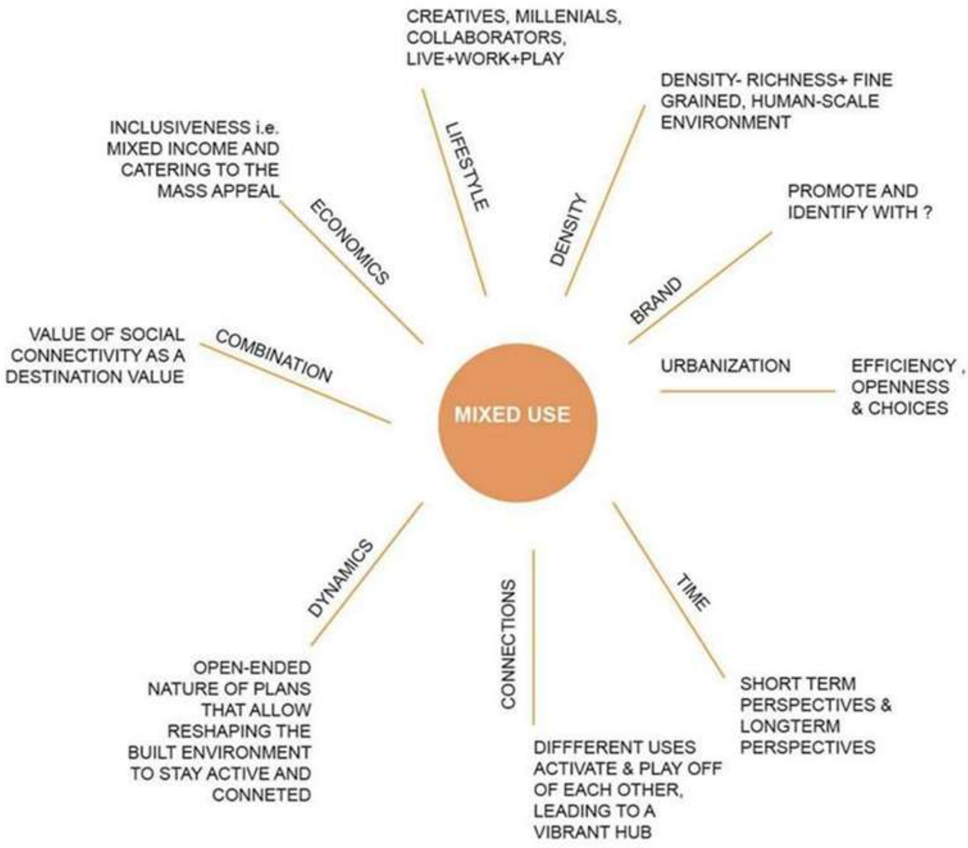


Figure 2.3 Attributes of mixed-use developments
Source: Hoskere (2016)

Niemira (2007), defined mixed-use building as an adequately organised development project integrated with other facilities such as shops, offices, residents, restaurants etc.

He also said it is concerned with people and has features of a live-play-work area. Therefore, it increases the supreme use of the site provided, reduces road traffic, and provides infrastructures. Because of this, it has become widely adopted in urban centres as these characteristics ensure residents' comfort. It is, however, worthy of note that the various facilities combined have to be harmonising with one another, operate individually while existing as an individual unit.

According to Anunobi *et al*. (2015), Massive development has recently occurred in urban areas because of the increased migration and, in return, increased urban growth. As a result, many people now prefer and desire a Cohesive experience in a single location, and mixed-use buildings provide that. Mixed-use buildings existed as far back as in ancient times, but the current change in the needs of people has seen them resurface and become relevant once more. They have gained wide acceptance because they provide efficient land usage while providing comfort to the occupants and reducing over-dependence on automobiles. Thus, to achieve the live-work-play model. Some of its other advantages over the single building type model include effective utilisation of scarce land resources, optimisation of parking spaces, fostering neighbourhood relationships, and creating a comfortable environment for its users.

According to Carswell (2012), diverse transit options are available and attainable when mixing land uses. Also, the compactness created by proximity reduces sprawl and benefits the environment. Previously, in the 20th century, segregated land uses connected by highways and freeways were the norm. Zoning became popular in major cities, but the development of multiuse buildings came about in the 21st century because of constant complaints of traffic congestion, housing affordability and loss of natural resources. As a result, compact communities were formed, and mixed-use buildings became the order of the day. The idea of smart growth became common and was translated through planning and design efforts. It aimed to reduce environmental degradation, social isolation, and automobile dependency. It became necessary to reduce zoning and segregation of land uses to achieve this, which brought about the "new urbanist" movement, which incorporated mixed-use buildings.

Hoppenbrouwer and Louw (2005), agree that the main ideas of mixed-use buildings should be advocated for, particularly in city centres, to bring additional variability and vivacity into modern living. Residential and office units and other harmonious facilities ought to be placed within the same spaces to reduce pollution and the need for transit while conserving energy.

Pahuja (2017), states that the basics of mixed-use developments include a higher density than single-use developments and creating pedestrian-friendly environments with various uses to promote living in one place. It was further stated that three variations of mixed-use buildings exist: mixed-use walkable areas, horizontal mixed-use sites, and vertical mixed-use buildings.

2.4 Benefits of Mixed-use Buildings

Mixed-use buildings are chosen for several reasons; while some developers use them to aid them in integrating several housing types and building types, others might use them to enhance the urban development of a city and use it to revitalise poor areas and cause economic spurge. But, regardless of the reason for the choice of mixed-use buildings, their numerous benefits are glaring.

Sanya (2018), states that mixed-use buildings serve as facilitators for maximum utilisation of spaces and compact designs. They further lessen the use of automobiles reducing several harmful environmental factors such as air pollution and energy use. The compact nature of the design also shortens trips and reduces land consumption. They also facilitate the optimum utilisation of services by using existing public facilities and eliminating or reducing the need for new ones such as streets, water lines and sewers. In addition, they provide more opportunities and housing choices for the steadily increasing population. Also, they encourage the green environment movement and reduces carbon emissions and pollution.

Pahuja (2017), also agrees with some of Sanya (2018), views by stating that some of the benefits of mixed-use buildings are greater housing variety and density, more affordable housing, creating an efficient blend of compatible land use, better access to services. Some others include crime reduction, earning opportunities for disabled and older people, efficient use of the land, stable environment for small businesses, stronger neighbourhood character, reduction in the cost of transportation, low cost of operation for businesses and reduction in travel distances.

2.5 Problems Associated with Mixed-use Buildings

Like all other forms of development, mixed-use facilities have several problems associated with them. Narvaez and Penn (2016), highlighted the issue of zoning of facilities and seamless transition between public and private spaces and the need for separate entities to exist as a whole and part of a whole.

Anunobi *et al.* (2015), also state that one of the issues associated with mixed-use developments is parking. Parking is essential in mixed-use developments, but it is also highly costly because of the number of parking spaces required by individual facilities. This can present a challenge to the designer as the need to fulfil and meet specific design standards is there, but that will create rows of parking lots. To prevent this, there is usually a shortage of available parking spaces in mixed-use facilities. They provided a solution to this by suggesting the use of shared parking facilities; this principle involves using one parking facility by multiple people by leveraging their distinct peak periods in different times and seasons. Therefore, functions with the same peak periods should be avoided when providing mixed-use facilities.

Sanya (2018), while stating that mixed-use building has been able to achieve several incredible feats, also said that they come with adverse effects. Which include the fact that they are isolated and offer few choices, and because of the way they operate, they have no relationship with their environment, which is dangerous to human health. Also, the lack of versatility can affect social relationships. They are highly energy-dependent buildings that consume a lot of energy for their numerous activities. As a result, they lack sustainability and lack informal social interaction.

Pahuja (2017), also states that despite the benefits of mixed-use buildings, they have some disadvantages. They include traffic congestion around the facility, noise pollution and environmental pollution, high density, lack of parking areas for residential owners if they do not have designated parking lots, construction costs and pressure on the infrastructure like water, sewage, and electricity.

Another issue associated with mixed-use developments is energy consumption. A mixed-use building is typically designed to suit the live-work-play model, and this involves the provision of primarily residential and commercial buildings. And according to Ürge-Vorsatz *et al.* (2012), residential buildings contribute 23% to the final energy demand, and commercial buildings contribute 8%. Still, in Africa, residential buildings contribute 54% to the final energy demand. In comparison, commercial buildings contribute 3%; however, this is set to increase exponentially over the years, with most of the energy being obtained from non-renewable sources. There is, therefore, a need to conserve the energy used in buildings.

2.6 Benefits of Energy Conservation

According to Ürge-Vorsatz *et al*. (2012), Energy conservation in buildings has been championed over the years as a viable means for achieving sustainable projects and, in the long run aiding the achievement of sustainable development goals. Although they believe that the achievement of energy conservation in buildings comes with extra added benefits such as health benefits, research has been done on the existing links between human health and energy use in buildings. These researches have established the need for access to clean energy sources by producing energy-efficient equipment for services within the building. The mortality rate, especially in developing countries, can be reduced drastically by proper energy conservation measures.

They also believe that it produces social effects. For example, improvement in the rate of energy efficiency in buildings increases thermal comfort and reduces cost leading to a reduction in spending and an indirect decrease in poverty. Improved energy reduces energy costs giving users more money to be used for other needs. Additionally, Families can improve their life quality. Kids in schools can study and learn faster. Hospitals can heal more quickly. Data centres can reduce energy costs, and other feats can be achieved.

Ugreen (2021), also states that adopting energy conservation measures in buildings ensures some benefits, such as Energy conservation can change the economic landscape. Increased adoption of energy conservation measures will increase real estate value while lowering the cost of energy prices. In developing countries, countries with better energy sources will reduce the dependency on imported energy sources. The thermal comfort of buildings interior spaces directly affects the output of the occupants in a variety of ways, including the sick building syndrome, which may directly or indirectly affect the company's economic growth. Energy efficiency also ensures that comfort standards are achieved with fewer resources.

Also, energy conservation causes an increase in productivity. According Wargocki *et al*. (2006), a building where employees operate above the designated comfort range will have less productivity. The use of energy conservation measures affects the acoustics, lighting, heating, cooling, and overall operation of a building leading to better thermal comfort and improved productivity. It also reduces operational costs; it is a well-known fact in the built industry that the cost of a project is majorly determined by operation and maintenance costs. Energy conservation produces sustainable designs that reduce the cost of operation in the long term, and if applied adequately, it can also reduce short term costs. Heating and cooling facilities can be reduced during the design phase leading to less energy use. Also, building simulations can be used to foresee possible money consuming services in the building, and they can be adequately worked on before construction.

Energy conservation also has an ecological effect. The reduction of energy use in buildings causes a decrease in pollutants that cause harm to the ecosystem and reduces negative climatic phenomena like acid rain, noise pollution and ozone depletion. The choice to retrofit buildings rather than destroy them also reduces construction and demolition wastes. And cause a reduction in construction waste. Furthermore, the adoption of energy conservation measures will ensure sustainable design, which also causes project optimisation through building lifecycle design which promotes reusability and recyclability of materials. All these benefits aid in attracting investors and creates a constant influx of income (Ürge-Vorsatz *et al*., 2012).

2.7 Ways to Achieve Energy Conservation in Buildings

Thapa and Panda (2015), states that the reduction of energy usage in buildings is the reduction in the overall energy used for erecting the structure, maintenance of facilities post-construction, the use of adequate design and the adaptation to the climate to produce passive and active features, the installation of more efficient equipment and the addition of renewable elements.

The United Nations (UN) (2015), recognised the need for energy conservation and came up with sustainable development goals, including establishing affordable and clean energy, sustainable cities and communities and others. However, energy conservation is a global problem that can only be handled if drastic life-changing measures are taken.

Over time several methods have been proposed to aid in achieving energy conservation both generally and specifically to buildings. The researcher examines some of these established measures, selecting those who are only related to architecture and can be achieved through careful planning of the space and form of building structure.

2.7.1 Mixed mode building design

A few people have also suggested Mixed-mode buildings; it is a building that is a combined method to the acclimatising of space. It utilises the merging of artificial and natural means of achieving thermal comfort. An adequately designed mixed-mode structure allows buildings to be ventilated naturally on occasions where it is desirable and only uses mechanical ventilation as a supplement when the natural ventilation is inefficient. This model may not suit all scenarios and buildings, especially in areas with high humidity or high levels of noise or air pollution. However, that does not dampen its effectiveness in suitable systems. Some mixed-mode models have both types of ventilation co-occurring, but this will sufficiently decrease the amount of energy used by mechanical means if it were to be used solely. The decision on which model to adopt in a building will affect the envelope design, energy use, lighting options, thermal comfort, and ventilation. However, it is best to analyse how to strike a balance between comfort optimisation and energy conservation. Some of the benefits of mixed-mode buildings include ensuring the adaptability of a building, futureproofing, user comfort, energy-saving and conservation, reducing the environmental impact, and saving cost (Brager *et al.,*2007).

Deuble and Dear (2012), state that mixed-mode buildings have great energy-saving potential if used correctly and that mixed-mode combines Naturally ventilated (NV) designs and Air-conditioned (AC) designs, creating a state of equilibrium and offering the best of both worlds. It also caters for the future needs of the building; in the advent of climate change or shortage of electricity, the building can function effectively and provide its occupants with a comfortable environment.

2.7.2 Contemporary design options

Oginni *et al.* (2012), suggest that contemporary design options are necessary for achieving thermal comfort for buildings. It was argued that the fitting of buildings into their natural environments creates a model for less energy usage and maximum thermal comfort. They proposed some options that can be taken during the design phase to achieve this phenomenon; they include Adequate lighting and ventilation, the creation of a microclimate and the adaptation of sun shading techniques/devices. In addition, they strongly proposed the notion that buildings could exist without the inclusion of artificial means of cooling or heating if designed well. However, in their research, they focused on Arid climates, left out the frigid zones, and did not propose a solution for existing structures.

Garima (2016), argues that the primary use of a building is to give thermal comfort to its users. He is also of the notion that energy conservation is primarily about reducing the use of mechanical devices to produce thermal comfort while ensuring that the minimum standard of comfort levels is still delivered. He states that the energy use of most buildings depends on the climate the facility is located, the usage of the building and the rate of the quality of life of its users. The analysis of different energy usage rates in varying seasons was conducted in his research to produce relevant data that will aid the achievement of thermal comfort in all seasons. However, he also analysed possible solutions to existing structures and focused on the future buildings that will be constructed. He concluded that the type of building form that will always exist is the mixed-mode method where passive and active elements work hand in hand to provide comfort. However, he believes the use of functional elements could be reduced drastically.

There are several ways contemporary design and planning can be adapted to achieve sustainable buildings; the goal is to ensure possible sources of unsustainability are pre-empted and accounted for by counter-intuitive design rather than waiting for errors t occur in the future trying to resolve them. Some of these principles are discussed by the researcher.

2.7.2.1 *Proper orientation and zoning of buildings*

Adebisi *et al.* (2019), state that the positioning of building forms on a site is the act of orientation. The orientation of buildings is a passive method that, when adopted, aids in thermal comfort realisation. In the tropical regions, good orientation is obtained when the east-western axis houses the length of the building; the principle is simply the reduction of exposed surfaces to direct sunlight, thereby minimising heat gain and radiation and reducing or eliminating the use of energy to combat that effect.

Oginni *et al.* (2012), also say that the excellent orientation of structures reduces bad climatic occurrences such as thunderstorms and solar radiation. They propose the alignment of rooms in order of frequency of use such that the most frequented ones should be positioned on the east-western axis to reduce heat gain. They believe that positioning features within a building structure are also important in the passive way of energy conservation. They also agree with Adebisi *et al*. (2019), that the proper building orientation in the topics is placing the longest side on the east-western axis, as seen in Figure 2.4. However, areas with the most glass should face the sun to capture maximum lighting, and kitchens should face east, openings should be southward, sleeping quarters to the north to reduce the filtration of light and living quarters to the west or south. Houses can be zoned to ensure different spaces receive sunlight at other times of the day.

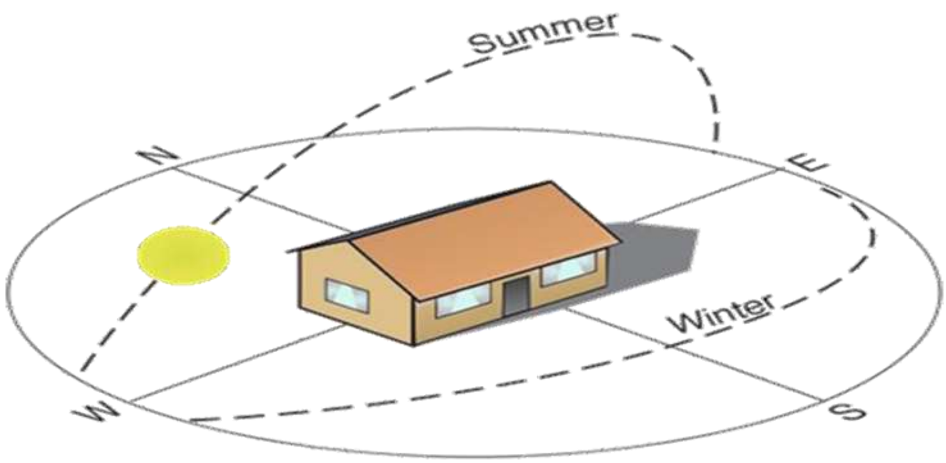


Figure 2.4 Proper building orientation
Source: Oginni *et al*. (2012)

2.7.2.2 ***Use of shading devices on buildings***

Raeisi and Taheri (1999), state that the precise use of overhangs on window openings made by accurate calculations could aid reductions of the cooling loads in structures. Also, the use of trees is also an excellent passive option, but they should be carefully packed to avoid bare trees during dry months of the year. Adebisi *et al.* (2019), states that shading is the most effective technique in reducing solar radiation in tropical regions. As such, it should be considered primarily when designing buildings and their sites. The use of trees and the vegetative matter is effective in this passive means of reduction only when they are strategically located on the site and not just randomly inserted. Trees and vegetative matter have several effects when used around building structures, such as evapotranspiration and shade to reduce the temperature of the surrounding air by about 9 degrees.

Additionally, large, crowned trees protect parts of the building from heat gain. The use of overhangs and fins in structures is necessary because when properly utilised, they serve as blockades from the sun's radiation reducing the solar gain in structures. Their design should be made in consideration of the orientation of the building on the site and the movement of the sun. There are several types of fins such as, egg crate, vertical and horizontal, proper analysis should be done to determine the most effective per building area. The use of textured walls can also aid in cooling buildings because of the reduced parts of the wall directly exposed to the sun.

After extensive research, it was discovered that shading is more effective in incrementing thermal comfort within buildings. The use of external shading devices for windows such as horizontal fins or overhangs and internal measures such as binds and curtains of light colours and semi-loose fabric (Oginni *et al.*, 2012). Also, a simulation run by Bataineh and Alrabee (2018), showed that the use of Shading devices had shown high viability with its overall low cost and high annual saving; the use of overhangs achieved maximum results.

2.7.2.3 *Use of local building materials*

Godwin (2011), postulate that the material used during construction is significant to energy conservation. Using local materials that are already adapted to the climate is the best bet for achieving sustainable designs. The use of imported materials is inefficient as they harbour a lot of embodied energy due to maintenance, installation and even transportation. Akande *et al*. (2015), also states that local building materials have lower internal energy and little environmental effect compared to most modern construction materials. However, caution needs to be practised when using them as they must be treated well to stand the loads that will be carried.

2.7.2.4 ***Appropriate building colours***

The colours used on surfaces have an essential effect on the building form; they can reduce or increase heat gain. Bright colours should be used on walls as they reflect heat, while dark colours that absorb heat can be used on rigid landscape forms and perimeter walls, the adoption of this principle will aid the reduction of solar gain in tropical buildings (Adebisi *et al.*, 2019).

Oginni *et al.* (2012), also agree, stating that Paint colours also are climate responsive. The type of colour used can affect the amount of heat generated into the indoor space of buildings. Light coloured roofs and walls aid in the reduction of glare and heat gain; this is a phenomenon known as whitewashing. Godwin (2011), also state that colours are an essential defence line in preventing heat gain in buildings; materials like reflective tiles, limestone, and light-coloured marble can reflect solar heat, and generally, light should be given preference over dark colours.

2.7.3 Designing with the climate

Thapa and Panda (2015), suggests the design of climate-responsive buildings, calculation of the thermal load in buildings to enable accurate suggestions, design of zero energy buildings and thermal comfort. According to energy informative, energy-saving techniques are simple measures that, when implemented, can reduce the amount of energy used drastically. Some of the methods include: Getting rid of incandescent bulbs, sealing air leaks in buildings to conserve energy used in heating, turning off electrical devices when they are not in use, use of energy-efficient windows and doors and use of energy audit. There are several ways a building can be designed to fit the climate it will be used in, and the researcher examines some of these methods.

2.7.3.1 *Passive cooling and solar techniques*

Techniques like proper lighting will aid in the reduction of cooling loads; this is because daylight contains the least amount of heat. Incandescent bulbs and other light sources should be exchanged for Compact Fluorescent Lamps (CFL), which do not give out heat into the lighting area. (Oginni *et al.,* 2012).

Kumar and Mahalle (2016), also suggests the use of green roofs. They are considered a passive cooling technique and a part of sustainable architecture. However, its effectiveness depends on the type of plants used and climatic and geographic conditions. Still, it has the benefits of reducing energy consumption by reducing dependence on artificial means of cooling, and it also reduces stormwater runoff, CO2, and noise levels. Akande *et al*. (2015), also advises that the adoption of natural ventilation will significantly reduce cooling loads in buildings.

2.7.3.2 *Energy efficient materials*

Garima (2016), states that the dependence on electromechanical devices that are not energy efficient increase the rate of energy consumption in buildings, efficient equipment's should be installed for essential functions that are inevitable such as heating, cooling and ventilation, also, renewable energy sources should be incorporated into the design.

2.7.3.3 *Location of trees and vegetation*

A microclimate is usually created with trees and vegetative matter; they make a calm and serene environment both within the building and on the site in the tropics. Therefore, frequently used spaces in buildings should be positioned close to such climates to maximise their comfort levels for extended periods (Oginni *et al.,* 2012).

2.7.3.4 *Insulation of buildings*

Building performance can be affected by several things, including air leakage. The indoor air quality, thermal comfort, artificial cool and heating and other functions can be affected by infiltration. Infiltration is the exchange of air between the indoor and outdoor environment through unplanned channels. It is an uncontrolled flow of air in and out of the building through cracks and openings in the roof, wall, floors and around the house, which can be prevented using primarily good builders, proper maintenance, weatherising and caulking (Oginni *et al.,* 2012).

2.7.4 Other methods used to achieve energy conservation

Faggal (2007), argues that the fields of architecture and engineering are the major contributors to the recent climate change by the construction and design of harmful projects which cause energy degradation. He, therefore, suggests that they cooperate with other fields to create living spaces with minimal impacts on the environment. One of the concepts proposed is applying biomimicry, which is the imitation of nature to solve human problems. It has been divided into three levels: organism, behaviour, and ecosystem, any or a combination of this can be adopted. It applies to other disciplines like medicine, structures, and form, one of its earliest applications was the adaptation of birds forms in the designs of aeroplanes. In architecture, biomimicry has been used in several ways to produce energy-efficient and self-reliant buildings, from the production of cutting-edge materials and technology like self-healing cement and self-cleaning paint to the enhancing of building forms and structures using photovoltaic cells, phase change materials, smart shading devices, building envelope design and a functional recycling system. According to Faggal (2007), Biomimicry has come a long way in affecting the forms of buildings and thereby creating more sustainable environments.

Buildings energy use is essential to the functionality of the entire building. When it isn't monitored or regulated, it causes loss to the building occupants and the earth via the release of harmful gasses directly or indirectly, causing drastic climatic changes. The correction of erected buildings to make them more sustainable is achievable and should be advocated for to improve thermal comfort and reduce waste (Akande *et al*., 2015).

It was noted by, Ganhão (2012), that in designing structures, their lifecycle should be paid close attention to and considered to aid the erection of a fully sustainable structure from inception to demolition. Also, the level of comfort criteria and standard of living of a building's user determines the amount of energy consumed as the need for more thermal comfort produces more energy usage. He also suggests using simulation and building assessment tools to project the possible amounts of energy that will be consumed by building before their construction.

Okorieimoh (2019), believes that the amount of provided energy also determines the rate of energy usage. He thinks a lower energy supply leads to increased amounts of energy use. He proposes that energy must be used daily should spur the production of large quantities of energy from the source provider to ensure efficiency. He believes that energy conservation is not the total elimination of energy use, but it is a continuous effort of reduction in the rate of energy required for comfort. He also postulates two principles that can be adopted to aid energy efficiency: the behavioural approach that focuses on changing the culture and the technological approach, which focuses on changing the devices used. He proposes that the first step towards the technological approach is swapping energy-guzzling bulbs with energy-efficient ones.

The techniques adopted for the conservation of energy in buildings will be more efficient if they are tailored to suit the climatic conditions the building will be experiencing, like Thapa and Panda (2015), suggested, climate-responsive buildings is the proactive way of tackling energy conservation in buildings amongst other techniques. Akande *et al*. (2015), also suggests that building retrofits should be done to suit the prevailing climate to ensure the thermal comfort of the occupants.

2.8 Identification of Appropriate Energy Conservation Measures to be Adopted in the Study Area

The American Society for Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) defines thermal comfort as "that condition of mind which expresses satisfaction with the thermal environment" (Brager and Dear 2001). The researcher used the computer software; Climate consultant, whose primary purpose is to give graphic representations of hourly climate data of a specified location and aid the user in visually seeing the unique patterns and subtle details that characterise different climates. Its main aim is to assist the achievement of indoor thermal comfort. It uses weather data in Energy plus Weather (EPW) format, which can be downloaded from within the software, to give data projections for the specified location. It also has four comfort definitions integrated into it. However, the researcher uses the ASHRAE 55 standard to simulate the study area. After the simulations are run, the climate consultant then gives the best strategies to be adopted in the specified location that will lead to more comfortable hours and a reduction in heating and cooling loads, as seen in Figure 2.5. in Figure 2.6, we see detailed steps that can be taken via the modification of shapes and building forms to achieve the measures specified. Because of the lack of Energy plus Weather (EPW) data in Nigeria, the researcher used the closest data, Lagos EPW data, to run simulations for the study area, which is 315km away from Lagos and shares a similar climate.

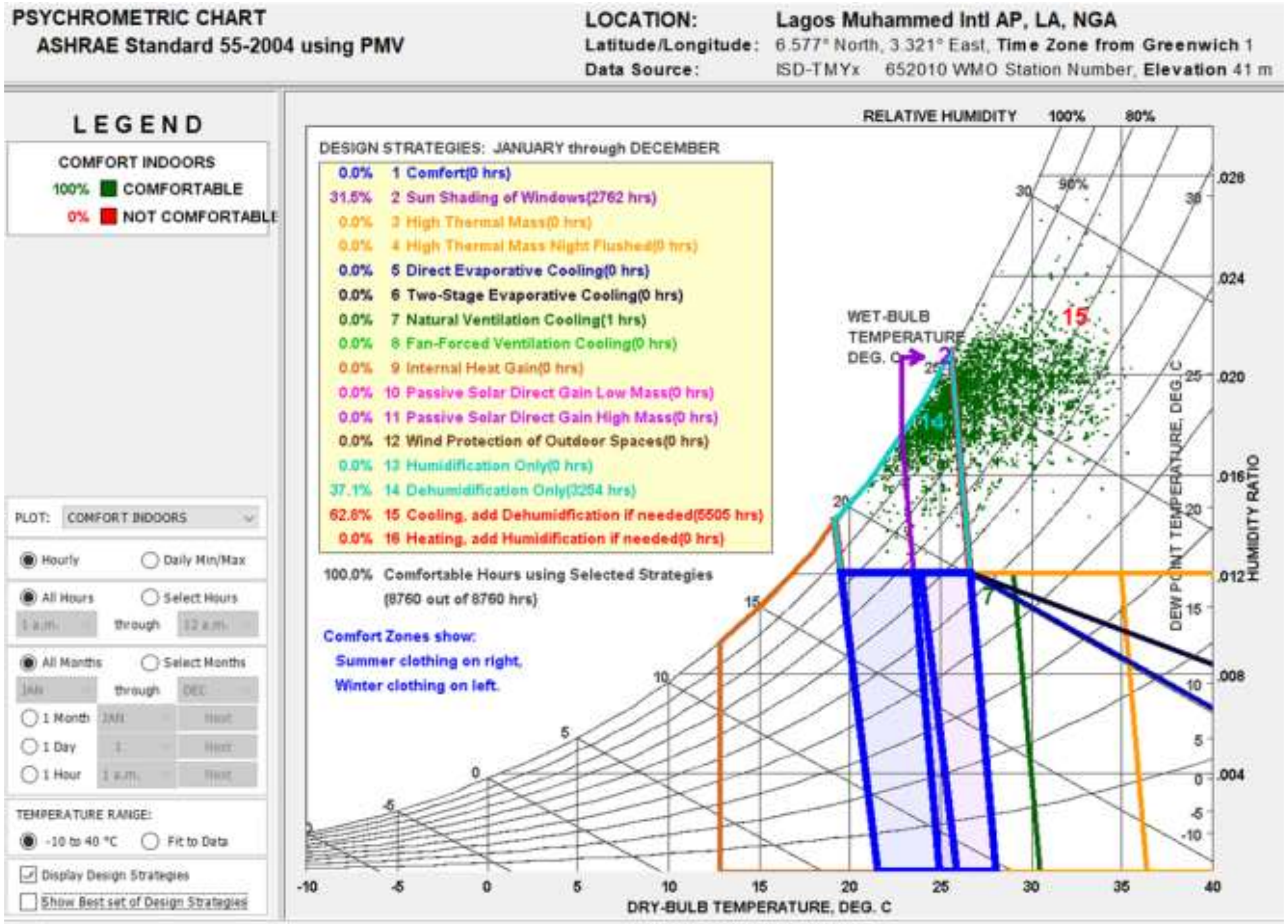


Figure 2.5 Best strategies to be adopted for energy conservation
Source: Author's work (2020)

DESIGN GUIDELINES (for the Full Year)	**LOCATION:** **Lagos Muhammed Intl AP, LA, NGA**
ASHRAE Standard 55-2004 using PMV	**Latitude/Longitude:** 6.577° North, 3.321° East, **Time Zone from Greenwich** 1
Best Set of Design Strategies, User Modified Criteria	**Data Source:** ISD-TMYx 652010 WMO Station Number, **Elevation** 41 m

Assuming only the Design Strategies that were selected on the Psychrometric Chart, 100.0% of the hours will be Comfortable.
This list of Non-Residential Design guidelines applies specifically to this particular climate, starting with the most important first. Click on a Guideline to link to the 2030 Palette for related passive design ideas (see Help).

65	Climate responsive buildings in warm humid climates used high ceilings and tall operable (French) windows protected by deep overhangs and verandas
68	Climate responsive buildings in hot humid climates used light weight construction with openable walls and shaded outdoor areas, raised above ground
59	In this climate air conditioning will always be needed, but can be greatly reduced if building design minimizes overheating
37	Window overhangs (designed for this latitude) or operable sunshades (awnings that extend in summer) can reduce or eliminate air conditioning
17	Use plant materials (bushes, trees, ivy-covered walls) especially on the west to minimize heat gain (if summer rains support native plant growth)
30	High performance glazing on all orientations should prove cost effective (Low-E, insulated frames) in hot clear summers or dark overcast winters
32	Minimize or eliminate west facing glazing to reduce summer and fall afternoon heat gain
38	Raise the indoor comfort thermostat setpoint to reduce air conditioning energy consumption (especially if occupants wear seasonally appropriate clothing)
56	Screened occupancy areas and patios can provide passive comfort cooling by ventilation in warm weather and can prevent insect problems
57	Orient most of the glass to the north, shaded by vertical fins, in very hot climates, because there are essentially no passive solar needs
26	A radiant barrier (shiny foil) will help reduce radiated heat gain through the roof in hot climates
46	High Efficiency air conditioner or heat pump (at least Energy Star) should prove cost effective in this climate
25	In wet climates well ventilated pitched roofs work well to shed rain and can be extended to protect entries, outdoor porches, and outdoor work areas
27	If soil is moist, raise the building high above ground to minimize dampness and maximize natural ventilation underneath the building
33	Long narrow building floorplan can help maximize cross ventilation in temperate and hot humid climates
35	Good natural ventilation can reduce or eliminate air conditioning in warm weather, if windows are well shaded and oriented to prevailing breezes
43	Use light colored building materials and cool roofs (with high emissivity) to minimize conducted heat gain
18	Keep the building small (right-sized) because excessive floor area wastes heating, cooling, and lighting energy
42	On hot days ceiling fans or indoor air motion can make it seem cooler by 5 degrees F (2.8C) or more, thus less air conditioning is needed
53	Shaded outdoor buffer zones (porch, patio, lanai) oriented to the prevailing breezes can extend occupancy spaces in warm or humid weather

Figure 2.6 Ways to achieve specified measures through space and form
Source: Author's work (2020)

2.8.1 Dehumidification and cooling

Lechner (2015), proposes that a tiered design approach should be used to aid thermal comfort with passive methods. The first tier will tackle heat avoidance; at this tier, the designer utilises all available resources to reduce heat gain in buildings; some strategies that can be adopted include orientation, shading, appropriate colours, insulation, vegetation, and control of internal heat sources. The second-tier deals with passive cooling and can be achieved with the use of passive cooling systems. Sometimes, however, the two tiers will not be enough to achieve appropriate thermal comfort. Therefore, the third tier will have to be utilised, which is the use of mechanical equipment and results in a mixed-mode design. However, the equipment's will be used in moderate amounts because of the already established tier one and tier two, as seen in Figure 2.7. In humid areas, dehumidification of the air in hot months is necessary for thermal comfort and mildew control. There are two primary ways to reduce moisture in the air: using a desiccant (drying agent) and colling of air below the dew point temperature.

Figure 2.7 The tiered approach of sustainable design
Source: Lechner (2015)

Lechner (2015), states that, in hot and humid climates, the emphasis of most buildings is on ventilation. Lightweight constructions are best suited to this climate, and that because of the un-comfortability of the humidity, the heating from the sun, though not as much as in arid climates, is burdensome. Summers in Japan are humid and hot, to maximise ventilation, they use lightweight construction, which also enables them to adopt lightweight, flexible paper walls; they also use large overhangs and have buffer zones. Also, in French Louisiana, where they have a very humid climate, buildings were built with tall openings and high ceilings, deep verandas that shaded the walls and open hallways.

2.8.1.1 *Types of passive cooling systems*

Lechner (2015), states that the type of cooling system to be used depends on the climate. For hot and humid climates, only comfort ventilation will be helpful; Comfort ventilation is the process whereby outdoor air is brought into buildings during the day and night and passes over people directly to facilitate evaporative cooling on their skins. However, it is worthy of note that most hot and humid climates only experience hot and humid conditions in the hotter months of the year and have relatively stable weather in the cooler months of the year, therefore a mix of various forms of passive cooling techniques can be applied, however as previously established the best port of call should be heat avoidance.

The use of plants and vegetation for cooling and shading cannot be overemphasised. They are graphically represented in Figure 2.8. The proper selection and location of vegetation on the site and buildings can aid in the reduction of the heating and cooling loads of structures by 25%. The use of vegetative matter on sites and buildings is widely popular. However, they are majorly used for purely aesthetic purposes. Aside from their aesthetic and cooling benefits, plants have been known to improve individuals' health significantly; having a view of greenery dramatically enhances people's performance. Plants also act as windbreakers in cold months and shading devices/evaporative coolers in hotter months. In addition, they reduce erosion, noise and air pollution, and carbon dioxide and create a stable microclimate while being visually pleasing (Ulrich, 1984).

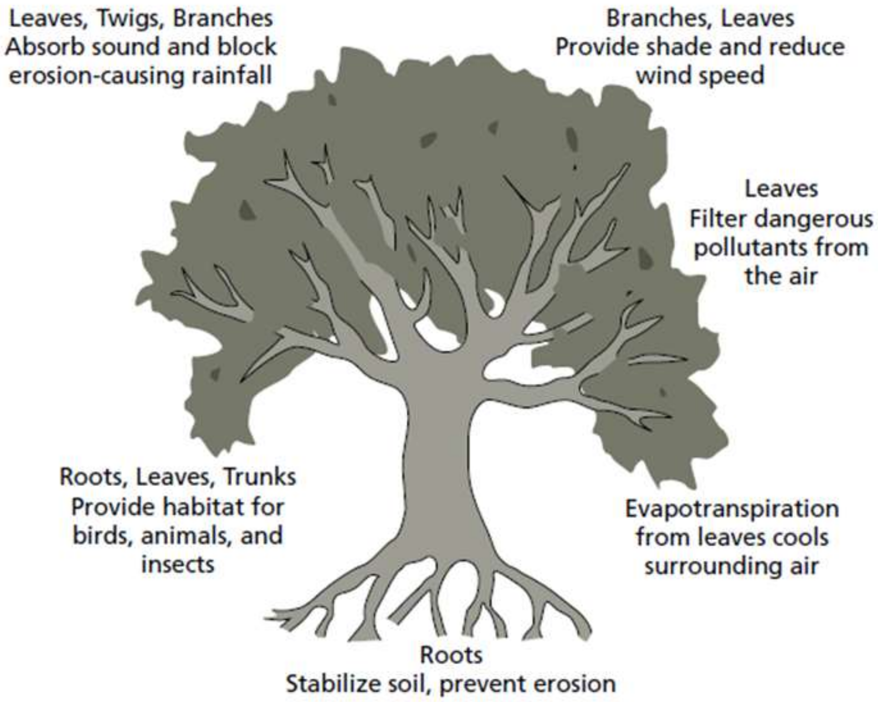


Figure 2.8 Benefits of trees
Source: Lechner (2015)

Also, the shading provided by plants is more desirable because they do not heat the building but rather cool it down through transpiration; grassy areas are more desirable than paved areas because they do not store up the heat, Figure 2.9 shows the way different tree species react with the environment and affect buildings.

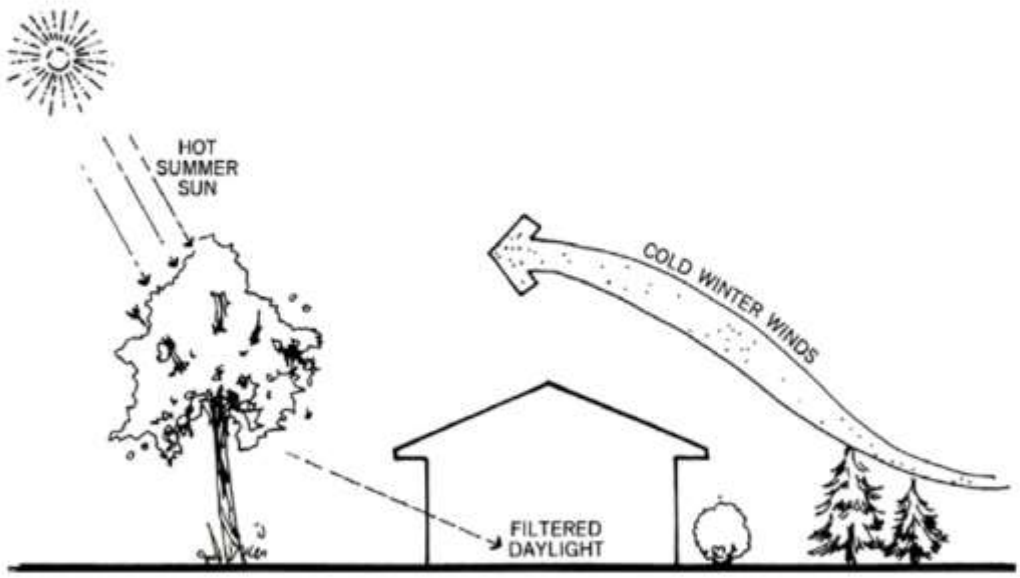


Figure 2.9 The use of different plants on sites
Source: Lechner (2015)

Furthermore, green roofs have become increasingly popular over the years because they actively reduce the cooling loads of buildings. Also, green/vegetated walls are effective in multistorey buildings along the east-west axis that are constantly exposed to the sun; this is achieved with climbing plants. Figure 2.10 shows landscaping techniques suitable for hot and humid climates. Finally, hanging plants should be used to shade windows as they provide all the benefits of vegetation while allowing the users to have a comprehensive view of their surroundings (Lechner, 2015).

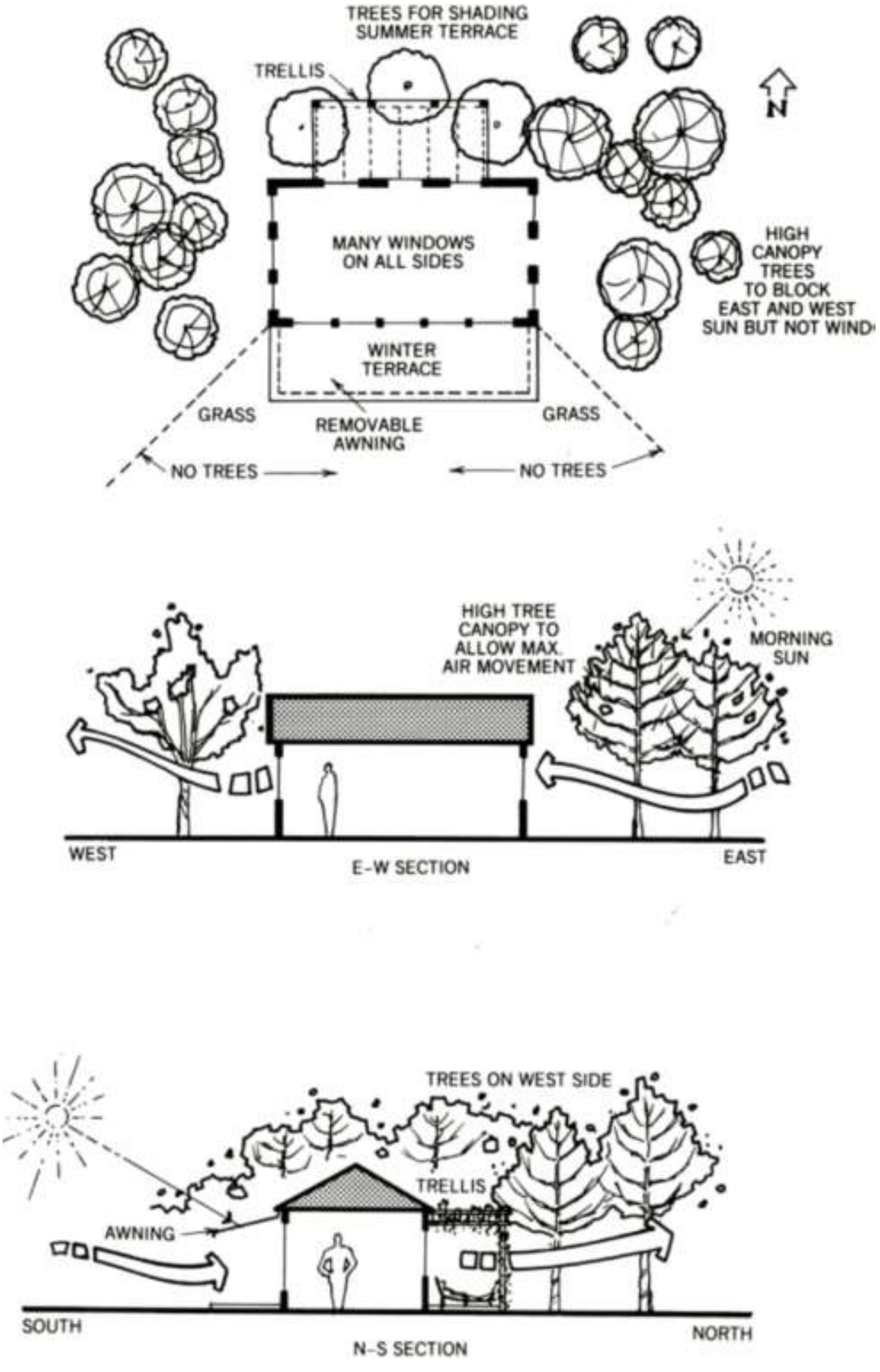


Figure 2.10 Landscaping techniques for hot and humid climates
Source: Lechner (2015)

Water is also an effective mechanism for passive cooling, especially fountains; they should be placed downwind in hot and humid climates to prevent more humidity in the surrounding atmosphere. In addition, a sustainable system should be made to ensure the purity of the water body and prevent the growth of harmful bacteria; we can also be shaded in scorching climates to avoid overheating (Ulrich, 1984).

The appropriate use of colours in buildings can aid heat avoidance. And since there is no law forcing the use of the same colour type on all walls, individual walls can be specifically treated to fit the needs of the building. For example, walls on the east-west axis could have bright colours to reflect the sun, and those on the south could have darker colours to aid heat gain. However, in scorching climates, all exterior walls should use bright colours. As shown in Figure 2.11, the lighter the colour, the higher its solar reflectance, this is also applicable to roofing materials and is seen in Figure 2.12 (Lechner, 2015).

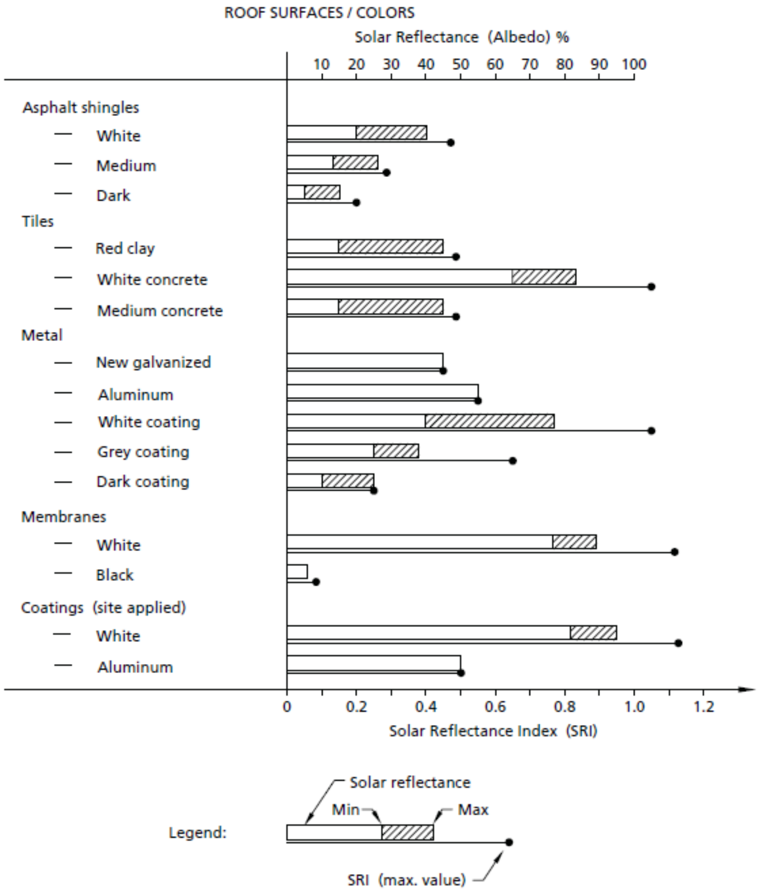


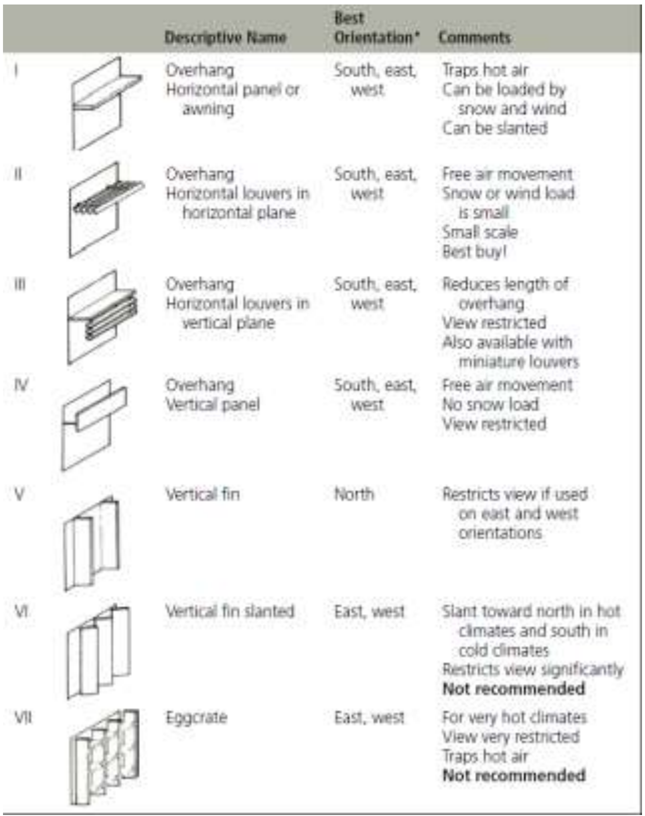
Figure 2.11 Solar reflectance of roofing materials
Source: Lechner (2015)

Surface	Solar Reflectance	
	Normal Finish	"Cool"*
White—high reflectance	85	—
White—typical	75	80
Cream-color coating	60	67
Galvanized steel	50	—
Aluminum	50	—
Weathered concrete	35	—
Light gray coating	30	50
Middle green coating	30	40
Brick red coating	25	30
Dark green coating	25	30
White asphalt shingles	20	—
Dark bronze coating	10	25
Dark asphalt shingles	10	—
Black membrane	5	—

Figure 2.12 Solar reflectance of colours
Source: Lechner (2015)

2.8.2 Sun shading

Lechner (2015), states that shading aims not only to reduce solar radiation but also to allow as much view of the exterior as possible. He believes that sun shading can be gotten by several methods, including glazing, indoor shading devices and external shading devices which is detailed in Figure 2.13.



	Descriptive Name	Best Orientation*	Comments
I	Overhang Horizontal panel or awning	South, east, west	Traps hot air Can be loaded by snow and wind Can be slanted
II	Overhang Horizontal louvers in horizontal plane	South, east, west	Free air movement Snow or wind load is small Small scale Best buy!
III	Overhang Horizontal louvers in vertical plane	South, east, west	Reduces length of overhang View restricted Also available with miniature louvers
IV	Overhang Vertical panel	South, east, west	Free air movement No snow load View restricted
V	Vertical fin	North	Restricts view if used on east and west orientations
VI	Vertical fin slanted	East, west	Slant toward north in hot climates and south in cold climates Restricts view significantly **Not recommended**
VII	Eggcrate	East, west	For very hot climates View very restricted Traps hot air **Not recommended**

Figure 2.13 Types of fixed shading devices and their most suited locations
Source: Lechner (2015)

Among these three methods, he believes that external shading devices have the most pronounced effects on a buildings aesthetics and are the most effective sun barriers. He also believes that flexible shading devices will be more effective as they adapt to the varying building needs in different seasons. He outlined some of the flexible shading devices in Figure 2.14. he also proposes that various forms of vegetation can be combined to achieve effective shading and cooling, as seen in Figure 2.15.

	Descriptive Name	Best Orientation	Comments
IX	Overhang Awning	South, east, west	Fully adjustable for annual, daily, or hourly conditions Traps hot air Good for view Can be retracted during storms Best buy!
X	Overhang Rotating horizontal louvers	South, east, west	Will block some view and winter sun
XI	Fin Rotating fins	East, west	Much more effective than fixed fins Less restricted view than slanted fixed fins
XII	Deciduous plants Trees Vines	East, west southeast, southwest northeast northwest	View restricted but attractive for low-canopy trees Self-cooling **Highly recommended**
XIII	Exterior roller shade	East, west, southeast, southwest northeast northwest	Very flexible, from completely open to completely closed View is restricted when shade is used **Provides security**

Figure 2.14 Types of flexible shading devices and their most suited locations
Source: Lechner (2015)

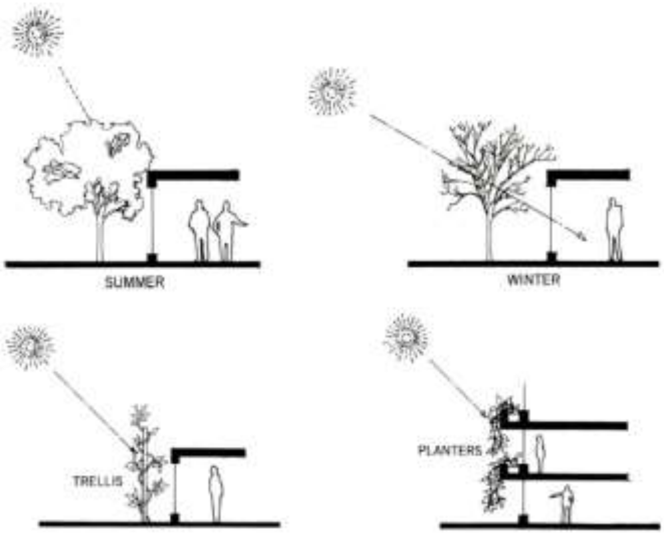


Figure 2.15 The use of vegetation as a shading device
Source: Lechner (2015)

Kamal (2010), simulated the passive cooling of buildings through sun shading and came up with several facts. His analysis showed that sun shading is a valuable tool to maintain the thermal comfort of building interior spaces. He also stated that the choice of placement of sun shading devices and when they should be placed go a long way in determining the effectiveness of sun shading and the option of shading devices. Shading can be provided in several ways, including the use of recesses in the exterior of buildings as seen in Figure 2.16, the use of movable or immovable blinds in building exteriors or louvres, transient shading achieved by the orientation of the building walls, shading by the surrounding buildings, and the shading of roofs. Although whatever method is adopted, it is that their effectiveness lies in the precision of its application.

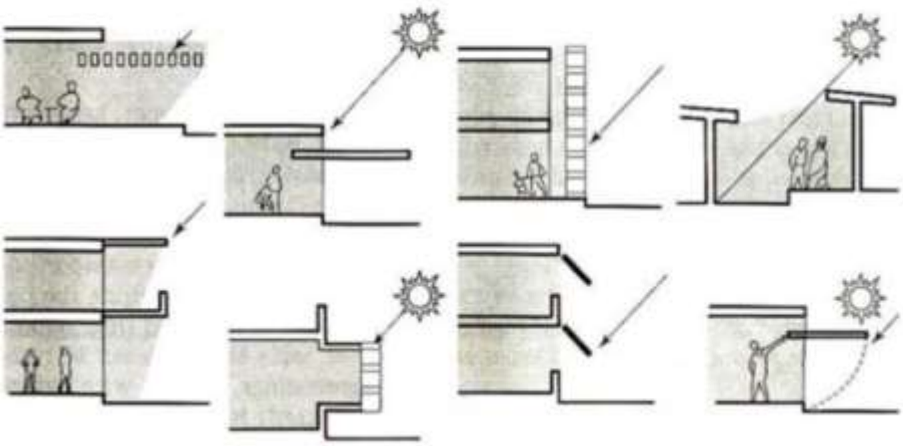


Figure 2.16 Different types of shading devices
Source: Kamal (2010)

Kamal (2010), stated that fixed horizontal overhangs are more effective on south-facing windows but less effective for west-facing windows. In all orientations, horizontal shading is more effective than vertical ones because it can run the entire length of the façade, reduce daylight penetration, and restrict the view of the exterior surroundings. He however classified shading devices into three broad categories; Movable opaque devices that reduce solar gains but also impede air movement, louvres that can be fixed or adjusted that provide shade but also restrict ventilation minimally, and Fixed devices that are mounted on walls and protect against sun and rain.

Sun *et al.* (2018), state that sun shading in buildings is an essential energy-saving technique and is helpful to isolate heat energy and regulate the thermal comfort of buildings while preventing glare and saving light energy consumption. They also believe that effective sun shading can aid indoor natural ventilation.

Maleki (2011), proposes that shading is a simple method of blocking the sun before entering the building and has multiple domino effects. First, it minimises solar radiation and cools the building effectively, thus dramatically affecting the buildings energy performance, which helps in energy conservation. He states that because of the wide variety of buildings and several climates, it is impossible to generalise the design of shading devices. However, some design recommendations can be applied generally. These recommendations include but are not limited to the sun angles, which should always be consulted when designing shading devices. They have a significant effect on the choice of the devices themselves and the orientation of the building as a whole. Also, the use of porches and overhangs in the buildings should be considered. They can serve as fixed shading devices incorporated from inception into the design of the building and provide shading at all times and seasons throughout the year. However, their depth and position on the building should be calculated to allow sunlight penetration to warm the building during cold months. The use of glass on the east and west axis of buildings should be limited. However, vertical or egg-crate shading works if they are mounted close to each other. Movable/flexible blinds also aid in the reduction of heat gain in Arid climates. However, in warm and humid temperatures where airflow is desired, they restrict ventilation. Finally, internal shading, i.e., blinds and curtains, blocks unwanted solar radiation but still converts the sunlight to heat within the envelope. It is worthy of note that all shading devices affect the view out of windows, but some have a more significant effect than others.

Kamal (2010), also states that proper landscaping can aid the shading of buildings and that trees effectively reduce heat gain of buildings through shading and evapotranspiration (the process by which plants release water vapour into the atmosphere). Maleki (2011), agrees and adds that although different types of plants are available to be used, some factors have to be considered in their choice, such as Deciduous trees provide shade during the summer but not in winter where they allow sunlight to reach interiors and provide warmth. Therefore, they are best located on the southern sides of buildings. Also, trees with heavy foliage obstruct the sunrays and create cooler shadows than filtered sunlight. Additionally, evergreen trees situated on the southern and western sides give the best protection from the sunsets. For the east and west vertical shading is best. Dense shrubs and trees should do the screening. Insulation and shading for walls can be provided by climbing plants or plants supported by walls, horizontal shading is preferable for the southern sides of buildings, and deciduous plants are most recommended.

Because the researcher intended to access the use of energy conservation measures in mixed-use buildings in Akure, Ondo state, to fully understand this phenomenon, the researcher analysed the selected samples with the general energy conservation methods as seen in Table 2.1. Furthermore, the specific methods to the specified study area, as seen in Table 2.2, to enable the researcher to determine if the energy conservation measures are entirely non-existent, they are existent but not the suitable methods for the area, or they are existent and are the appropriate measures for the study area. Therefore, the following make up the variables used to access existing buildings to determine their level of integration of energy conservation principles.

Table 2.1 General methods of energy conservation

Method	Applicable methods	Code
Mixed method	-	M
Contemporary design options	Orientation	O
	Zoning	Z
	Use of shading devices	SD
	Use of local building materials	BM
	Appropriate colours	AC
Designing with climate	Passive cooling	PC
	Energy efficient materials	EM
	Location of trees and vegetation	T
	Insulation	I
	Passive solar techniques	PS

Source: Author's work (2020)

During the research, the researcher discovered that for the specific energy conservation methods, there are repeated principles that could apply to all three methods, as seen in Figure 2.17. therefore, for the analysis, these repeated principles are not analysed separately in relation to each method but are analysed collectively in their application in the chosen samples, however for ease of reference, they are also coded as seen in Table 2.2.

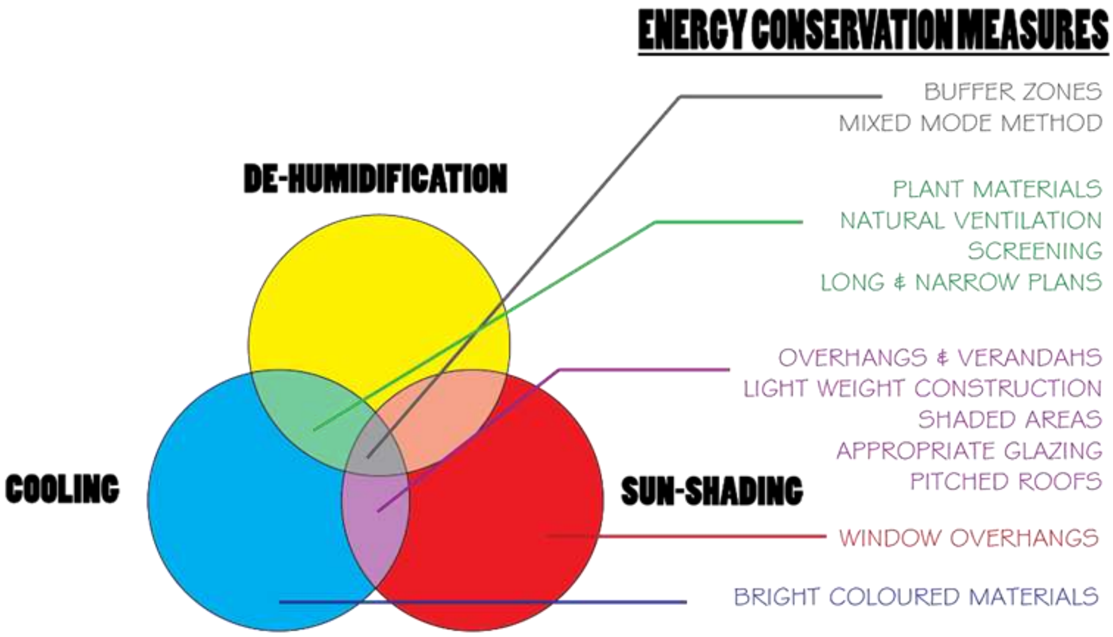


Figure 2.17 Specific methods of energy conservation
Source: Author's work (2020)

Table 2.2 Specific methods of energy conservation

Applicable methods	Code
Buffer zones	B
Mixed mode method	M
Plant materials	P
Natural ventilation	N
Screening	S
Long and narrow plans	LN
Overhangs and verandas	OV
Light weight construction	LC
Shaded areas	SA
Appropriate glazing	AG
Pitched roofs	PR
Bright coloured materials	BC
Window overhangs	WO

Source: Author's work (2020)

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Method

The Qualitative research method was used in this research. Meurer *et al.* (2007) describe qualitative research as a form of research that includes a set of methods wherein data is gotten from a small cluster and are not analysed with arithmetical techniques but rather detailed oral or written explanations of the observed data. It is a descriptive research approach. Descriptive research is a scientific method that involves observing and describing the nature and behaviour of a subject. The researcher, therefore, employs observation as a means of collecting data (Walliman, 2011). The researcher chose the qualitative research method because of the research design selected for the study, which evolved from the aim of the research; to integrate energy conservation measures in the design of a mixed-use building for sustainable development.

3.2 Research Design

A survey research design was implemented in this research. It is a type of research where data is obtained from samples to make extrapolations about a group. It is used to study attitudes and opinions (Creswell, 2012). A cross-sectional survey design was used. It is used to get data from one point in time and measure current practices or attributes. This aspect of survey design corresponds with the aim of the research. The program evaluation aspect of the cross-sectional survey was applied, and it involves using a survey to analyse and provide helpful information regarding the research aim.

3.3 Study Area

The study area of this research was mixed-used buildings in Akure, Ondo state Nigeria.

3.4 Sampling Technique

Purposeful Sampling was used. Researchers intentionally select individuals and sites to comprehend a dominant phenomenon (Creswell, 2012). This technique was used because the research required the observation of only energy conservation measures in mixed-used buildings alone. The sampling strategy adopted was Homogeneous Sampling, a purposeful sampling strategy where a researcher samples individuals or sites because they can aid the researcher generate or find a theory or peculiar concepts within the theory (Creswell, 2012). The homogeneous sampling technique was adopted because the researcher aimed to evaluate the energy conservation measures in mixed-use buildings, a subgroup of several building forms and features. Therefore, a sample size of 5 mixed-use buildings was taken from around the Federal University of Technology, Akure (FUTA), as shown in Table 3.1, because of their proximity to the proposed building site. They were assigned codes to aid in their reference throughout the research and used as case studies because they presented the researcher with the relevant data to evaluate the practices of mixed-use building construction in the study area.

Table 3.1 Buildings selected and codes

Case study	Code
Commercial centre FUTA	CC
Student centre FUTA	SC
Bayuk fuelling station FUTA road	BF
Christ Apostolic Church (CAC) church FUTA	CA
Adebowale commercial centre FUTA	AD

Source: Author's work (2020)

3.5 Variables of the research

As previously stated in the literature review of this research, several methods can be applied to achieve energy conservation in mixed-use buildings. Various studies postulated the use of multiple methods for more efficiency. The general suggestions of principles that can be applied to achieve energy conservation in buildings with the choice of only those that directly deal with the space and form of the building were selected, as seen in Table 2.1. However, the researcher further ran simulations using energy software and climate consultant to determine the specific methods suitable for the study area, as seen in Table 2.2. The researcher uses both methods: the general and specific methods to analyse the selected building samples. This was done to aid the data generated from the buildings as the researcher sought to know:

1. If there were any energy conservation measures applied in the mixed-use buildings observed
2. If yes, what type of energy conservation measures were applied, are they suitable for the climate (specific methods), or are they broadly general principles?

3.6 Method of Data Collection

Observation schedule, checklist, and Audio-visual materials were used to collect the primary data for this research because of the adopted research design, which requires observation of current trends of the various established variables. Observation is defined as assembling open-ended, direct information by watching people or places of research interest. The research was involved as a Non-participant Observer, which involved the researcher watching and recording the phenomenon under study. Audio-visual materials in the form of pictures and videos were taken to enable the researcher properly to analyse the phenomenon. In addition, a checklist was made from the established variables and was used to evaluate the buildings observed.

3.7 Data Type and Sources

Data analysed in this research was obtained from primary and secondary data sources. The qualitative methods of data collection were applied systematically to achieve the aim of the research adequately.

3.7.1 Primary data

Primary Data for this research was acquired by personal observation of the chosen case studies to evaluate the application of energy conservation measures. This information was recorded via the checklist developed by the researcher, which was formed using the established variables. As previously stated, the buildings used as case studies were obtained through the use of homogeneous purposeful sampling technique, where the researcher relies exclusively on her judgement when selecting buildings to use in the study; however, the chosen buildings were chosen based on the criteria relevant to the research work: mixed-use buildings, Akure, i.e. the buildings had to be of the mixed-use building typology and had to be located in Akure, Ondo state. The researcher formed the checklist used to observe the selected buildings through consulted academic repositories and energy calculation software, Climate consultant.

3.7.2 Secondary data

Secondary data was obtained from relevant academic repositories, which were chosen based on the necessary criteria: mixed-use buildings, energy conservation methods and sustainable design. The information gotten formed some of the variables of this research, as seen in Table 2.1.

3.8 Method of Data Analysis and Data Presentation

The data was organised using applicable codes allocated to each variable previously identified in the literature review. The classified data was analysed manually via content analysis which comprises the researcher quantifying and analysing the meaning of words or text and extrapolating it (Colorado State University, 2004). This was done with the use of excel spreadsheets, the data was transcribed appropriately, and the results were presented using tables and charts. A narrative discussion about the findings was done. The images captured were shown in plates and used to identify several phenomena observed.

The research observed individual case studies and accessed them on two levels: the application of general energy conservation methods and the application of the specific energy conservation measures as seen in Table 2.1.and 2.2. the researcher is aware of repeated variables between the two broad categories because the specific methods are an offshoot of the general methods. However, the researcher analyses such repeated principles individually under each method observed at the end of each case study analysis. The buildings level of energy conservation is calculated based on the available principles the researcher viewed to be operational and functional in the building.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Evaluation of Established Variables in Existing Mixed-use Buildings

The data for this research was manually collected and analysed using charts. The analysed data was done based on Objective 3 of this research as stated in the first chapter of the thesis, the Objective 1 and 2 have been adequately handled by the researcher in the second chapter of this research. The established variables seen in Table 2.1 and 2.2 were observed in the buildings, which served as a case study as seen in Table 3.1 for the research, and the resulting data were recorded and analysed.

4.1.1 Commercial centre FUTA

The commercial centre is located beside one of the male hostels in FUTA. They share the same site but have separate entrances to the facilities; this is a dual mixed-used facility as it just comprises the hostel and the commercial centre. However, they both exist mutually as the centre provides commercial services to the residents of the hostel, and the residents, in turn, patronise the businesses in the centre. This is a clear example of a harmonious mixed-use building where both facilities can exist individually and come together to exist as a cohesive unit.

The researcher carefully observed the building and the results can be seen in Table 4.1 and 4.2. It was evident that the level of integration of energy conservation measures was deficient. There was a complete absence of ample vegetation and other passive cooling methods. The materials used were neither lightweight nor local building materials, and there were no buffer zones, overhangs, or verandas. The only energy conservation measures used were the mixed-mode method, as there were several air conditioning units and fans, the zoning, use of pitched roofs and the bright coloured materials that aid in the reflectance of lightweight materials. The researcher further waited to observe the thermal comfort of the building interior with the absence of a power supply, and the experience was nothing short of suffocating. The need for alternative sources of power supply was immediate, majorly using petrol-powered generators, thus adding to the energy consumption of the building and generation of greenhouse gasses.

Table 4.1 General methods of energy conservation in Commercial centre FUTA

Codes	Methods	Scoring
M	Mixed mode method	✓
O	Orientation	x
Z	Zoning	✓
SD	Use of shading devices	x
BM	Use of local building materials	x
AC	Appropriate colours	✓
PC	Passive cooling	x
EM	Energy efficient materials	x
T	Location of trees and vegetation	x
I	Insulation	x
PS	Passive solar techniques	x

Source: Author's work (2020)

Table 4.2 Specific methods of energy conservation in Commercial centre FUTA

Codes	Methods	Scoring
B	Buffer zones	x
M	Mixed mode method	✓
P	Plant materials	x
N	Natural ventilation	x
S	Screening	x
LN	Long and narrow plans	x
OV	Overhangs and verandas	x
LC	Light weight construction	x
SA	Shaded areas	x
AG	Appropriate glazing	x
PR	Pitched roofs	✓
BC	Bright coloured materials	✓
WO	Window overhangs	x

Source: Author's work (2020)

On a general note, the building-integrated only 27% of the energy conservation measures, 3/11, which were the mixed mode method, zoning and the use of appropriate colours. Therefore it was apparent that because of the lack of other methods the building users had to augment by the use of artificial measures of cooling, thereby leading to more energy use. And on a specific note, the building-integrated only 23% of the energy conservation measures, 3/13, which were mixed mode method, pitched roofs and bright coloured materials, therefore it was apparent that the more detailed measures that cannot be classified as general methods too were lacking on the building structure as seen in Tables 4.1 and 4.2. This is low and will lead to more dependence on mechanical cooling methods, which will, in turn, surge the energy consumption of the building. The entrance to the structure is shown on Plate I, the pitched roofs can be seen but also the lack of proper glazing.

Plate I: Approach view of the commercial centre FUTA
Source: Author's work (2020)

4.1.2 Student centre FUTA

The student centre is a single-story structure comprising a student's lounge, classrooms, offices, commercial shops, and relaxation spots. The centre mixes commercial, recreational, and educational facilities. Which all exist in a single building structure, i.e., the building adopts the vertical mixed-use building model. All the various facilities are distributed randomly within the building; there is no zoning of similar activities to specified building sections; this leads to a more dynamic mixing method and fosters co-dependence of mutually existing facilities, which can be better than zoning of similar activities in some cases as it gives users a more diverse mix within a particular radius.

The researcher carefully observed the building, it was evident that the level of integration of energy conservation measures was high, as shown in Plate II, the building utilises fixed shading devices via horizontal and vertical fins, there is also the presence of trees around the building as seen in Plate III.

Plate II: Sun shading devices on the Student centre

Source: Author's work (2020)

Plate III: Vegetation around the site of the Student centre

Source: Author's work (2020)

Also the building's roof is pitched, and there are buffer zones, verandas and overhangs within the building as seen in Plate IV, additionally the building's roof is shaded as seen in Plate V. The researcher observed the building while power supply was absent. It is worthy of note that alternative modes of power supply were only used to facilitate the use of equipment for the commercial facilities. The indoor thermal comfort of the building did not need mechanical devices for regulation at that period.

Plate IV: Buffer zones in the Student centre
Source: Author's work (2020)

Plate V: Student centre FUTA showing pitched roofs
Source: Author's work (2020)

On a general note, the building-integrated 55% of the energy conservation measures, 6/11, which were mixed mode method, orientation, zoning, appropriate colours, passive cooling, location of trees and vegetation, which are key things to be considered in the design and planning stage of buildings. And on a specific note, the building-integrated only 69% of the energy conservation measures 9/13 which were buffer zones, mixed mode method, plant materials, natural vegetation, screening, over hangs and verandas, shaded areas, pitched roofs and bright coloured materials, which show that a great amount of thought went into the planning stage of both the building and environment surrounding it, and the result is a more temperate interior environment which the researcher experienced. The observed methods can be seen in Table 4.3 and 4.4. This is moderate, and although it will not eliminate the reliance on artificial cooling methods, it will minimise its usage and make the building comfortable for more extended periods. Also, the higher percentage of specific energy conservation measures integrated suggests that the building is suitable for its climate.

Table 4.3 General methods of energy conservation in Student centre FUTA

Codes	Methods	Scoring
M	Mixed mode method	✓
O	Orientation	✓
Z	Zoning	✓
SD	Use of shading devices	x
BM	Use of local building materials	x
AC	Appropriate colours	✓
PC	Passive cooling	✓
EM	Energy efficient materials	x
T	Location of trees and vegetation	✓

I	Insulation	x
PS	Passive solar techniques	x

Source: Author's work (2020)

Table 4.4 Specific methods of energy conservation in Student centre FUTA.

Codes	**Methods**	**Scoring**
B	Buffer zones	✓
M	Mixed mode method	✓
P	Plant materials	✓
N	Natural ventilation	✓
S	Screening	✓
LN	Long and narrow plans	x
OV	Overhangs and verandas	✓
LC	Light weight construction	x
SA	Shaded areas	✓
AG	Appropriate glazing	x
PR	Pitched roofs	✓
BC	Bright coloured materials	✓
WO	Window overhangs	x

Source: Author's work (2020)

4.1.3 Bayuk fuelling station FUTA road

The fuelling station uses a mixed-use walkable distance concept. It has residential facilities about 10 meters north of the fuelling ports and shopping complexes about 10 meters west. These facilities exist as individual facilities and have no co-dependency, thereby missing out on one of the principles of mixed-use design. They do not blend well together and thus stick out like a sore thumb.

The researcher carefully observed the building, and it was evident that the level of integration of energy conservation measures was deficient. The mixing of those facilities shouldn't exist, the commercial unit is shown in Plate VI, and the layout of the site showing the proximity between the facilities is reflected in Plate VII. This is a bad design, not only are the fumes from the station harmful to the occupants of the residential unit, but it is an unsafe design, and a fire outbreak is more likely to happen.

Plate VI: The commercial centre at Bayuk fuelling station
Source: Author's work (2020)

Plate VII: The proximity between facilities at Bayuk fuelling station
Source: Author's work (2020)

The only energy conservation measure in place is the use of pitched roofs and bright colours, as seen in Plate VIII and this spurs the use of the mixed-mode method. This is inevitable as the buildings exist in a heat island caused by only paved roads around them and no other form of passive cooling and shading.

Plate VIII: Light-coloured materials and pitched roof at Bayuk fuelling station

Source: Author's work (2020)

Also, the presence of the fuelling station does not allow the site to be adequately planned to suit the residential and commercial unit, because it is an active fuelling station which is evident in Plate IX, there will always be noise and air pollution. There are no vegetations on the site, as seen in Plate X. The only form of shading is from the canopy covering the fuelling station gas pumps; there are no buffer zones, verandas or overhangs, no water bodies, or proper zoning and orientation.

Plate IX: The active station petrol at Bayuk fuelling station
Source: Author's work (2020)

Plate X: Absence of vegetation at Bayuk fuelling station
Source: Author's work (2020)

On a general note, the building-integrated only 18% of the energy conservation measures, 2/11 which were mixed mode method and appropriate colours, but these are not enough to counter the effect of improper zoning and site planning leading to the use of more energy around and inside the building. And on a specific note, the building-integrated only 23% of the energy conservation measures, 3/13 which were mixed mode method, pitched roofs and bright coloured materials, which were also not enough to reduce large amounts of energy usage. The observed methods are seen in Tables 4.5 and 4.6. This is low and will lead to more dependence on mechanical cooling methods as observed by the researcher during the case study analysis, which will in turn create an upsurge in the energy consumption of the building.

Table 4.5 General methods of energy conservation in Bayuk fuelling station FUTA

Codes	Methods	Scoring
M	Mixed mode method	✓

O	Orientation	x
Z	Zoning	x
SD	Use of shading devices	x
BM	Use of local building materials	x
AC	Appropriate colours	✓
PC	Passive cooling	x
EM	Energy efficient materials	x
T	Location of trees and vegetation	x
I	Insulation	x
PS	Passive solar techniques	x

Source: Author's work (2020)

Table 4.6 Specific methods of energy conservation in Bayuk fuelling station FUTA

Codes	Methods	Scoring
B	Buffer zones	x
M	Mixed mode method	✓
P	Plant materials	x
N	Natural ventilation	x
S	Screening	x
LN	Long and narrow plans	x
OV	Overhangs and verandas	x

LC	Light weight construction	x
SA	Shaded areas	x
AG	Appropriate glazing	x
PR	Pitched roofs	✓
BC	Bright coloured materials	✓
WO	Window overhangs	x

Source: Author's work (2020)

4.1.4 CAC church FUTA

The church is located within a site that comprises a residential building on the left and a row of shops on the right. They all share the same services but have different entry points but one gate is used to access the site, this is shown in Plate XI. However, the site has no distinction as they are all fenced into a single site and owned by the same company. The only difference is that the shops are outward-facing, which is seen is Plate XII, while the residential unit and church's activities are primarily within site. Its primary activities take place outside, on the borders of the site. This type of mixing of uses is not equally balanced as there is no adequate distance between the residential unit and the church to prevent noise pollution during usage. Furthermore, the shops are the only revenue-generating facility. They only exist in harmony with the residential unit, and the third facility, the church, can threaten this said harmony.

Plate XI: The site entrance at CAC church FUTA
Source: Author's work (2020)

Plate XII: The row of shops at CAC church FUTA
Source: Author's work (2020)

The researcher carefully observed the building, and it was evident that the level of integration of energy conservation measures was deficient. For example, there is no ample vegetation on the site save a singular lone tree in between the church and residential unit as seen in Plate XIII, the site is not zoned correctly or oriented, there are no buffer zones or overhangs. The energy conservation measures that exist are pitched roofs and bright coloured materials and the building relies on the mixed method as mechanical methods of power supply and cooling are required.

Plate XIII: The residential and church unit placements on the site
Source: Author's work (2020)

On a general note, the building-integrated only 18% of the energy conservation measures, 2/11 which are mixed method and appropriate colours, which can be deemed as after thoughts as they are only introduced after the construction of buildings. And on a specific note, the building-integrated only 31% of the energy conservation measures, 4/13 which are mixed mode method, natural ventilation, pitched roofs and bright coloured materials, which are not enough to reduce energy use in a significant amount. The methods can be seen in Tables 4.7 and 4.8. This is low and will lead to more dependence on mechanical cooling methods, as observed by the researcher during the case study analysis, which will, in turn, surge the energy consumption of the building.

Table 4.7 General methods of energy conservation in CAC church FUTA

Codes	Methods	Scoring
M	Mixed mode method	✓
O	Orientation	x
Z	Zoning	x
SD	Use of shading devices	x
BM	Use of local building materials	x
AC	Appropriate colours	✓
PC	Passive cooling	x
EM	Energy efficient materials	x
T	Location of trees and vegetation	x
I	Insulation	x
PS	Passive solar techniques	x

Source: Author's work (2020)

Table 4.8 Specific methods of energy conservation in CAC church FUTA

Codes	Methods	Scoring
B	Buffer zones	x
M	Mixed mode method	✓

P	Plant materials	x
N	Natural ventilation	✓
S	Screening	x
LN	Long and narrow plans	x
OV	Overhangs and verandas	x
LC	Light weight construction	x
SA	Shaded areas	x
AG	Appropriate glazing	x
PR	Pitched roofs	✓
BC	Bright coloured materials	✓
WO	Window overhangs	x

Source: Author's work (2020)

4.1.5 Adebowale commercial centre FUTA

This complex embodies the mixed-use style prevalent in Akure, Ondo state. It comprises multiple residential structures within the site, with a single-story commercial building about 20 meters away from the residential facilities. They are all fenced in as they share the same site and are owned by the same person. Though outward-facing, the commercial units rely on the main residential building for energy supply and thus do not exist on their own. There is a co-dependence between the dual uses, and the only visible drawback will be a cramped site with no room for ample vegetation.

The researcher carefully observed the building, and it was evident that the level of integration of energy conservation measures was deficient. For example, there was no space on the site for natural ventilation, and the site was paved all through with no vegetation cover, and had only one tree on the border of the site. Furthermore, as seen in

Plate XIV, the residential units are overshadowed by duplex commercial structures on three sides, preventing the inflow of natural air.

Plate XIV: Site entrance to the residential units on the site
Source: Author's work (2020)

Also, the residential units are overshadowed by duplex commercial structures on three sides, this is shown in Plate XV and Plate XVI, preventing the inflow of natural air; no overhangs or shading devices were observed.

Plate XV: The commercial units on the site
Source: Author's work (2020)

Plate XVI: Other commercial units on the site
Source: Author's work (2020)

On a general note, the building-integrated only 18% of the energy conservation measures, 2/11 which are mixed mode method and appropriate colours. And on a specific note, the building-integrated only 23% of the energy conservation measures, 3/13 which are mixed mode method, pitched roofs and bright coloured materials as seen in Tables 4.9 and 4.10. This is low and will lead to more dependence on mechanical cooling methods, as observed by the researcher during the case study analysis, which will intensify the energy consumption of the building.

Table 4.9 General methods of energy conservation in Adebowale commercial centre FUTA

Codes	Methods	Scoring
M	Mixed mode method	✓
O	Orientation	x
Z	Zoning	x
SD	Use of shading devices	x
BM	Use of local building materials	x
AC	Appropriate colours	✓
PC	Passive cooling	x
EM	Energy efficient materials	x
T	Location of trees and vegetation	x
I	Insulation	x
PS	Passive solar techniques	x

Source: Author's work (2020)

Table 4.10 Specific methods of energy conservation in Adebowale commercial centre FUTA

Codes	Methods	Scoring
B	Buffer zones	x
M	Mixed mode method	✓
P	Plant materials	x
N	Natural ventilation	x
S	Screening	x
LN	Long and narrow plans	x
OV	Overhangs and verandas	x
LC	Light weight construction	x
SA	Shaded areas	x
AG	Appropriate glazing	x
PR	Pitched roofs	✓
BC	Bright coloured materials	✓
WO	Window overhangs	x

Source: Author's work (2020)

4.2 Summary of Findings

Please refer to Table 2.1 and 2.2 for the coding of variables used in this data presentation by the researcher and Table 3.1 for the coding of case studies that will also be used in this data presentation by the researcher. After carefully analysing the data gathered via observation schedule, checklist and audio-visual materials, the researcher has the following results.

1. All the samples observed has an integration of at least one measure of energy conservation.
2. The percentage of integration of energy conservation measures in the buildings is relatively low, and the researcher uses the following grading system to access the building's integration of energy conservation measures:

   70 - 100% = A (very good)

   60 - 69% = B (good)

   50 – 59% = C (moderate)

   45 – 49% = D (moderately fair)

   40 – 44% = E (fair)

   0 – 39 % = F (fail)

As seen in Table 4.11, most of the buildings, 4 out of the 5 observed, fall within the fair range (F) in both categories, general and specific methods of energy conservation measures. However, only one building has a moderate grade in both categories. Thus, the level of integration of energy conservation measures in mixed-use buildings in Akure state is low.

Table 4.11 Percentage of observed integrated energy conservation measures in the samples

Codes	Samples	Percentage of general methods of energy conservation integrated (%)	Grade	Percentage of specific methods of energy conservation integrated (%)	Grade
CC	Commercial centre FUTA	27	F	23	F
SC	Student centre FUTA	55	C	69	C
BF	Bayuk fuelling station FUTA road	18	F	23	F
CA	Christ Apostolic Church (CAC) church FUTA	18	F	31	F
AD	Adebowale commercial centre FUTA	18	F	23	F

Source: Author's work (2020)

3. In Figure 4.1, it is evident that the percentage of general energy conservation measures observed in the buildings is bad for 4 out of the 5 buildings and only moderate in one building.

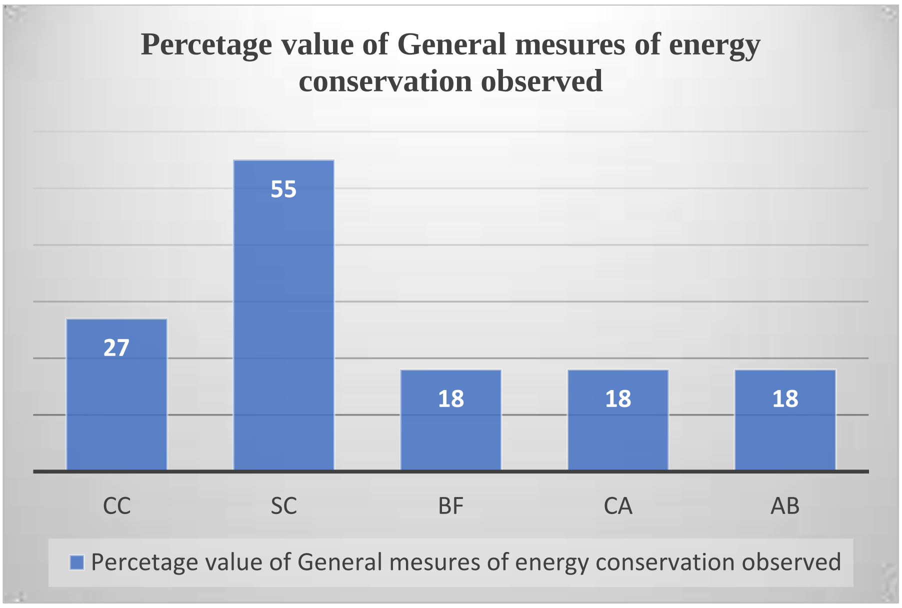


Figure 4.1 Percentage of general measures of energy conservation observed
Source: Author's work (2020)

4. As seen in Figure 4.2, the percentage of specific energy conservation measures observed in the buildings is bad for 4 out of the 5 buildings and only moderate in one building.

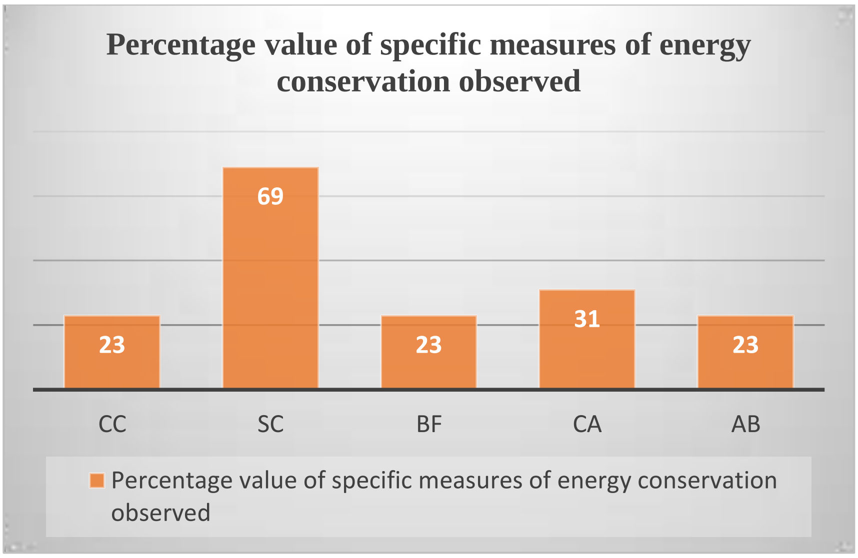


Figure 4.2 Percentage of specific measures of energy conservation observed
Source: Author's work (2020)

5. 4/5 of the buildings observed integrated more of the specific measures of energy conservation compared to the integrated general measures, this is shown in Figure 4.3. This implies that even though the integration of energy conservation measures in the buildings is relatively low, the measures applied are mainly suitable to the buildings' climate

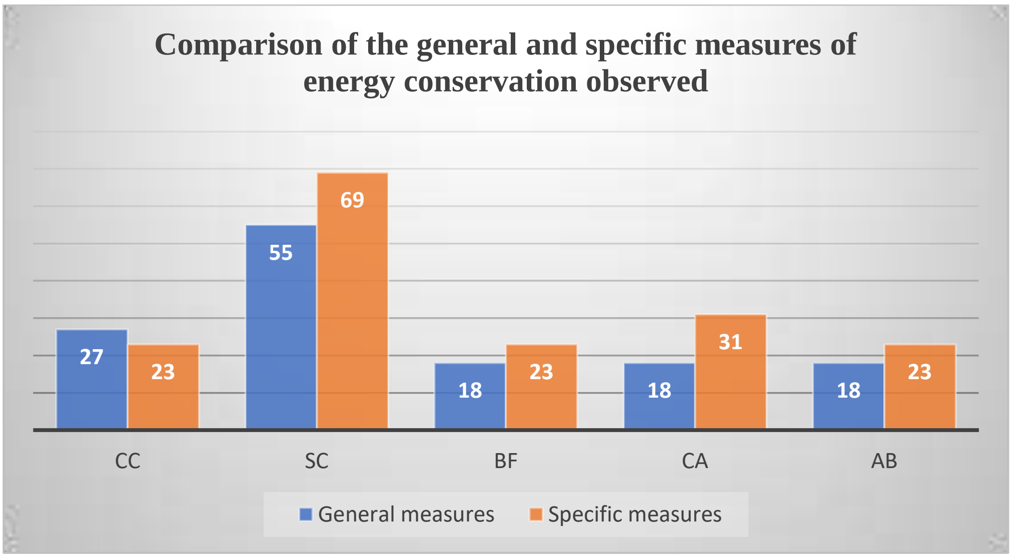


Figure 4.3 Comparison of the general and specific measures
Source: Author's work (2020)

CHAPTER FIVE

5.0 PROPOSED DESIGN

The researcher proposed a design based on the established variables and the building type. Below are some details regarding the design.

5.1 Site Location

The site is located along the Akure-Ilesha expressway, about 5km to the entrance gate of the Federal University of Technology Akure (FUTA). It is an adjacent Forte oil fuelling station beside a residential area this is seen in Plate XVII and Plate XVIII.

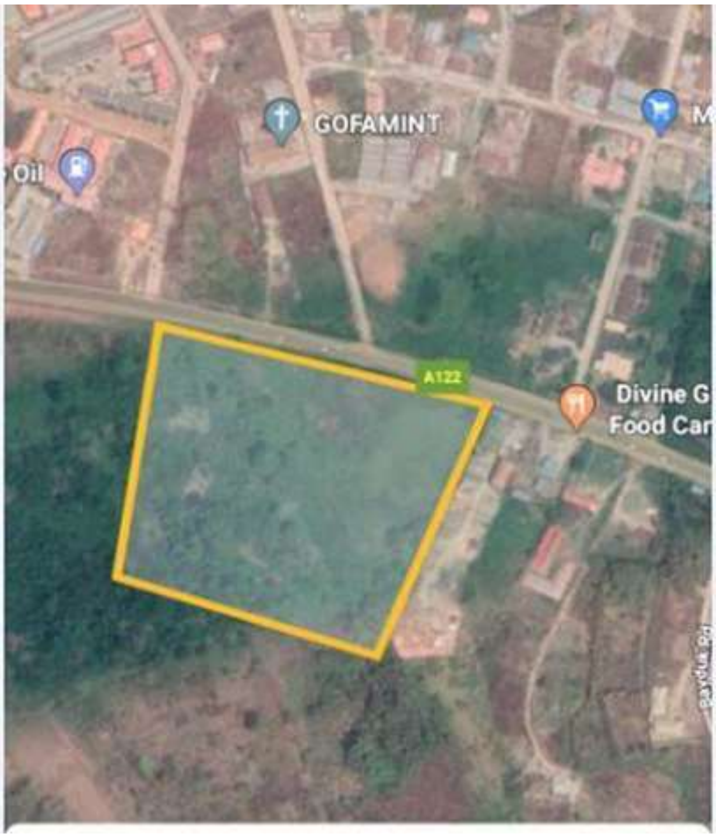


Plate XVII: Site location
Source: Author's work (2020)

Plate XVIII: Site layout
Source: Author's work (2020)

5.2 Site Analysis

The location of the respective axis of the site was noted to enable the researcher to place the buildings properly on the site, as seen in Plate XIX. Furthermore, existing services such as electrical poles around the site were noted, suggesting the availability of public power supply on the site, as seen in Plate XX.

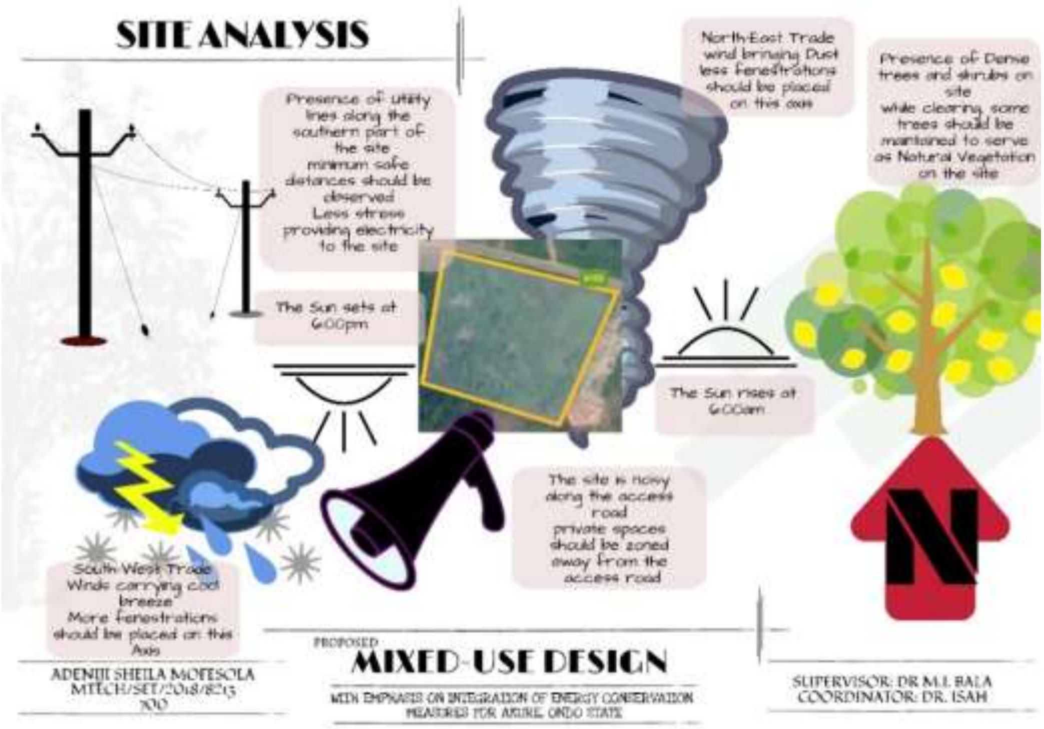


Plate XIX: Site analysis
Source: Author's work (2020)

Plate XX: Services on proposed site
Source: Author's work (2020)

In addition, the researcher observed access roads to the approach, and the right borders of the site make it easily accessible on these corners; the researcher also zoned the site into quiet and noisy zones to aid in the site planning, as seen in Plate XXI.

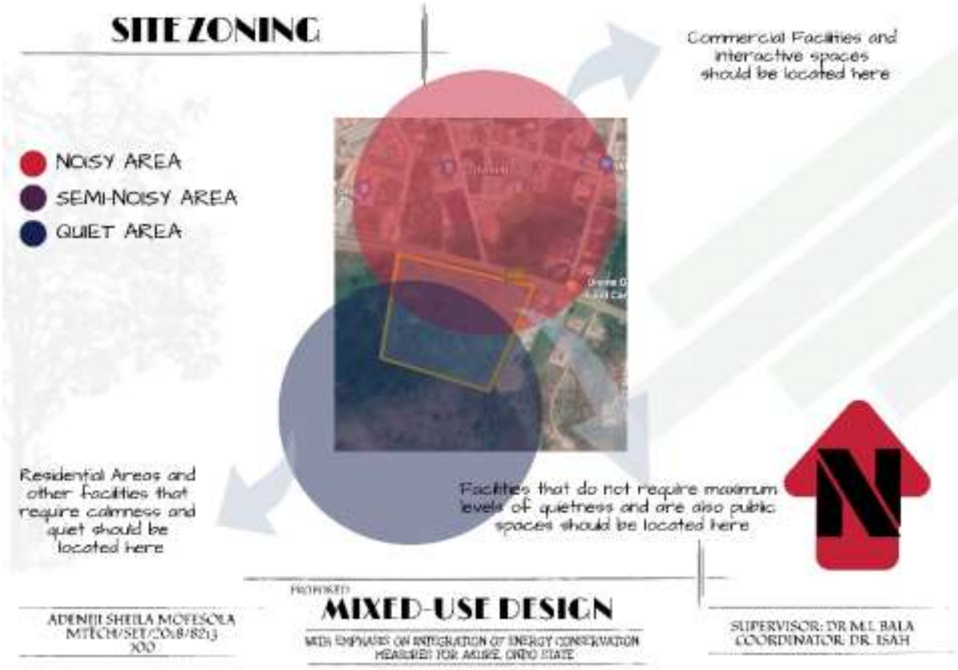


Plate XXI: Site zoning
Source: Author's work (2020)

The site is relatively flat. But a proper analysis will be conducted to help the building personnel in designing a steady structure. There is a presence of dense shrubs and trees on the site, some of which will be retained and adequately manicured to fit the recreational and shading requirement of the site. At the same time, the others will be cleared to give way for the erection of the structure. The site is assessable from two roads, a major highway on the southern side and a road by the left. A stable soil was observed on site. But due to the number of floors for the proposed structure, a suitable foundation will be used as a measure to ensure adequate stability.

5.3 Site Plan

Access to the site is provided along its southern and eastern axis. Two access points are provided to the site. There are two parking lots, the smaller one located on the southwest axis that caters to the residential units and the larger one on the south side of the site that caters to all other commercial activities and offices, Plate XXII. Shrubs and kerbs are used to direct walk and driveways. The site was zoned utilising the direction of the trade winds and the analysis of the quiet and noisy areas as seen in Plate XXI to locate all building facilities properly.

Plate XXII: Site plan
Source: Author's work (2020)

5.4 Conceptual Analysis

The recycling logo was used as the concept for the building, because it is an iconic representation of the issue the building seeks to address – energy conservation. The logo also made it possible to adequately achieve the mixed-use walkable model of mixed-use building design with an appropriate walkable distance between facilities. The logo further signifies the harmony between the various building facilities as it should be in a mixed-use building design, as explained in Plate XXIII.

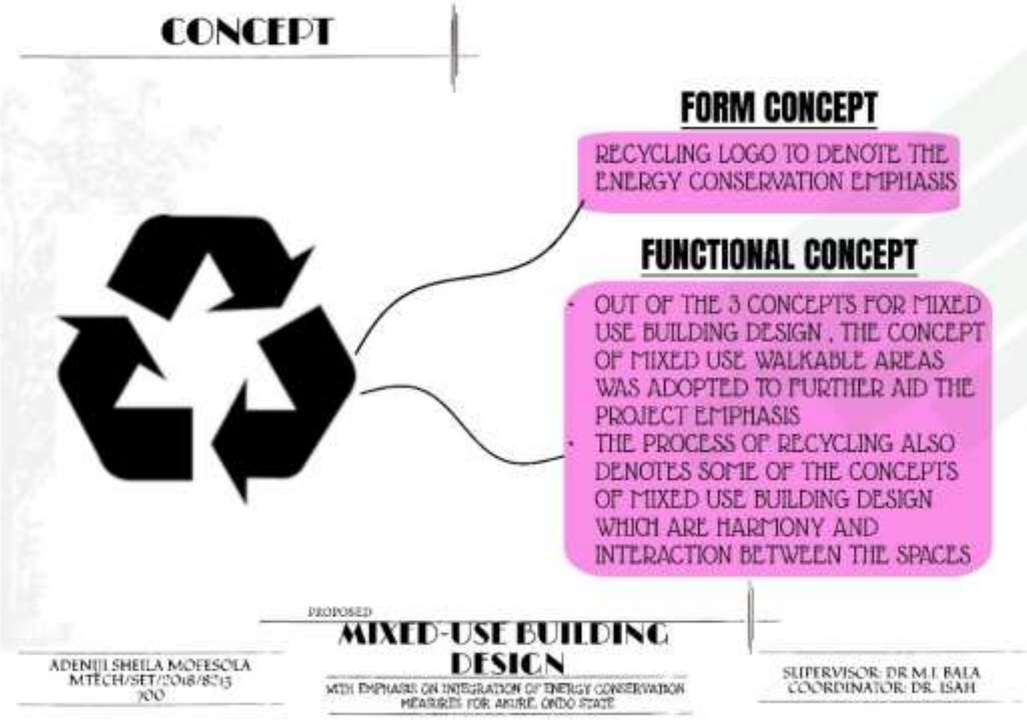


Plate XXIII: Concept
Source: Author's work (2020)

5.5 The Main Building

The ground floor of the central building is made to cater for offices along with the first floor. The second to the sixth floor of the building is zoned for residential activities. The building on the left part of the site serves as a commercial hub providing lettable shops and halls. The building on the right part of the site serves as the shopping mall with various services shown in Plate XXIV.

Plate XXIV: The main building
Source: Author's work (2020)

5.6 Design Considerations and Planning Principles

The structure was functionally appropriate for the events expected to be done. The use of standard sizes of furniture and fixtures aided the researcher in providing adequate spaces. The design aimed to aid in the conservation of energy via the use of space and form. Key principles discovered during the literature review were applied, such as the use of overhangs and fins to provide sun shading, buffer zones and verandas to prevent heat gain, the presence of water bodies on the site to aid cooling, less paved areas to prevent the creation of a heat island, an atrium, water bodies, green areas, courtyards and verandas, all these applied principles can be viewed in Plate XXV, XXVI, and XXVII.

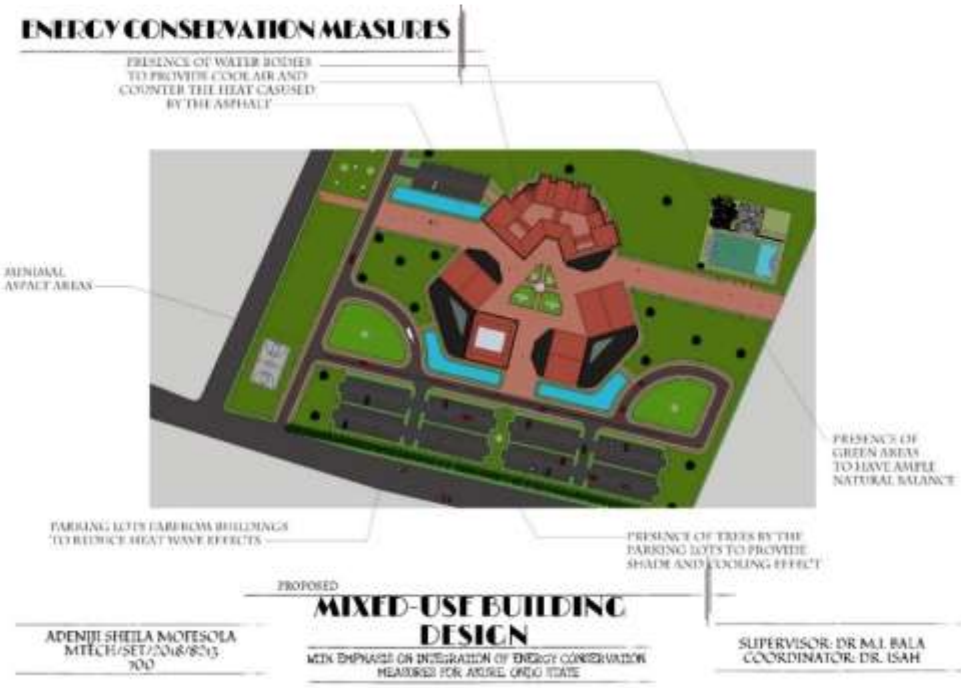


Plate XXV: Energy conservation measures on the site
Source: Author's work (2020)

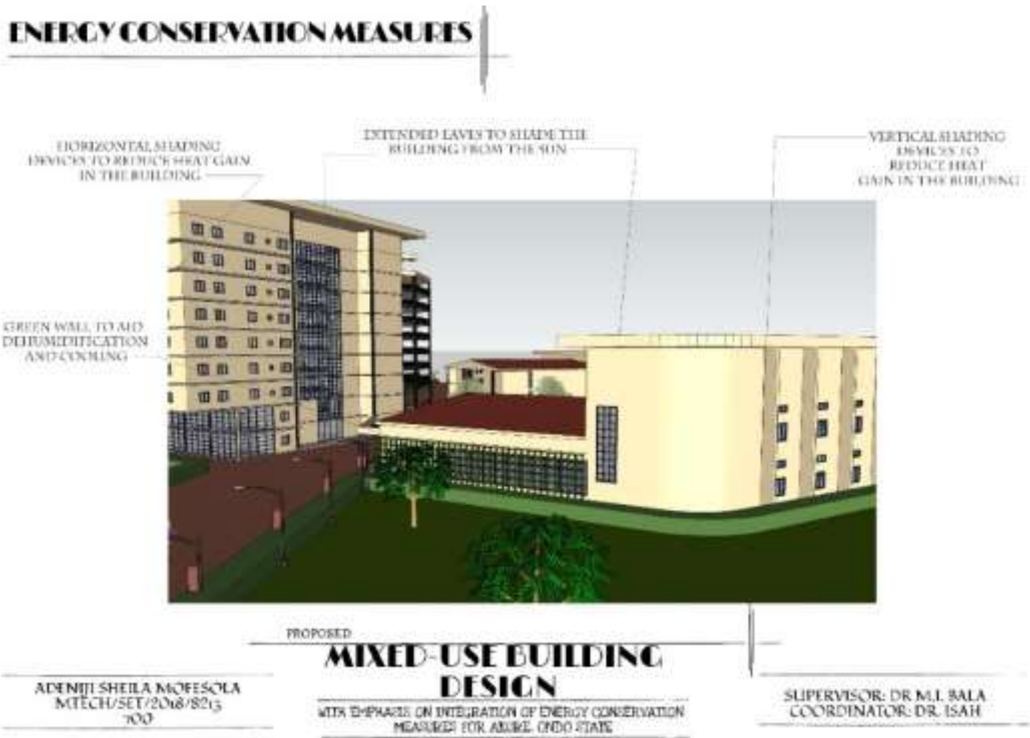


Plate XXVI: Energy conservation measures for sun shading
Source: Author's work (2020)

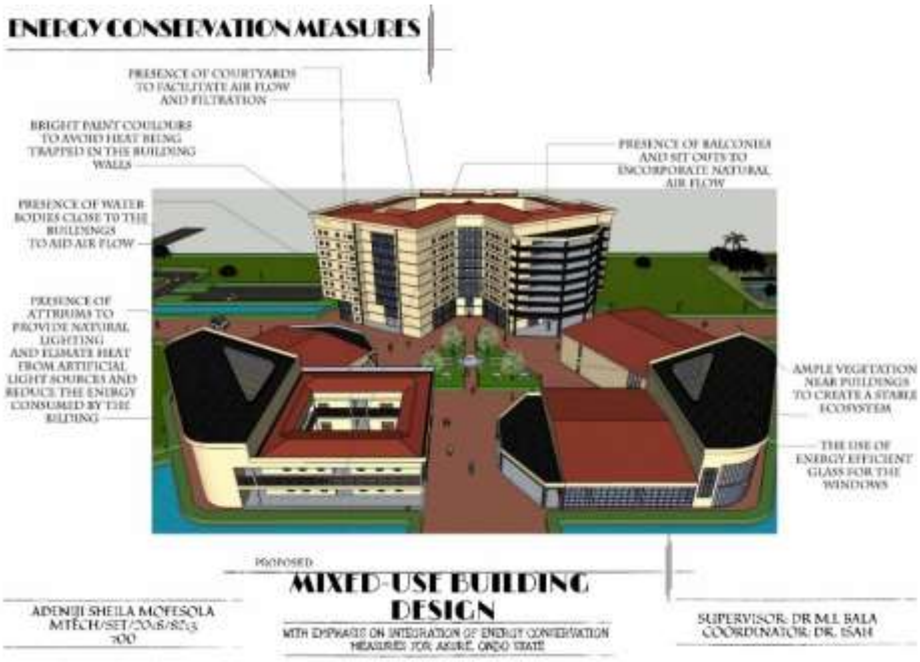


Plate XXVII: Energy conservation measures for cooling
Source: Author's work (2020)

The use of light weight construction shown in Plate XXVIII was also adopted along with the use of green walls to create evapotranspiration for cooling, the use of bright coloured materials to aid light reflectance and the location of proper vegetation such as Boston ivy and Masquerade trees as seen in Plate XXIX on the site.

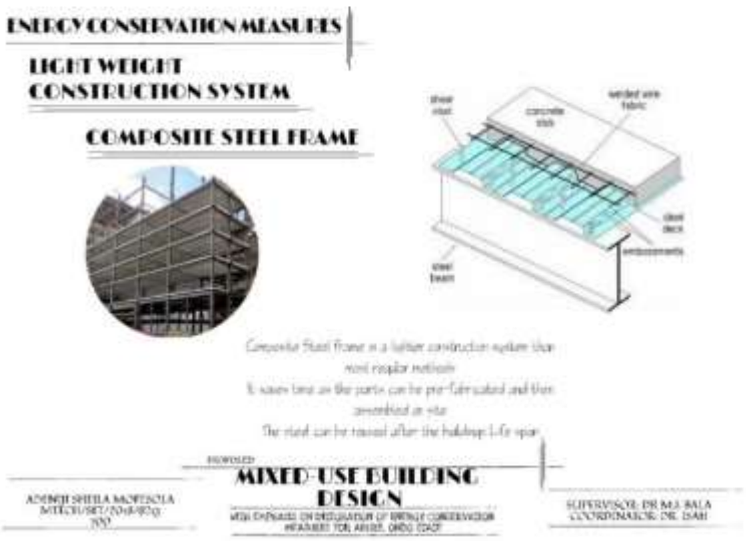


Plate XXVIII: Energy conservation measures: light weight construction materials
Source: Author's work (2020)

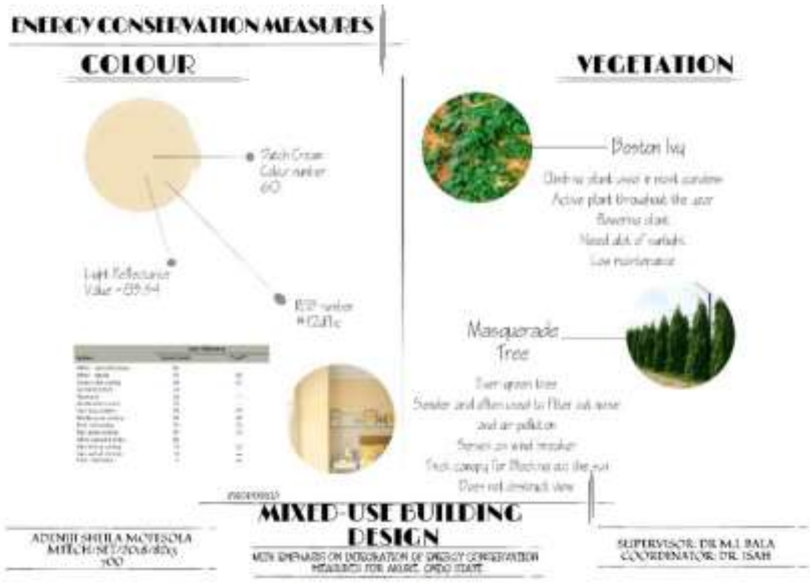


Plate XXIX: Energy conservation measures: bright colours and vegetation
Source: Author's work (2020)

Casement windows were used to aid free flow of large amounts of air into the buildings and promote the presence of natural ventilation at all times , this is seen in Plate XXX, along with the vertical and horizontal fins for shading of the windows, which have a depth of 1200mm and width of 150 mm to make their coverage more effective while also giving room for air flow,

Plate XXX: Energy conservation measures: appropriate glazing and shading
Source: Author's work (2020)

Human comfort was one of the primary considerations as the researcher designed the space to be used adequately by humans. Therefore, appropriate measures were taken such as minimal walking distances, location of exit and entry points, stairways and elevators, provision of adequate ventilation and lighting, and security to enable users to enjoy being in the space.

5.7 Construction System

Box frame construction will be adopted in the erection of the structure. This entails the erection of the structural members (columns, beams, and slabs) and then partitioning spaces using hollow blocks. This construction technique saves time, and errors in design are easily discovered while erecting the frame. Also, it provides the avenue for lightweight construction materials to be used as wall fillings.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

While working on this research, the researcher discovered multiple ways of achieving energy conservation in buildings. However, some can be applied during the construction phase, while some can be applied after completion. It is best to use both methods for efficiency as they increase the chances of achieving energy conservative designs. The research also discovered that random energy conservation measures would not automatically make a building more sustainable. The measures applied must be suitable to the climate the building will be in. The analysis of the appropriate specific measures to be adopted in this research was done with energy calculation software – Climate consultant.

All the samples studied by the researcher aided the researcher to conclude that the integration of energy conservative measures in mixed-use building design in Akure Ondo state is low. However, the minimal measures adopted in the building construction are majorly part of the recommended measures suitable to the climate. Therefore if more specific measures are applied, more energy will be conserved in the buildings.

The researcher, using the data generated from the primary and secondary sources, designed a mixed-use building for Akure, Ondo state, which integrated the established variables suitable to the climate seen in Figure 2.17: Buffer zones and verandas as seen in Plate XXVII. Mixed-mode method by giving room for artificial means of heating and cooling in the space design. Plant materials such as Boston ivy and Masquerade trees as shown in Plate XXIX. Natural ventilation and appropriate glazing by using casement windows as shown in Plate XXX. Screening and Overhangs at a depth of 1200mm as seen in Plate XXX. Long and narrow plans and lightweight construction by using composite steel frame method as shown in Plate XXVIII. Bright coloured materials by using a Dutch cream paint as shown in Plate XXIX, and shaded areas, pitched roofs, window overhangs as seen in Plates XXV, XXVI, and XXVII. The use of Climate consultant was instrumental in the accurate determination of appropriate measures to be integrated. The researcher therefore concluded that the above measures should be considered when designing in Akure, Ondo state in order to produce buildings that use up less energy resources.

6.2 Recommendations

The government should create policies that include the mandatory use of energy conservative practices in construction. Workers should be trained in constructing these new types of buildings so there will be an availability of skilled personnel. There should be seminars and workshops for personnel in the built industry and the general public to create awareness of the benefits of the proposed new sustainable designs. Architects and other construction personnel should adopt energy simulation software in their designs to create the best possible structure on paper before it gets built physically, thus reducing the need for retrofitting. Architects and other professionals should train in the built industry by trained professionals on how to consider energy conservation strategies while designing and constructing buildings.

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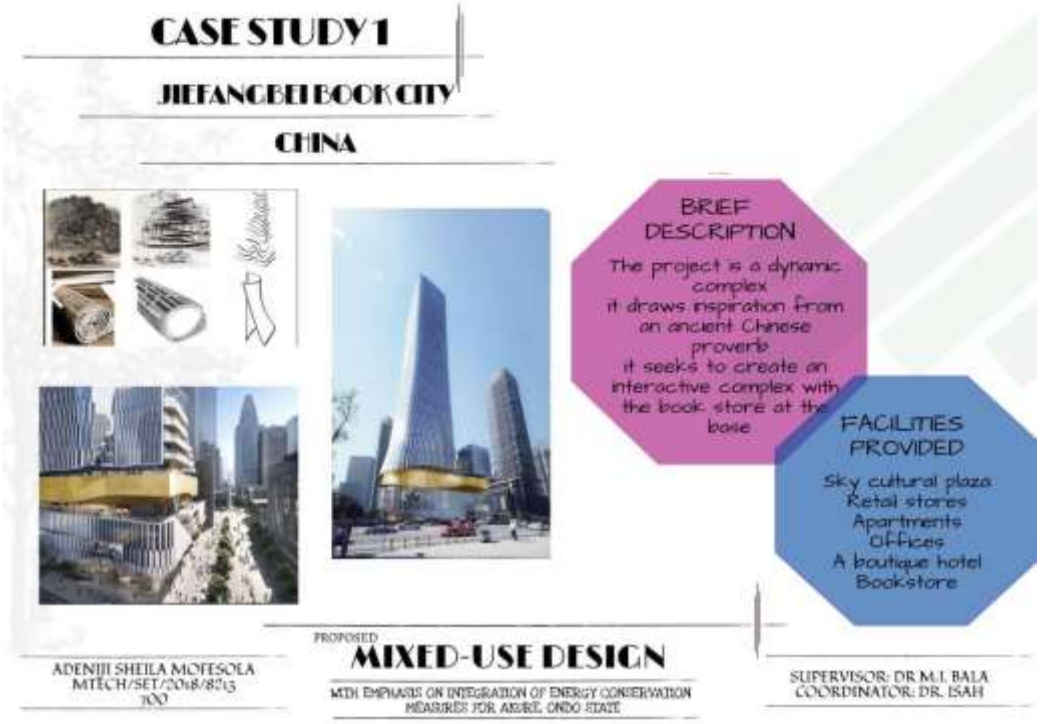
APPENDICES

Appendix A: Jiefangbei book city



Appendix B: Alcantara gardens

Appendix C: Central park Jakarta

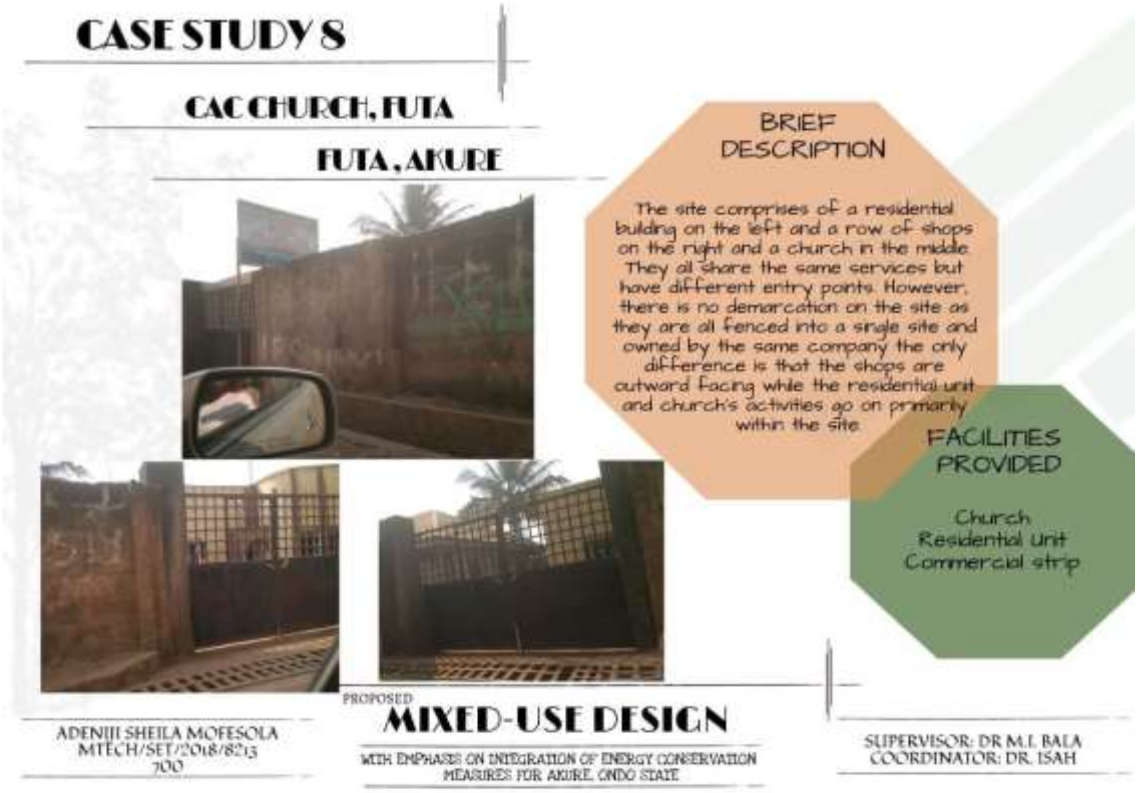
Appendix D: Nestoil towers

Appendix E: Commercial centre FUTA

Appendix F: Student centre FUTA

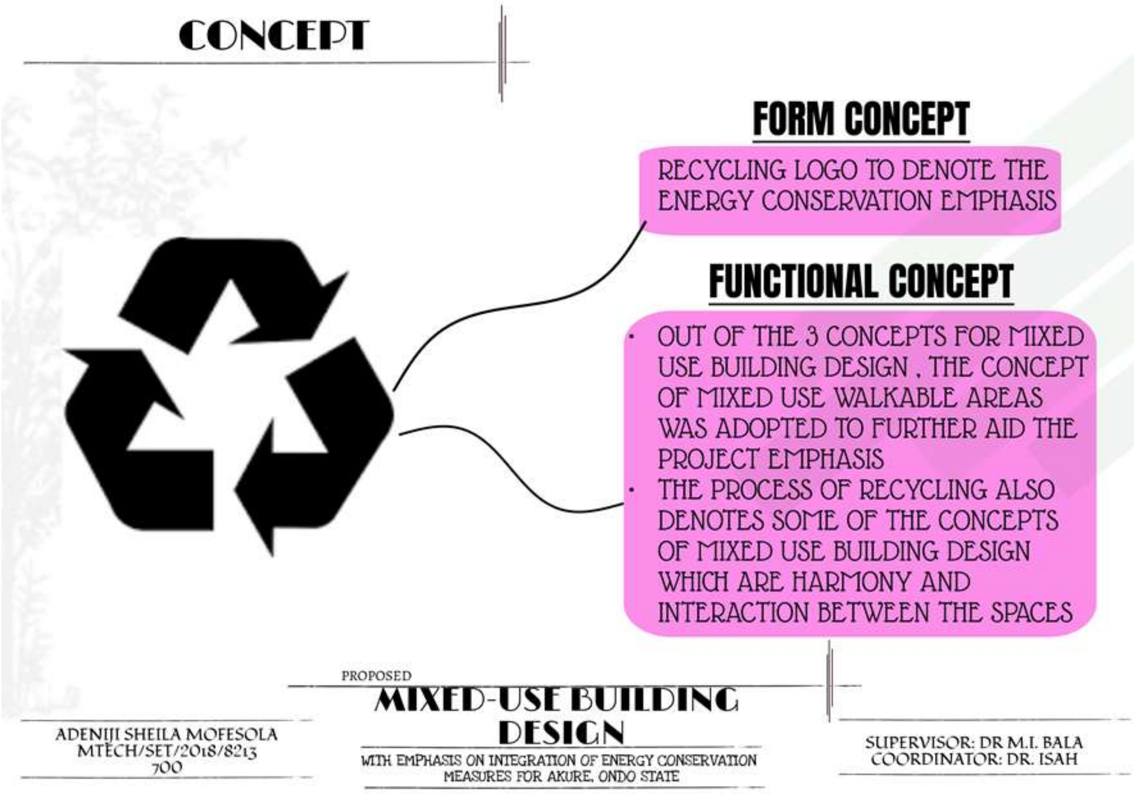
Appendix G: Bayuk fuelling station FUTA

Appendix H: CAC church FUTA

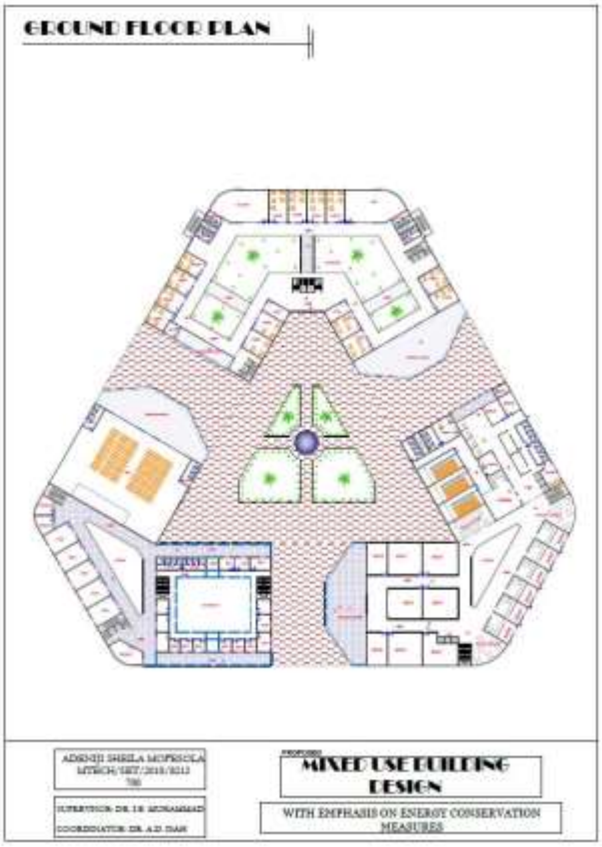


Appendix I: Adebowale commercial centre FUTA

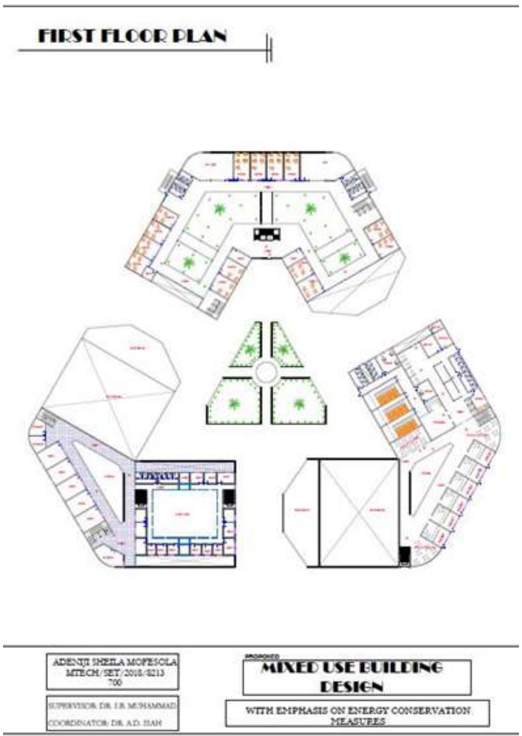
Appendix J: Concept



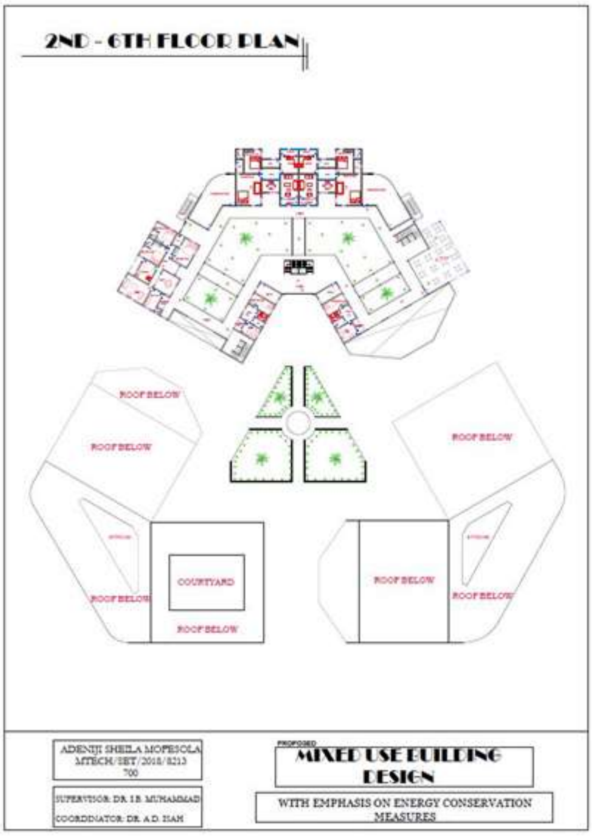
Appendix K: Ground floor plan



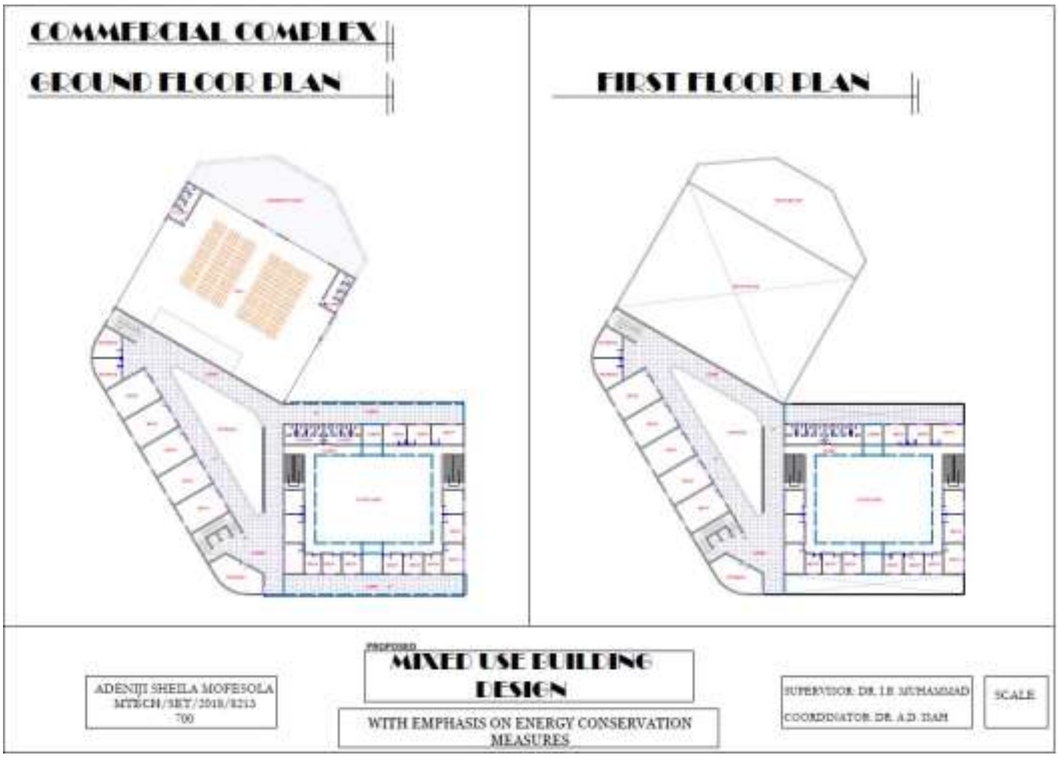
Appendix L: First floor plan



Appendix M: 2^{nd}-6^{th} floor plan

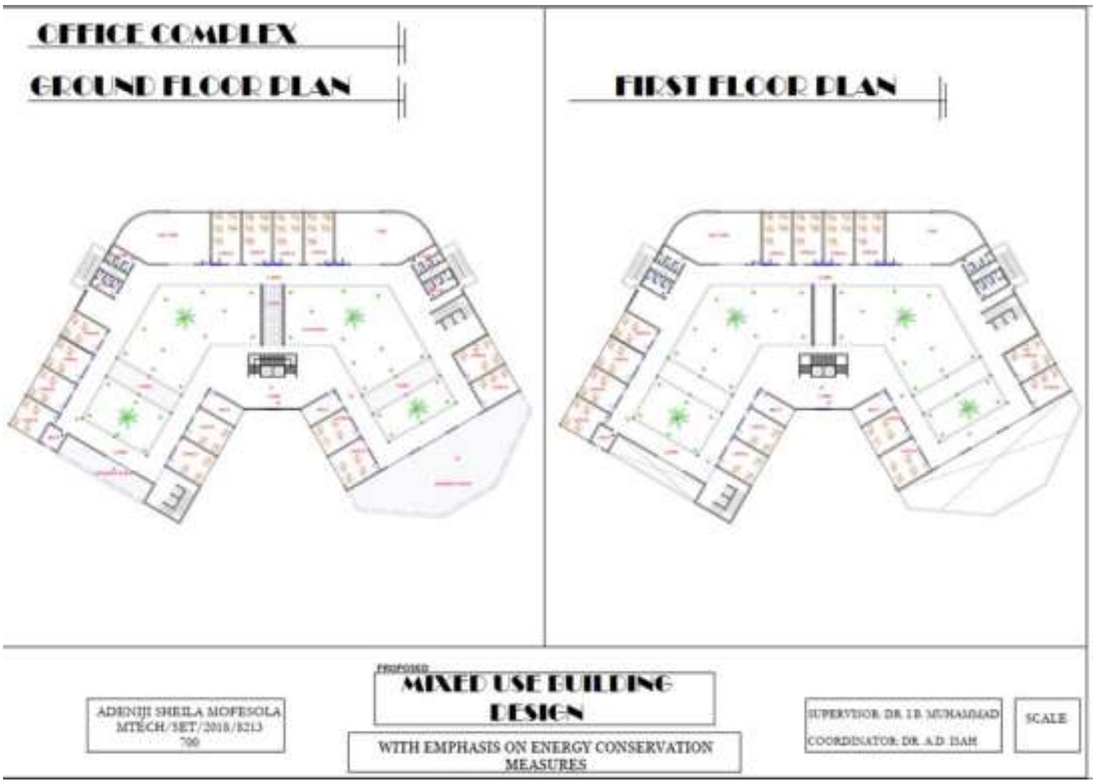


Appendix N: Commercial complex floor plan

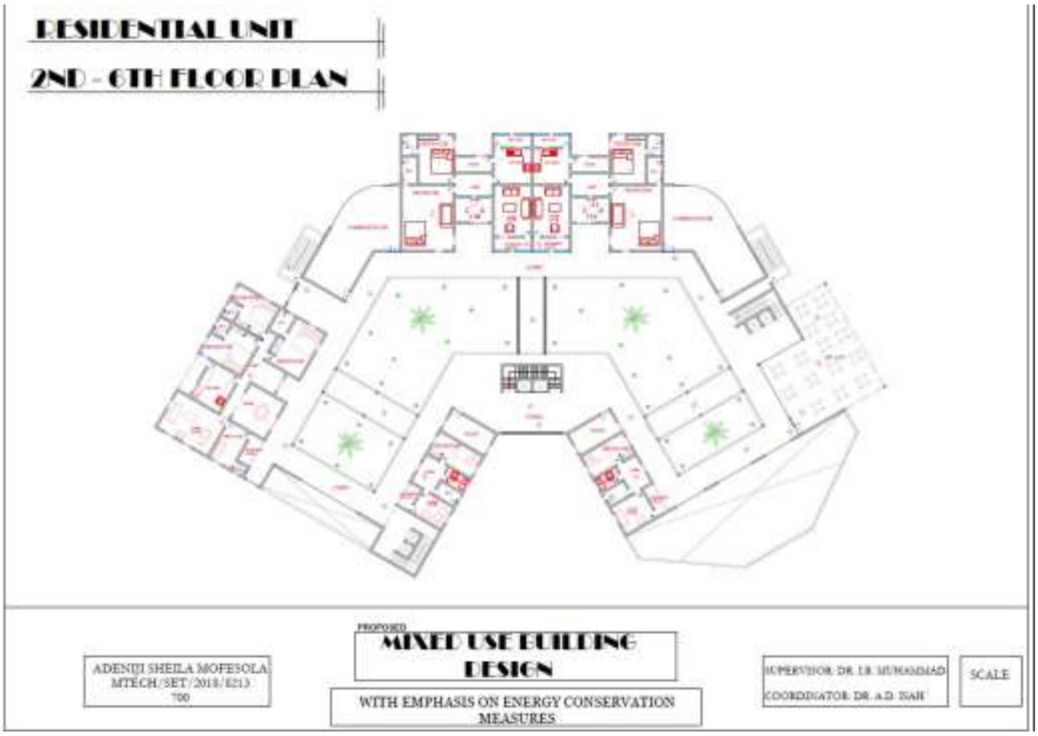


Appendix O: Shopping mall floor plan

Appendix P: Office complex plan



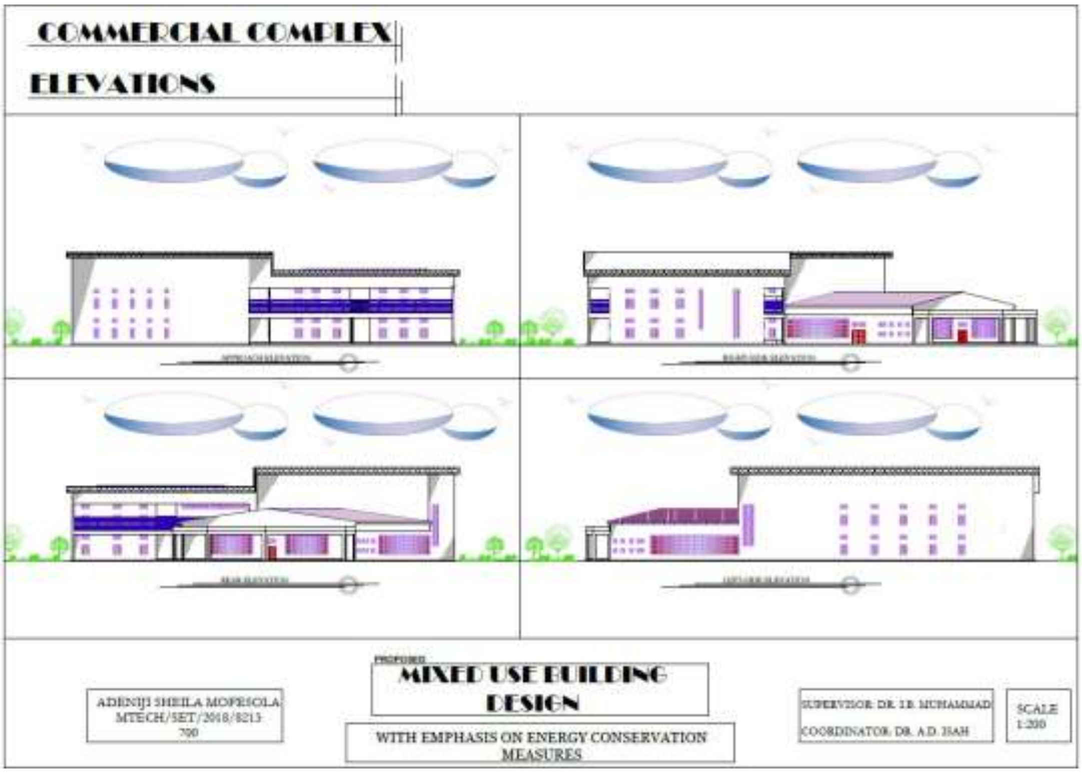
Appendix Q: Residential floor plan



Appendix R: Site plan

Appendix S: Office/Residential elevations

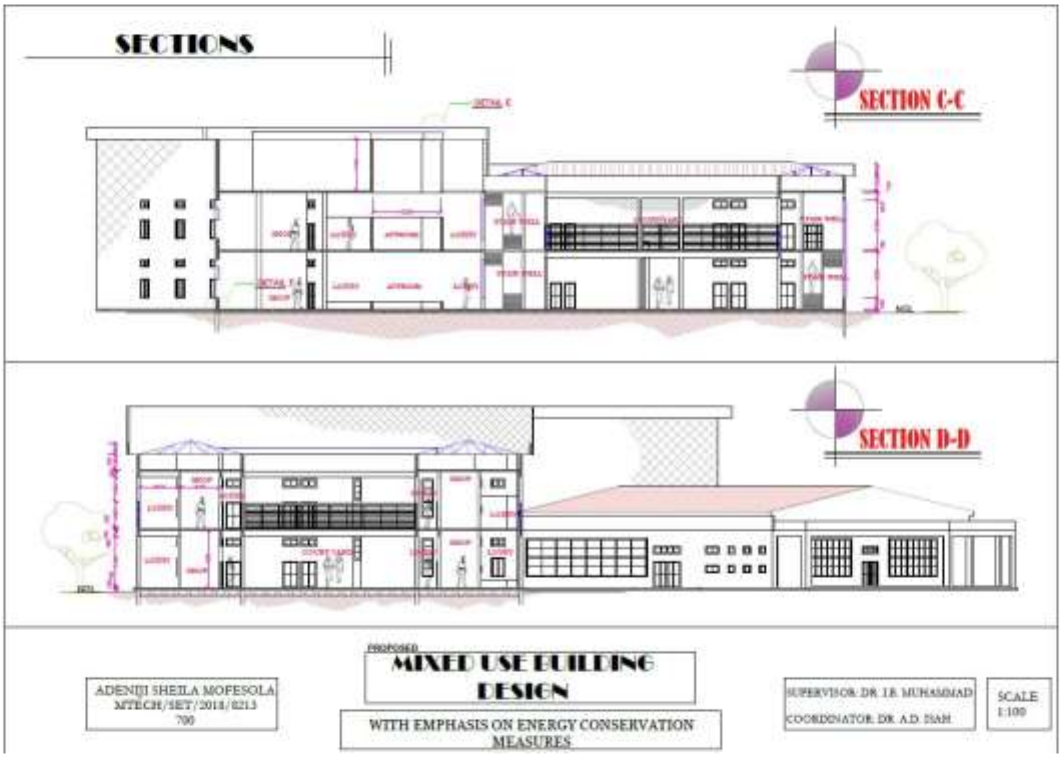
Appendix T: Commercial complex elevations



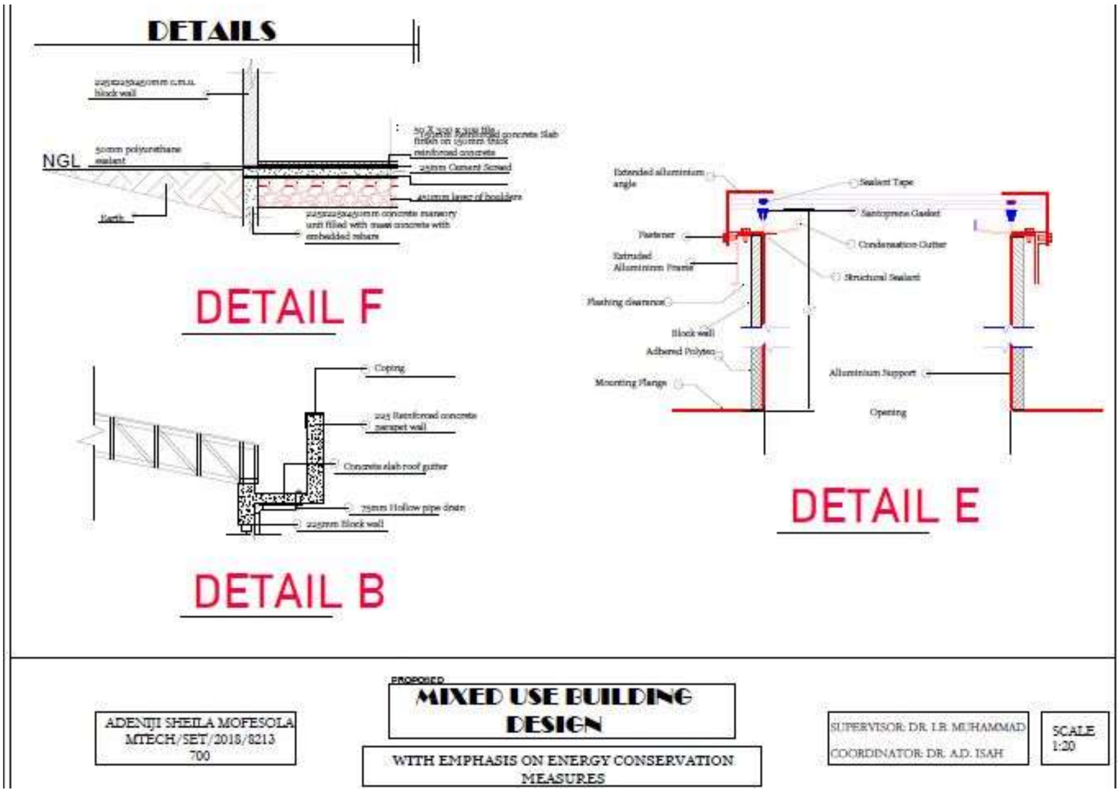
Appendix U: Shopping mall elevations

Appendix V: Sections A-A and B-B

Appendix W: Sections C-C and D-D



Appendix X: Details



Appendix Y: 3Ds of the buildings

Appendix Z:3Ds of the energy conservation measures