EVALUATION OF THE COOLING PERFORMANCE IN THE DESIGN OF A CONVENTION CENTRE IN MINNA, NIGER STATE, NIGERIA.

BY

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MTech/SET/2019/9643

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY IN ARCHITECTURE

AUGUST, 2023

DECLARATION

I hereby declare that this thesis titled: **Evaluation of the Cooling Performance in the Design of a Convention Centre in Minna, Niger State,** is a collection of my original research work and has not been presented for any other degree anywhere. Information from other source (published or unpublished) has been duly acknowledged.

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CERTIFICATION

The Thesis titled: **Evaluation of the Cooling Performance in the Design of a Convention Centre in Minna, Niger State,** by: Menegbe Micheal Majiyebo (M.Tech/set/2019/9643) meets the regulations governing the award of the degree of MTech of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to the all loving God for the strength given to me for this thesis, my mother Mrs. Mary G. Menegbe, siblings and immediate family members for their prayers, encouragement and support and also to my supervisor, Prof. S.N. Zubairu for her support throughout the entire project.

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ABSTRACT

High energy demand in buildings has become an issue of concern all over the world, more than 40% of energy consumption is due to buildings. With the need to improve indoor environmental quality and conditions various strategies and methods were applied in buildings. Cold countries being concerned about keeping the space warm, whilst countries with high temperatures are worried about keeping their spaces cooler. With exceptional increase in the utilisation of artificial cooling mechanisms such as; air conditioning system, air coolers and fans for cooling in buildings. Increased energy consumption is one of the major reasons that have led to emission of greenhouse gases causing environmental pollution resulting to global warming and ozone layer depletion. The aim of this paper is to evaluate the cooling performance in convention centres; towards reducing energy demand in buildings in Nigeria. The hypothesis is that building orientation, location and regional temperature, will generally influence the effects of the cooling performance of convention centres. Various cooling systems used in and within the building were determined; an evaluation of their performance was carried out to determine its effects. This study using the Quasi-experimental research method embarked upon an empirical study of a convention centre in Minna Niger State. With the view to explore the challenges of energy use, from the view point of both the building owners and the users, using quantitative research approach. This entailed participants' observation and conduct of interviews. The findings showed that the use of active cooling techniques involving mechanical energy in one or other forms are used to cool mainly the interior parts of the building. Due to the increased energy demand of these structures caused by the use of air conditioning (A/C) systems, air handling units, and ceiling fans, all of which need a power source, adverse environmental effects have been created. The research recommends that in designing for convention centres, the use of natural cooling methods and practices in buildings should be adopted in the construction. And it would mainly depend on interaction of the building and its surroundings, thereby reducing energy demand in buildings.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

A convention centre generally refers to large comprehensive building and group of buildings with activities such as exhibitions and conventions as their main function. Convention centres typically offer sufficient floor area to accommodate several thousand attendees. According to Gentry (2000) very large venues, suitable for major trade shows which are sometimes known as exhibition centres, the advantages of this type of development as being convenient and a comfortable provision of a live-play-work and retail/commercial environment. The primary usage of a convention centre can range from weddings, graduations, concerts, organisational conventions and more. Convention centres usually have a mixture of large spaces, such as exhibition halls, ballrooms, auditoria and smaller spaces like meeting room's concert halls, lecture halls, and conference rooms (Daichendt *et al*., 2010).

Compared with the traditional exhibition building and large public building, the former has its distinction in site selection and planning, function organisations, spatial shape creations, structural forms, fire prevention issues, architectural technical design (Sheridan *et al.,* 2003). Creating a passive cooling structure with new technologies will help build a connection to the environment, site and city through sustainable measures, to lessen the impact architecture has on the natural world. Architecture has a responsibility to protect, preserve and improve society with sustainable design. With proper design strategies, technologies, and materials, large facilities such as convention centres can be created as energy-efficient structures serving to improve the environment and local community.

1.2 Statement of the Research Problem

In recent times the environmental technology sectors are looking for various approaches to limit or reduce to the barest minimum the energy consumption of all building types. Several factors have contributed to the existence of an inefficient building stock in the country, including a construction boom; a lack of stringent green building practices and codes; artificially cheap prices of electricity and limited awareness with green building practices when compared with most of the advanced countries (Aswad *et al.*, 2012). A study of cooling procedures and mechanisms would help understand the alternative methods of merging science with technology and with ecology so as to encourage sustainable based designs in all building sectors.

Buildings are one of the biggest energy consumption tool in the world, accounting for one-quarter to one-third of all energy use and a similar amount of greenhouse gas emission (UN Habitat, 2014). A convention centre presents a unique opportunity to test the limits general of cooling performance, sustainable technologies and materials in a building that hosts numerous events with a variety of needs on a daily basis improving indoor environment, and presents a great environment to test new technologies and materials in a variety of ways. Mechanical cooling in buildings generate fossils and if these systems are replaced with natural cooling methods, the problem of energy consumption would be checked. Buildings use about one third of the net energy produced globally, a proportion that will continue to increase as the population grows and becomes more urban and affluent (UN Habitat, 2014).

1.3 Aim and Objectives

1.3.1 Aim of the study

The aim of this study is to evaluate cooling performance, the techniques for achieving cooling and use these measures to design an energy sustainable convention centre in Minna, Niger State.

1.3.2 Objectives of the study

The objectives of the study are:

i. To determine factors that affect cooling in public buildings

ii. To evaluate various cooling performance in design of a convention centre, thus reducing cooling demand in buildings.

iii. To design a convention centre in Minna city, Niger State with energy efficiency considerations.

1.4 Justification

The 2030 Agenda for Sustainable development, adopted by all United Nations member states in 2015, provided a blueprint having 17 sustainable development goals, The 11th goal entails sustainable cities and communities while the 13th is climate action; cool structures play a large role in achieving these goals. With growing concerns on the impact these buildings have on the environment; architects should be obligated to test these solutions in real design. Designs can offer a new testing field through large scale design typologies such as convention centres, which require great flexibility in design programmes, offering the perfect grounds for realization.

Ananda *et al.* (2021) carried out a research on Techno-economic assessment of air cooling/ ventilating methods for the college convention centre. Chetan *et al.* (2020) also did a research on the Review of Passive Cooling Methods for Buildings, also considering researches done on other large building types that consume a lot of energy, looking at the ways the cooling problems were considered and solved; various researchers have evaluated the cooling performance as well as the assessment of air cooling in convention centres, but none is known in the study area.

1.5 Scope of the Study

This study is focused on natural cooling performance in a convention centre in Minna, Niger State. Evaluating the possibilities of reducing energy demand as regards cooling and integrating these measures in the design.

1.6 Study Area

Niger State was formed on the 3rd of February, 1976. It was carved out from defunct North-Western State in the government of Late General Muritala Ramat Mohammed. The State is situated in the North Central Geopolitical Zone (Middle Belt) of Nigeria. It is between the Longitude 03^{o} 30’ to 07^{o} 40’ East and latitude 80^{o} to 11^{o}:30’ North. The State is bounded to the North by Zamfara State, to the West by Kebbi State, to the South by Kogi State, to the South West by Kwara State, to the North-East by Kaduna State and to the South East by the Federal Capital Territory (FCT) (Figure 1.1). It also has an International Border with the Republic of Benin along Agwara and Borgu LGAs to the North West. The State covered a land area of 74,244 square Kilometers, which is 8% of the total land area of Nigeria. The population figure is 3,950,249 based on the 2006 Census. The choice of the study area was as a result of its location in the Middle-belt of Nigeria which by influence, houses developments and settlement of migrants from Northern and Southern parts of Nigeria (Niger State Department of Budget and Planning, 2015).

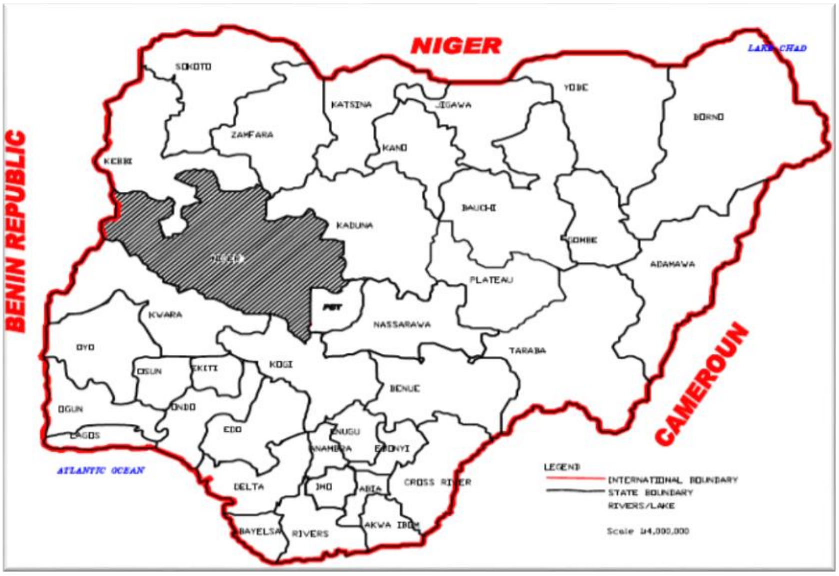

Figure 1.1. Nigeria showing Niger State
Source: Niger State Ministry of Lands and Housing (2015)

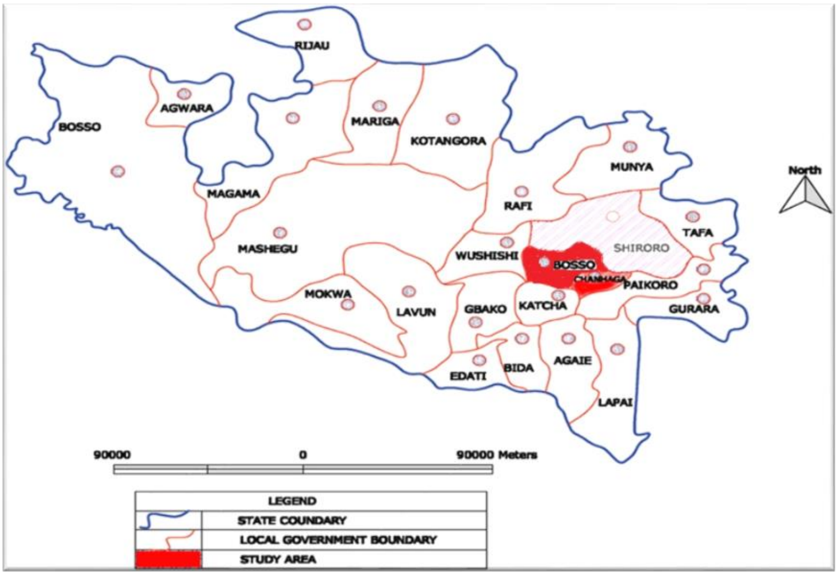

Figure 1.2. Niger State Showing the 25 LGAs
Source: Niger State Ministry of Lands and Housing (2015)

1.6.1 Climate

The annual rain fall regularly changing from 1,100mm in the north parts of the state to 1,600mm in the south parts of the state. The highest temperature (regularly not more than 94^{o}C) is noted around March and June, while the least is usually between December and January. The rainy seasons last for about 150 days in the north parts of the state to about 120 days in the south parts of the State.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General Overview of Cooling

Minna, the capital of Niger State in Nigeria, experiences a typical tropical continental climate with distinct seasonal regimes, oscillating between cool to dry and humid to wet. These two seasons; rainy and dry season reflect the influence of tropical continental air masses.

Better building designs are highly cost-efficient. The design stage is crucial, when extra effort is minimal. Three steps are needed for cool low-carbon buildings: avoid - shift – improve (see Fig. 2.1)

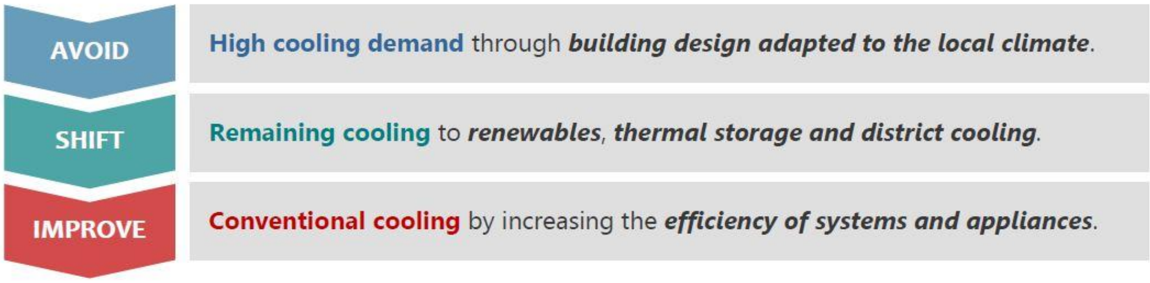

Figure 2.1. Steps for low carbon buildings
Source: Kovacic and Zoller (2015)

If buildings are adapted to the local climate and use passive cooling techniques, they can keep cool naturally. Variations depend on the climate zone, the local building culture and building use. While there are many variations, the following principles apply:

i. In humid climates, light- to mid-weight structures and open, spacious layouts allow for constant natural ventilation.

ii. In dry climates, buildings should be massive to block the heat during the day and naturally cool down at night.

The energy and economic growth are potentially linked with each other. In one way, the sustainability of the economic growth greatly depends on the efficient use of energy. On the other way, the economic growth results in higher living standards, which ultimately leads to higher energy consumption (Hasanov *et al.*, 2017). According to the International Energy Agency 2018 (IEA 2018) report, it is projected that the total energy demand will increase by more than 48% from 2012 to 2040, as shown in Table 2.1.

Table 2.1 World energy consumption by country grouping, 2012–2040 (quadrillion Btu)

	2012	2020	2025	2030	2035	2040	2012–40 (change in percentage)
OECD	238	254	261	267	274	282	18.5
Americas	118	126	128	131	134	138	16.9
Europe	81	85	87	90	93	96	18.5
Asia	39	43	45	46	47	48	23.1
OECD with U.S. CPP	238	252	258	265	272	280	17.6
OECD Americas with U.S. CPP	118	124	125	128	132	136	15.3
Non-OECD	311	375	413	451	491	533	71.4
Europe/Eurasia	51	52	55	56	58	58	13.7
Asia	176	223	246	270	295	322	83.0
Middle East	32	41	45	51	57	62	93.8
Africa	22	26	30	34	38	44	100
Americas	31	33	37	40	43	47	51.6
Total World	549	629	674	718	766	815	48.5

Source: Siddique *et al.,* (2018).

The table shows a slow rise in energy consumption in the OCED (the Organization for Economic Cooperation and Development) countries, which is only about 18%, due to the developed infrastructure and slower-growing economies. About 40% of the total global energy is consumed in building sector (Ahmed *et al*., 2015) especially for the purpose of heating and cooling of the building envelopes. Conventional air-cooling systems are accountable for consuming enormous energy as well as it creates considerable negative impacts on environment. The energy consumption and hazardous impacts on the environment can be reduced by adopting different strategies in buildings. The passive air cooling (PAC) system is one of them which can save energy in the passive process without using any habitual mechanical units.

This study aims to investigate possible techniques that may be used to integrate natural cooling strategies in the design of a convention centre in the city taking into consideration the high humidity during the rainy season.

2.1.1 Natural cooling/ ventilation

Cooling is the transfer of energy from a space or from the air, to a space, so as to achieve a lower temperature than that of the regular environment. Various ventilating frameworks are utilised to control the temperature, dampness, substance dissemination and virtue of air inside of a space, with a specific end goal to accomplish the needed impacts for the occupants (Geetha, 2012).

Natural and passive cooling covers every normal procedure and systems for cooling structures. It is cooling with no type of vitality information, other than renewable energy sources. Passive cooling techniques are firmly connected to the general comfort of the occupants. It is likewise conceivable to expand the adequacy of detached cooling with mechanically helped heat transfer techniques, which improve the common cooling techniques.

2.1.1.1 Wind-driven cross ventilation

Wind-driven cross-ventilation happens through ventilation openings on reverse sides of the confined room. Figure 2.2 reveals the representation of the cross air flow serving multi-storied structure. To guarantee enough ventilation airflow generally, there ought to be a variation of wind strain b/w the outlet as well as inlet openings & least inner resistance. Chetan *et al.,* (2020) have examined the motion of air along with the distribution of Carbon-dioxide in a ventilated atrium as well as workplace room by the

Numerical outcomes as well as tactic discloses that all natural ventilation has been effective at obtaining appropriate Carbon-dioxide level.

Raja *et al.,* (1998) have performed research in Oxford & Aberdeen, the UK on the thermal comfort of normally ventilated business buildings as well as their experiments have been concentrated to discover the result in changing the indoor winter factors. They've realized that the cross-ventilation with the command settings plays a tremendous part in decreasing the inside temperature.

Sinha *et al.,* (2000) mathematically assessed room air atmosphere division with and maybe with no buoyancy consequences for a various outlet or inlet alignments for the cross-ventilated rooms. The ventilation qualities of an area with various opening alignments were studied by Ayad (1999). The model has been confirmed by evaluating the results of constant 2-dimensional flows near much long square cylinder submerged in an atmospheric boundary level with experimental standards. This kind of analysis is considered as an orientation to the model, the computational domain name just for the atmospheric airflow around the model room. (See Figure 2.2)

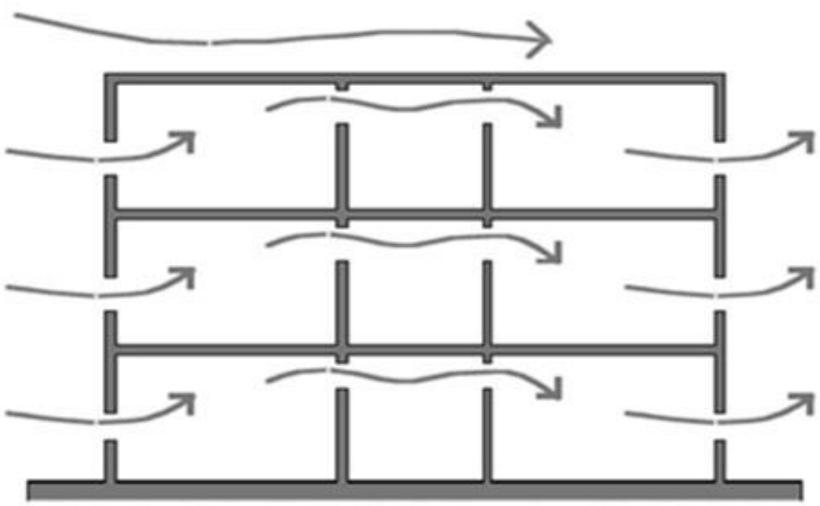

Figure 2.2. The line diagram of wind driven cross-ventilation
Source: (Chetan *et al.,* 2020).

2.1.1.2 Wind-driven single sided ventilation

Single-sided ventilation as the name implies, makes use of only one side of the living space for inflow fresh air and outflow of used air. This type of ventilation, the main driving force for is wind turbulence. In this situation, lower ventilation rates are produced in this situation, and the ventilation air does not infiltrate as far into the room. As a general guideline, the limitation depth for optimal ventilation is around 2/5 the building's floor to ceiling height. Figure 2.3 illustrate the process of Single-sided ventilation within a living space with the inflow of cool fresh air and the outflow of used air on the same side.

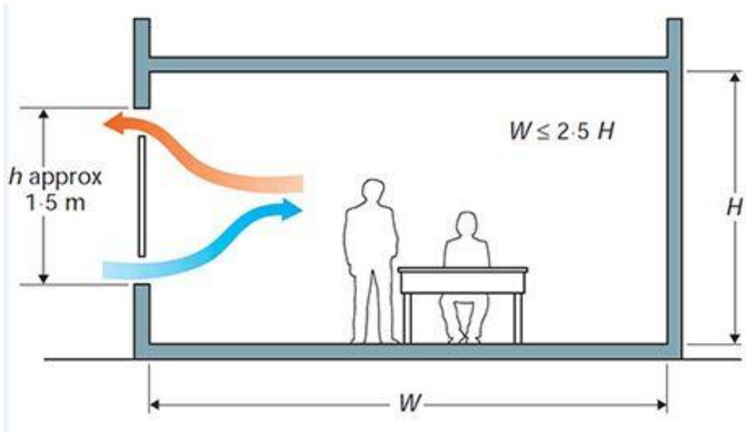

Figure 2.3: Inflow of fresh cool air and outflow of polluted air on a single-sided space.
Source: Andrew (2014).

2.1.1.3 Wind-driven Stack ventilation

Density and temperature changes cause stack ventilation process. The method pulls air across the ventilated space before exhausting it via a vertical flow channel. This means that populated zones should be cross ventilated, with air entering from one side and exiting from the other. This can be achieved with a dedicated chimney or through an atrium. A specialized chimney or an atrium can be used to accomplish this. Atrium circulation has the ability of drawing air from both sides of the building to a centralized extract location, dramatically increasing the design width that can be ventilated by natural processes.

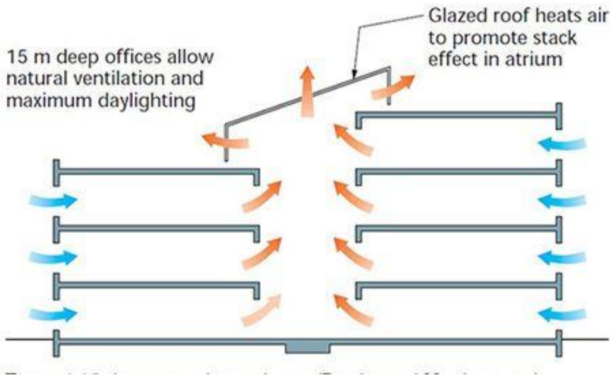

Figure 2.4: Inflow of fresh cool air and outflow of polluted air through a stack ventilation process.
Source: Andrew (2014).

2.1.1.4 Evaporative cooling

Evaporative cooling has been a method that employs the outcome of evaporation as the natural heat dissipater. Sensible heat coming from the atmosphere has been engrossed to be utilized as latent heat needed to dry out the water. Sensible heat immersed depends upon water quantity which may be soaked (Chetan *et al.*, 2020).

Evaporative cooling is a typical type of cooling buildings for thermal comfort since it is comparatively low priced and requires less energy than other forms of cooling. Evaporative cooling is best when the relative humidity is on the low side, limiting its acceptance to dry climates. The substantial climate considerations are dry-bulb temperature, wet-bulb temperature, and wet bulb depression during the summer (Ananda *et al.*, 2021).

Evaporative cooling has been an age-old procedure, having the beginning of some 1000 years back, in old Persia and Egypt. Contemporary evaporative coolers have been based upon the models designed in the first 1900s within the US. Amer (2006) has discovered that among several passive cooling methods, the evaporative cooling yielded an outstanding cooling effect, accompanied by solar smokestack that tapered internal air temperature by 9.6°C and 8.5°C, correspondingly.

Evaporative cooling air conditioning systems use the cooling of the evaporation of liquid water to cool an airstream directly or indirectly. An evaporative cooling system comprises of an intake chamber, filter(s), supply fan, direct-contact or indirect contact heat exchanger, exhaust fan, water sprays, reticulating water pump and water sump, air movement is to control air circulation. In view of their size, construction, and working characteristics, air conditioning systems could be categorized as shown in Figure 2.5.

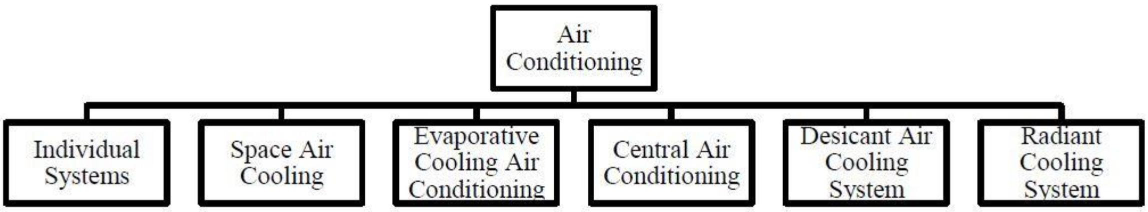

Figure 2.5. Categorization of air-conditioning systems
Source: Ananda *et al.* (2021).

Filtered and cooled by an evaporative air cooler, the outdoor fresh air is ceaselessly sent into the indoor space through the air duct and appropriated outlets. With the constant supply of fresh air, the indoor space is in a positive pressure condition, in this manner the original hot air containing odour and dust will be wiped out of the building, bringing about a cool, ventilated, clean and comfortable condition (Ananda *et al.,* 2021).

Wanphen and Nagano (2009) assessed the achievement of roof resources on the impact of evaporative cooling as well as obtained that, as compared to the mortar concrete, the siliceous shale can reduce the top surface heat at approximately 8.63°C.

Erens and Dreyer (1993) and San José-Alonso *et al.,* (2018) defined, Indirect Evaporative Cooling (IEC), and it offers power expense that is very low for the air conditioning.

Raman *et al.,* (2001) created a solar air flow heater for the solar submissive layouts that will collaborate with the evaporation for the summertime cooling. Numerous varieties of heating exchangers that make use of just the fan as well as water pumping energy had been analysed hypothetically along with conventionally by different scientists for Indirect Evaporative Cooling (IEC) applications.

2.1.1.5 Ground cooling

The idea of terrain cooling has been dependent on the dissipation of the high heat on the soil from the structure that, throughout the winter season the heat is going to be cheaper compared to the exterior air. This particular dissipation could be accomplished possibly by the immediate communication associated with a crucial part of creating an envelope with ground and even by injecting air underground into the structure by the way of earth-to-air heat temperature exchanger.

A building exchanges the heat with earth by radiation, conduction, as well as convection, for a regular structure, the primary mechanism has been convection, because most of the structure has been in touch with the surrounding air. After that comes radiation as well as lastly conduction, because the area of the structure in exposure to the soil has been definitely the littlest, the concept of terrain cooling by immediate communication has been increasing conductive heat exchange. The construction temperature drops since the soil has been at the reduced compared to the environment throughout cooling time (Carmody *et al.*, 1985). Carmody also clarified that earth contact structures have benefits associated not just to their power efficiency, however additionally to the visual effect aesthetics, upkeep of the surface wide open areas, environmental advantages, as well as noise vibration management along with safety (Carmody *et al.*, 1985).

2.2 Passive Cooling in Buildings

For reducing the cooling load on the buildings, there are different cooling methods viz. Passive Cooling Methods and Active Cooling Methods. Design or technological featured formed for providing cooling to the buildings with or without using a minimum amount of energy is known as Passive Cooling (Geetha, 2012). These are used for improving the effectiveness of energy (Pacheco *et al.*, 2012). Whenever power consumption occurs, passive cooling methods are small set alongside the consumed cooling compared to active methods of cooling. Further, it is often run on energy sources that are highly renewable (Pacheco *et al.*, 2012).

Passive techniques of cooling are the most important for building cooling. Successful passive cooling designs used in the buildings require efficient knowledge regarding the patterns of airflow around a building as well as the effect other buildings in the neighbourhood have on it. Different types of Passive cooling methods are derived based on the internal gain of heat, transfer of heat in an envelope form along with transfer of heat occurring in outdoor and indoor air.

2.2.1 Building envelope

In dry climate zones, dense materials such as stone and brick reduce thermal fluctuations. Traditional buildings with thick earthen or stone walls rarely need to be cooled artificially. When using lighter materials, thermal insulation is needed. In humid climate zones with open building layout, lighter materials, such as wood (only where sufficiently available, avoiding deforestation) and composite materials may be used (Kovacic and Zoller. 2015). In general, materials with low embodied energy should be applied, avoiding excessive use of steel, glass and aluminium

2.2.1.1 Shading

For reducing a direct gain of solar radiation shading is used. It is an effective technique used in reducing the gain of solar radiation to the covering of the building named as shading. Doors with curtain, roofs, and windows walls, all helps in avoiding the excessive gain of solar radiation, where the use of curtains might be porous to provide better air circulation. There is a connection between thermal performance and daylighting for shading devices, hence, the analysis integration has to be performed to include the interactions taking place among various parameters also for attaining optimum outputs. Nonetheless, as per some exceptions, the issue just isn't used during the early phase of design, where some decisions which are critical under a small effect on the economy might results in significant savings of energy throughout the life span of a building (Clarke, 2001).

Noh-Pat *et al.*, (2011) studied illumination from daylight for the sub-tropical classroom, looking for some optimum geometry used as a shading device. Also, analysed the lighting power required for enhancing the illumination within a classroom. Poor-quality lighting is the main disadvantage of this technology (David *et al.*, 2011). In this connection combined thermal and lighting analysis has to be carried out. The most important parameters that to be considered at the early stages of optimization are the area of glass, shading properties and control (De Carli and De Giuli, 2009). Many researchers have performed a detailed analysis of shading and concluded that on average, the indoor temperature has been reduced by 3°C. Shading devices shield a building exterior surfaces and interior spaces from solar radiation, their effectiveness depends on their form and angle of orientation to the sun, these devices include overhangs, louvers, blinds, egg-crates and trees adjacent to the building as shown in Figure 2.6.

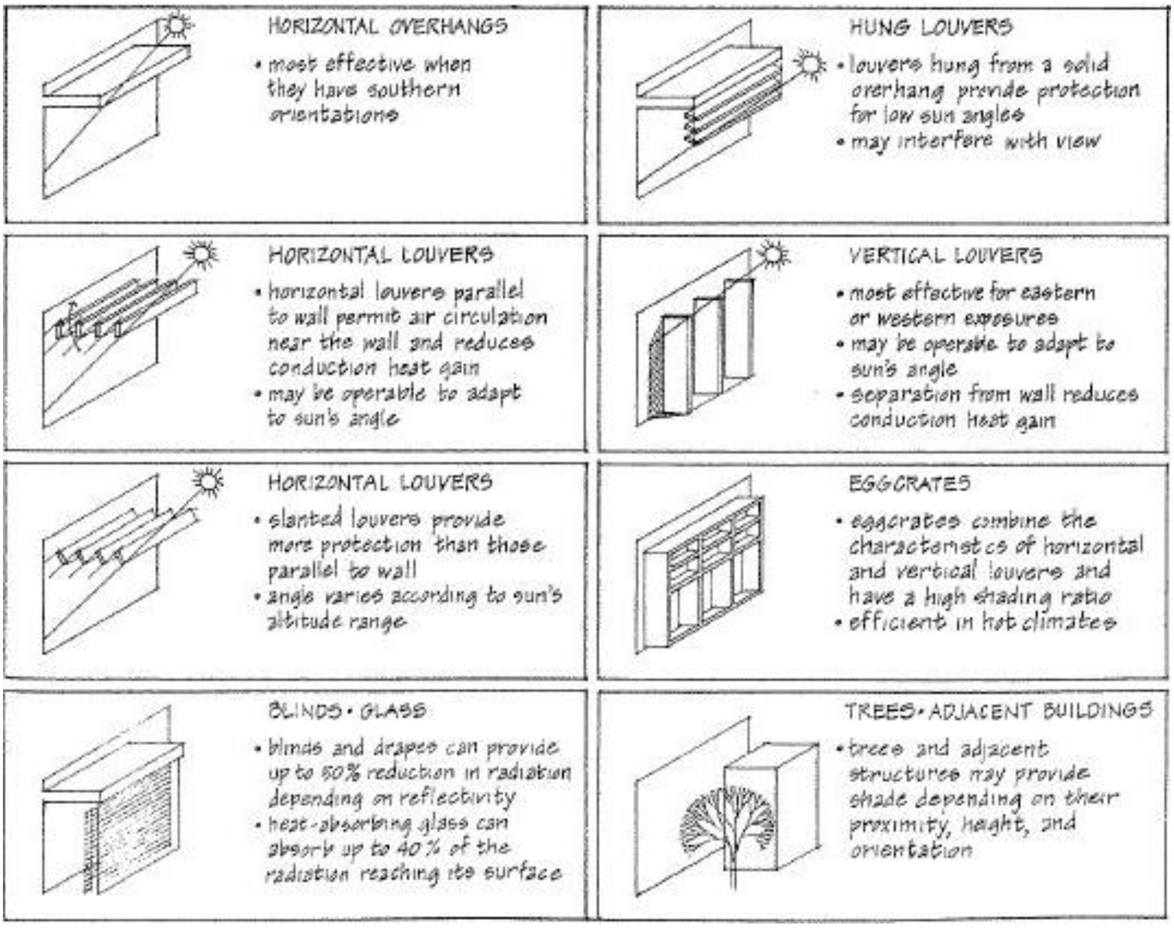

Figure 2.6. The various forms of shading devices
Source: Ananda *et al.*, (2021).

Figure 2.6 shows the different forms shading devices and its application, horizontal overhangs are mostly effective when they have southern orientations, vertical and horizontal louvers permit air circulation and can be operable to adapt to the suns angle, egg-crates combine the characteristics of vertical and horizontal louvers they have high shading ration which is most effective in hot climates.

Plate I. The use of egg-crate for shading in Sufyan_Altuajeri house Iran
Source: Mueller (2005).

2.2.1.2 Glazing.

Few of the thermal aspects of the glazed surface of the building envelope affects the solar radiation penetrating into an internal space. This convection process is mainly affected by channel dimensions and widths for the outlet and inlet openings, thereby, affecting the overall cooling performance. Making usage of double glazing (Figure 2.4) increases the rate of flow to 11-17 percent. Having said that, insulation of the inner surface regarding the storage wall to provide summer cooling helps in avoiding extortionate excessive heating because of south-facing (Roos *et al*., 2001).

Numerous studies have actually stated a number of characteristics of selective films and coating for the applications of these windows. Roos *et al*., (2001) examined its impact associated with the angle of incidence of radiations from the sun in terms of optical properties of windows controlled by the sun. Nostell (2000) conducted a wide experimental campaign on different coatings and presented the results of it, while the three-layer systems optical property on the substrates of glass is measured by Durrani *et al*., (2004) below is Figure 2.7 with various glazing methods.

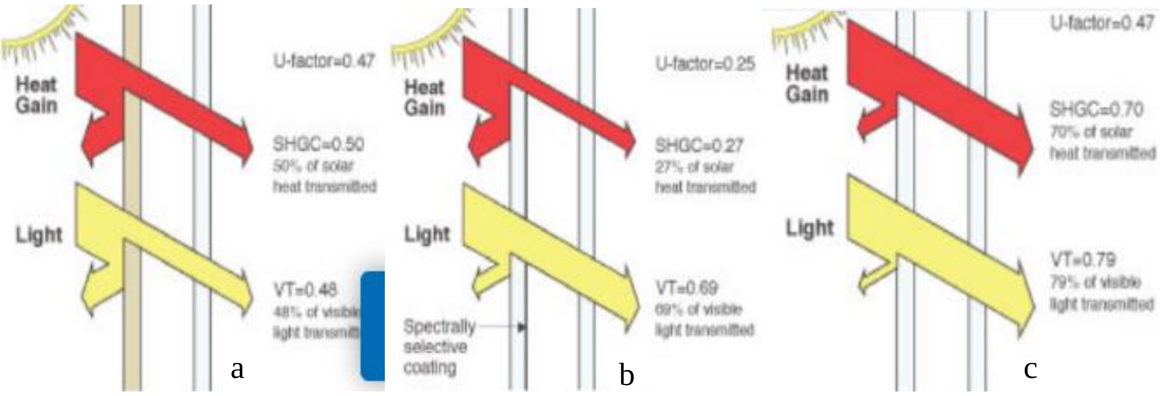

Figure 2.7. a. Double glazing with bronze tint, b. Low solar gain low-E double glazing c. Clear double glazing
Source: Ananda *et al.*, (2021).

Many researchers have analysed the modelling of (CFS) Complex Fenestration Systems which includes translucent materials, solar control films, shading devices and multi-layer glass panes, the Marble David located in Gouda South Holland is an example of how complex fenestration systems was applied.

Plate II. The use of low solar gain low-E double glazing in Marble David building
Source: Mueller (2005).

A model was developed by Maestre *et al.* (2007) for the optical properties dependent on the angle of glazed coating, even though, Laouadi and Parekh (2007) came up with CFS based optical models working on the distribution functions of bidirectional optical properties. The present studies by Bakker and Visser (2005) reviled a larger utilization of glazing controlled by the sun in EU nations could dodge the emanation of as much as 80million tons of carbon dioxide, that speaks to 25% of the objective built up in 2020 for saving energy by European Commission.

The heat from the sun is partly dispersed, partly reflected and partly absorbed by the atmosphere. The spread radiation is considered as diffused radiation. Ordinary glass retains a smaller percentage of the solar heat say round 6% and reflects or transmits the remaining. The amount of reflection is dependent on the angle of incidence which is the angle between the perpendicular to the glass surface and the sun rays (Ananda *et al.*, 2021). Depending on the latitudes, for each month in a year and for different exposures and on different timings Table 2.2 shows the calculations for the solar heat gain. This solar heat gain in Btu /hr/sqft. area is multiplied with the area of the glass and the factor depending on the shade.

Table 2.2. Solar heat gain- glass calculation

ITEM	Area (Sq.ft)	Temp. Difference	Factor	BTU/HR
Glass-N	246.84	16	0.56	2211.69
Glass-S	246.84	14	0.56	1935.23
Glass-E	296.82	163	0.56	27093.73
Glass-W	296.82	163	0.56	27093.73

Source: Ananda *et al.*, (2021).

2.2.1.3 Walling and roofing material.

In dry climates, the walls are massive to keep out the heat during the day and release the slowly absorbed heat at night while the roofs are massive or insulated. In humid climates, the walls are light with many openings and vents for ventilation while the roofs are light and insulated, bright and reflective coatings on roofs and façades reflect solar radiation and prevent it from entering the interior (Kovacic and Zoller. 2015).

Phase change materials (PCM) is developing innovations that comprise microcapsules made up of a blended wax, paraffin, and other material of low melting point which has a prime objective on a building, which will store the heat which will, in turn, works as a free system for cooling (Pomianowski *et al.*, 2013). The general principle of Phase Change Materials is to change the phase either Liquid to gas, Solid to Solid, or Solid to Liquid which will store the latent heat and release as and when required. The temperature variation of these materials is in a limited range as the stored heat is latent (Iten *et al.,* 2016).

In general, Phase Changing Materials could be linked to all the components and types of building envelopes, however, the characteristics and configurations will have its unique feature for different application areas. PCM is easily integrated with the walls of the building in two ways i.e. "Immersion" and "Attachment". “Attachment” is to attach one or many such materials will integrate into wallboard layers to a wall. In such a case, the Phase Change Materials will not be comprised of the material of the wall but would be integrated by layers enclosed beyond this wall.

With the integration of Phase Change Materials to the wallboard in place of the surface of the wall, these are regarded as an indoor element of the whole design work after associating the construction to the building envelopes. In recent days, mass production of wallboards such as Phase Change Material with the integration of Gypsum board and Phase Change Material integrated panels of composites by some typical companies, thereby increasing its efficiency which helps in reducing the cost. Ghoneim *et al*. (1991) carried out a simulation by performing a numerical analysis related to the collector-storage building wall to a completely different medium of thermal storage: ancient concrete, P116-wax, medicinal paraffin, and sodium sulfate decahydrate.

Its simulations as compared to the performances (specifically investigating the Solar Saving Fraction parameter) of varying Trombe walls having a varying thickness of the wall, thermal conductivities, ventilation conditions, Phase Change Material melting temperature as well as ratios of load-collector.

Khalifa *et al.* (2009) came up with a numerical model and worked on simulating the working of 3-thermal storage walls all with different materials: ancient concrete, paraffin wax and CaCl26H2O hydrated salt in Iraq's hot climatic conditions. Results of these numerical simulations depicts that so as to take care of a person's comfortable zone of temperature a desired minimum thickness of this wall ought to be Eight (8) cm for hydrated salt CaCl26H2O, Five (5) cm for paraffin wax, and 20cm in case of ancient concrete, an 8cm thick wall of CaCl26H2O hydrated salt will have the minimum number of fluctuations in the indoor temperature levels. (See Figure 2.8)

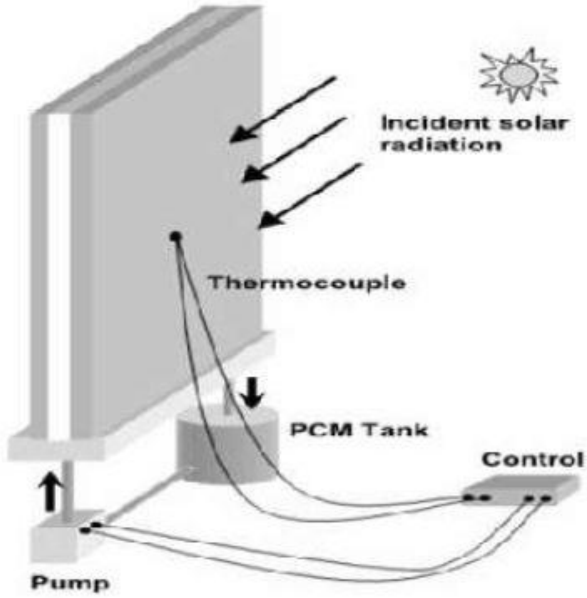

Figure 2.8. Experimental test rig of Phase Change Material filled wall board
Source: Chetan *et al.,* (2020).

Immersion is integrating the PCM to the construction materials of the buildings like concrete, plaster as well as bricks. There are three different methods for immersing the Phase Changing Materials with the materials used in building construction: micro-encapsulated, direct immersion, and micro-encapsulated Phase Changing Materials. As per Sharma *et al.* (2009) no such usage of “direct immersion” and “micro-encapsulated PCM” was a success in the commercial market. Presently an effective technique for immersing is the “microencapsulated PCM” into the material of building. The main idea behind “micro-encapsulated PCM” in encapsulating the membrane or the polymers where the dimension of every “micro-capsule” generally is just a few mm. Such an effective method of micro-encapsulation of PCM avoids directly immersed PCM or the macro-encapsulated shortages, like the matter of hard maintenance, leakage, shape distortion, and poor handling.

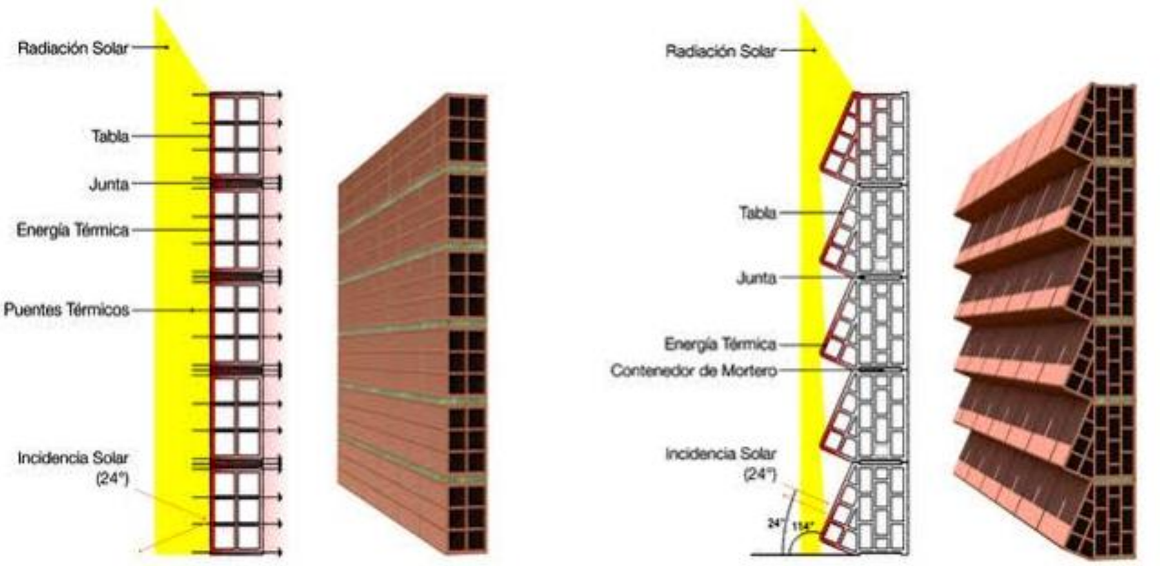

Figure 2.9. Bricks at an angle reducing the area exposed to solar radiation
Source: Chetan *et al.*, (2020).

A ceiling system assisted with Phase Changing Materials are used more in building applications because of the easy implementation and installation in building envelope. For realizing the equal approximation of storage capability with the heat gain in space during the daily cycle must be incorporated into this system in a retrofitted and light-weight building.

Koschenz and Lehmann (2004) came up with another method of ceiling panelling where the ceiling panel is comprised of the gypsum and micro-encapsulated PCM in the mixture, Figure 2.10 shows a suspended ceiling made with mineral fibre.

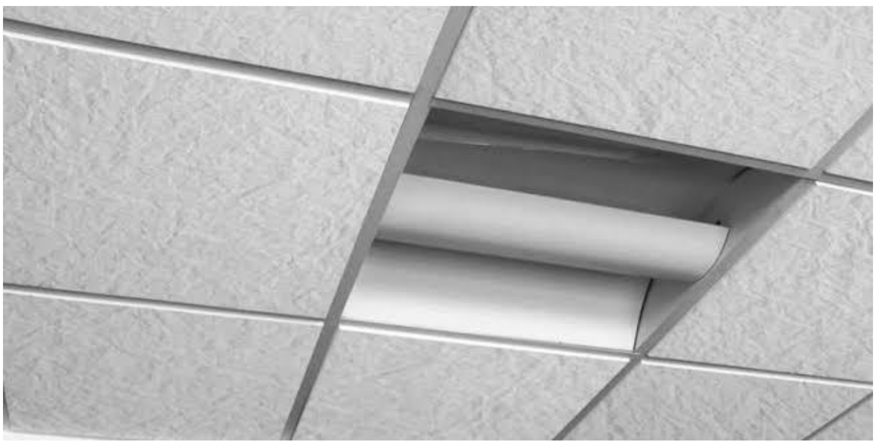

Figure 2.10. Suspended ceiling made with mineral fibre
Source: Schabbach *et al.*, (2018)

Additionally, the aluminium fins and capillary tubes were used incorporation with the thermal mass for increasing the process of heat transfer. During the occupancy of the day time, the ceiling panel of Phase Changing Materials is exposed directly to all sources of indoor heat and hence works as the heat sink, while at night the heat absorbed is released by cold water circulation in capillary tubes or through night air ventilation, insulated roofs also referred to as cool roofs are designed to reflect more sunlight and absorb less heat more than a standard roof. (See Figure 2.11)

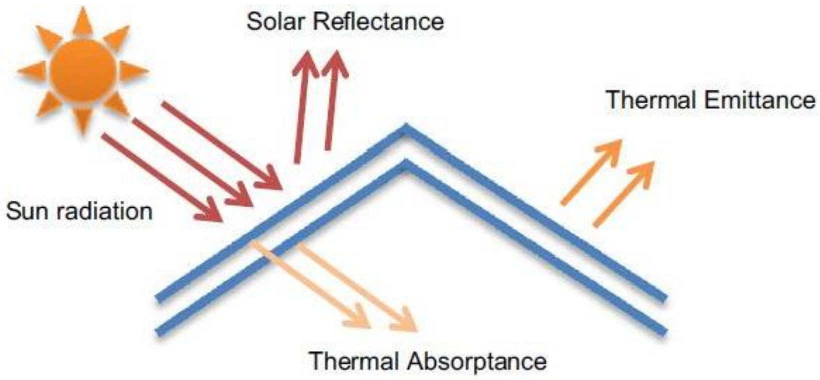

Figure 2.11. Showing Cool roof mechanism
Source: Chetan *et al.,* (2020).

Heat flows from higher level to the lower whenever there exists a temperature difference. The rate at which the heat flows inside varies with the opposition imposed by that material. The solar heat gain on the exposed wall does not become an instantaneous room load. The heat is absorbed by the external wall and is conducted gradually into the inner layers of the wall and only the convected and radiated heat from its inside surface of building wall is the room load. Because of this unsteady condition of heat flow, it is a general practice to consider an equivalent temperature difference. The equivalent temperature difference is the difference in temperature that occurs in the overall heat transfer into the structure due to varying solar radiation and outdoor temperature, Table 2.3 shows the different temperature of each face of a building and the roof.

Table 2.3. Solar and transmission heat gain in wall and roof-calculation

ITEM	Area (Sq.ft)	Temp. Difference	Factor	BTU/HR
Wall-N	5509.78	18	1.2	119011.25
Wall-S	5509.78	34	1.2	224799.02
Wall-E	6418.22	40	1.2	308074.56
Wall-W	6418.22	44	1.2	338882.02
Roof Sun	35223.17	45	0.6	951025.59

Source: Ananda *et al.,* (2021).

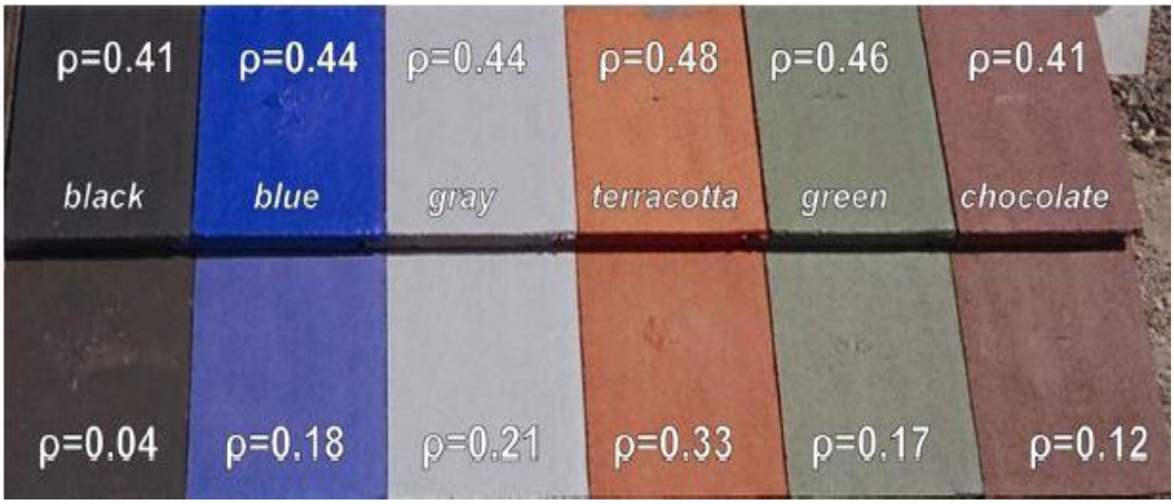

Figure 2.12. Cool dark colour roofs
Source: (Chetan *et al.,* 2020).

The performance of different PAC strategies depends on the local climates, building orientation, building materials and many more factors. Therefore, the utilization of appropriate passive cooling strategy is an incredibly preferred perspective with the raising concerns in regards to the cost-benefit impact of energy use. In the following, we investigate the advantages and shortcomings of different strategies depending on the local condition, table 2.4 shows comparison between these cooling methods.

Table 2.4 Comparison between the cooling strategies adopted

Strategies	Installation & maintenance costs	Results	Suitable climate conditions	Disadvantages
Natural ventilation	Very low	i. Can reduce up to 3°C ii. Lower 40% energy cost used by the air-conditioning systems	Low temperature region with available natural air flow	Free entry of dust, pollen, insects & security limitations
Evaporative cooling	Relatively high	i. Can reduce up to up to 3 to 4°C ii. May lower 50% of energy cost used by the air-conditioning systems	Hot & dry atmosphere	May cause an uncontrolled humidity & health hazard due to the development of bacteria
Wind tower	Relatively high	i. Can reduce up to 10°C ii. May lower around 60% of energy cost used by the air-conditioning systems	Hot & arid or humid areas	Not useful for high rise building
Earth pipe cooling	Installation cost is high but maintenance cost is low	i. Can reduce up to up to 3 to 4°C ii. May lower around 40% of energy cost used by the air-conditioning systems iii. Can be used as an additive with other PAC system in any climate conditions	Less dependent on local climate conditions	i. May cause health hazard in a closed loop system ii. May not work well in the high rise buildings.

Source: Siddique *et al.*, (2018).

2.2.2 Orientation and shape

2.2.2.1 Orientation

A building should be oriented from east to west along the main path of the sun, exposing only smaller façades to high solar radiation at low angles. Appropriate orientation on a building can provide a state of comfort in the building. According to Gut and Ackerknecht (1993), the longer axis of the building should lie along east-west direction for minimum solar heat gain by the building envelope. Openings should be avoided on the west and if they cannot be avoided, they should be adequately shaded by using verandas and tall trees. It helps excluding the unwanted effects of severe climate. This includes orienting the building to receive maximum solar radiation in winter, together with keeping out cold winds. And avoid solar radiation in summer together with admitting cool winds. The best orientation means receiving maximum solar radiation in winter and minimum in summer achieving indoor thermal comfort. Fig 2.13 shows how building should be placed. Another main parameter in determining the energy performance of buildings is the building massing and form as it can affect the received amounts of solar radiation, the rate of air infiltration and as a result the indoor thermal conditions (Nayak *et al.*, 2006).

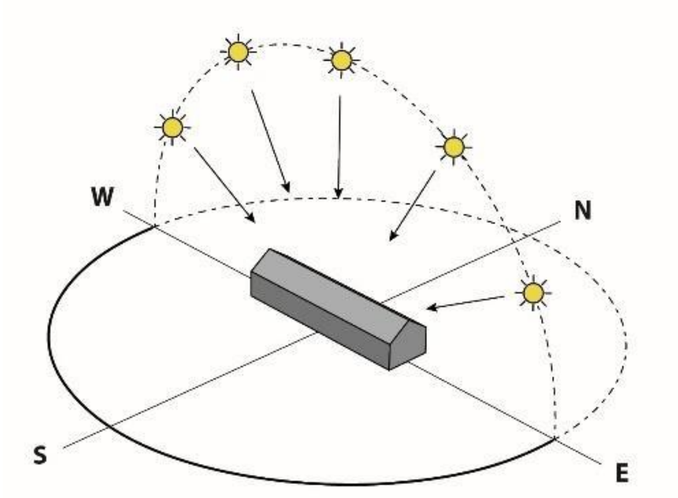

Figure 2.13. Orientation according to the sun
Source: Kovacic and Zoller (2015)

According to Keung (2010) on building planning and massing this study studied massing and orientation effects on the building environmental efficiency in Singapore. The study talks mainly about achieving sustainable development by applying various techniques and ways. Studying orientation and building massing on high rise built constructions was held. Dr. Keung in his study illustrated that things like the massing and orientation of buildings are fundamental for optimizing passive design, and that these are the first steps in minimizing the building energy demand, providing natural ventilation, daylight, shade, and thermal comfort. The study focused mainly on the technics of achieving optimum massing including design smaller building footprint, providing void decks at the ground floor and minimized floor depth, and orientation issue including minimal exposed to sun facades, providing extensive overhangs like balconies, planters and shading devices Mohamed et al. (2016) The Effect of Geometric Shape and Building Orientation on Minimizing Solar Insolation on High-Rise Buildings in Hot Humid Climate. This study examines the effect of geometric shapes and orientation on the total solar insolation received by high-rise buildings. Two generic building shapes (square and circular) have been studied with variations in width-to-length ratio (W/L ratio) and building orientation using the computer simulation program ECOTECT. The results revealed that the circular shape with W/L ratio 1:1 is the most optimum shape in minimizing total solar insolation. The square shape with W/L ratio 1:1 in a north-south orientation receives the lowest annual total solar insolation compared to other square shapes. This optimum shape receives the highest amount of solar insolation on the east-orientated wall, followed by the south-, west- and north-orientated walls respectively.

2.2.2.2 Shape

In humid climates, larger distances between buildings allow for better air circulation. In arid climates, compact buildings that are close together expose less façade to the sun and provide shade. Using eQUEST simulation program, the result and all calculations showed that the energy consumption of rectangular shaped building form is % 9-10 less than the energy consumption of L shaped building form, and the difference between the annual energy consumptions of L shaped building form and rectangular building forms which have the same floor area, total exterior facade area, volume, roof type and optical and thermo physical properties of building envelope are caused by having the same transparency ratio but differ different facade areas oriented in the same direction (Abed *et al.,* 2012).

Most openings (doors, windows, vents) should face north or south to reduce sun exposure, the window positions should allow optimal use of daylight, but with a small surface to avoid solar radiation inside, and horizontal glazing should be avoided. The window-to-wall ratio should be generally low to minimize internal heat gains while allowing for sufficient natural interior lighting. In hot climates, the total window area must not exceed 20% of the total wall area (Kovacic and Zoller, 2015).

2.2.3 Site adaptation

The design takes advantage of the site's surroundings, such as the surrounding vegetation, water bodies and the proximity to other buildings, which can partially or completely shade and cool both the roof and the façades of the new building, to reduce the urban heat island effect, green roofs, broad-leaved trees and bushes provide shade but do not obstruct air circulation (Kovacic and Zoller, 2015). Raeissi and Taheri, (1999) acknowledged the beneficial effects of trees. They stated that planting of trees can result in energy saving, reduction of noise and pollution, modification of temperatures and relative humidity and psychological benefits on humans. They also noted that trees can act complementary to window overhangs, as they are better for blocking low morning and afternoon sun, while overhangs are better barriers for high noon sunshine. Simpson (2002) have shown that tree shades can reduce annual energy for cooling by 10% -50%.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Design

This research used a descriptive and a quasi-experimental approach as a tool to achieve the answers to the various research questions. Various data collection tools employed include case studies, check list, notebook, and measuring tape, for the purpose of this study, purposive sampling was adopted. This is supported by the methods used in previous studies and the nature of the research. Such studies include but are not limited to: Abed, (2012), Al-Tamimi and Syed Fadzil (2011) and Alabi (2017).

3.2.1 Descriptive approach

The descriptive approach will be used for exploratory studies with little or no interest in finding out the relationship between the identified variables. For the objectives to investigate the determinants of the cooling performance in convention, and to explore the techniques for achieving cooling and use these measures to design an energy sustainable convention centre in Minna.

3.2.2 Quasi-experimental approach

The hypothesis here is "Natural Ventilation conserves energy in buildings", as such, the dependent variables are energy consumption and cooling demand while the independent variables to be looked at are classified into two groups: Climatic design variables and Natural Ventilation design variables. The Climatic design variables are; temperature, relative humidity and wind velocity while the Natural Ventilation design variables are Stack Ventilation, Single-sided Ventilation and Cross Ventilation. Energy consumption is measured in Watt-hours while the cooling performance is measured in terms of indoor dry bulb air temperature and operative temperature both measured in degree Celsius.

3.3 Population of Study

Population of study is made up of all the subjects that have the characteristics that are of interest to the researcher and to whom the result obtained can be generalized. The population of this study comprises of convention centres in Minna, from the five considered one was chosen as it meets the minimum requirements. The selection of this population of study is appropriate because it captures a specific range of data required for the study and also represents similar social-cultural elements of the area while comparing them to internationally accepted standards.

3.4 Sampling Procedure

The sampling technique adopted in this research was purposive in nature, identifying existing convention centre and carrying an in-depth research thereby achieving the goal of objective one as stated in chapter one of this research. One local and two foreign sample size was also added because of the higher standard they have. They were also identified to be within the hot-humid and dry climatic classification, similarly, convention centres with peculiar features of natural ventilation element across these climatic zones were identified and their energy consumption data for a minimum of a year are studied for it is crucial in investigating their energy usage.

3.4.1 Case study selection criteria

The various case studies for this thesis were selected based on certain criteria and sampled purposely to at least possess two amongst the following basis:

i. A convention centre located in the locality where the proposal is been carried out (Minna).

ii. A structure with adequate coverage in scope and facilities required to operate as a standard convention centre.

iii. A convention centre that represents a region, so as to look at factors involving regional and technological diversities.

Four facilities were chosen, two local and two international case studies. Each of which fulfilled at least two of the required basis for selection. The following are listed samples (convention centres) selected to be observed as shown in Table 3.1.

Table 3.1 List of Samples

S/No	Samples	Locations	Date
1	Justice Legbo Kutigi International Conference Centre	Minna, Niger State, Nigeria	May 2011
2	Abuja International Conference Centre (AICC)	Abuja, FCT, Nigeria	July 1991
3	Kigali Convention Complex (KCC)	Kigali Rwanda	November 2015
4	Qatar National Convention Centre (QNCC)	Doha, Qatar.	December 2011

Source: Author's field work (2023)

3.5 Data Type and Source

The various data for this study were gathered from both primary and secondary sources, majorly the primary source employs the use of case studies of related buildings while the secondary source utilizes the review of various literature on the subject drawn from both published books, articles, journals, papers and official documents of professional bodies. Case study method of data collection which was followed by an observation schedule as the research instrument, observations were made during case studies, field surveys, and visits to various convention centres. Also during the case study, a physical inventory of equipment used for ventilation and cooling were documented.

3.5.1 Instruments of data collection

Based on the qualitative nature of this research, the usage of observation schedule was considered as one of major the instruments for data collection. The observation schedule contains list of checklists that were used by the researcher to collect vital information about cooling techniques employed in the existing convention centres and way energy demand in these buildings were reduced. Some other instruments used for the primary collection and documentation of data in this study were.

i. Visual survey: tools included checklist, notebook, and sketchpad.
ii. Participant observation: tools included Camera, Video recorder, notebook and sketchpad.
iii. Computer simulation: tools included laptop, simulation software, and documentation software.

During the process of the study the activities being observed where not influenced either directly or indirectly because non-participant observation was employed, involving a visual survey of various processes and equipment that demand the use of energy in the various buildings, The observation schedule (see Table 3.2) contains two sections namely; part A, B and C. Part A of the schedule contains a general description of the observed centre which includes; the name of the centre, location of the building, type of the tourist centre, list of available facilities, sizes of the facilities and spaces. Part B outlines the design methods or practices adopted to enhance cooling in the building while part C contains general energy demand and consumption parameters being used. All these were outlined in a checklist format and also allowing for further description and collection of the data as observed.

Table 3.2 Checklist for observation and assessing sampled convention centres

S/No	Variables
1	Ventilation (cross/ one sided) - Size, and location - Provide shading devices for openings - Select the proper glazing to reduce heat
2	Evaporative cooling (natural/ artificial)
3	Building envelope - Provide construction and insulating materials to resist heat transfer - Use roof spray or roof ponds for evaporative cooling to reduce heat gain
4	Building orientation and Site Adaptation - Control shape, form and orientation - Coordinate with existing and new landscape and other elements - Reduced paved areas to lessen heat buildup around the building

Source: Author's field work (2023)

3.6 Method of Energy Audit

Energy audit is carried out for each building utilizing a standardized data collection process and technologies. It involved the use of observation schedules, taking inventory and pictures. The objective is to investigate energy demand and consumption in convention centres resulting in breaking down of total consumption into cooling, lighting and heating appliances. Energy consumption in these kind of buildings located in warm climates are dominated by cooling the interior of the building for the comfort of the user of various spaces in the building. With the hypothesis "Natural Ventilation conserves energy in buildings" being in relation to energy demand and consumption with ambient air temperature. These savings, in particular are in cooling performance by taking into consideration these design strategies in the building construction in an attempt to achieve energy reduction and conservation.

3.6.1 End-use calculations (energy usage)

The total energy consumption in the buildings is divided into end-uses. The end-use consumptions are the aggregate loads in the buildings. This covers cooling and ventilation, lighting, and Refrigeration Appliances, as well as water heating, culinary, office equipment, electronics, and common machinery.

3.6.1.1 Total energy demand

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

$$Qc = Qc + Ql + Qa \tag{3.1}$$

3.6.1.2 Cooling and ventilation demand (Qc)

$$Qc = Qc1 + Qc2 + Qc3 \ldots . Qcn \tag{3.2}$$

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

3.6.1.3 Lighting demand (Ql)

$$Qc = Ql1 + Ql2 + Ql3 \ldots . Qln \tag{3.3}$$

Where represent the variation in type and specification of lighting fixtures.

3.6.1.4 Appliances demand (Qa)

$$Qa = Q - (Qc + Ql) \tag{3.4}$$

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

$$\textit{Energy rating x quantity x hours of usage} \tag{3.5}$$

The hours of use are estimated based on the answers supplied by the respondents in a closed oral interview and limited observation. Also a physical count of all various appliances employed for cooling and ventilation, lighting and other equipment were made by the researcher. Ventilation and cooling the cooling load is calculated from an assessment of the units in the building and is in proportion to the lighting load, which is calculated from the light fixtures. The appliance demand load is calculated by energy rating with the information provided by the manufacturer or recorded on the equipment in form of a nameplate. Equipment that do not contain the information of the energy rating stated above is searched on the internet, cases were a product of that make is not seen the rating of a similar equipment was adopted. The challenge in applying the same calculation method as for cooling and lighting loads is estimating the number of hours of use for the various types of appliances that make up this end use. A better formula, shown in Equation 3.6 is:

$$Qa = Qt - (Qc + Ql) \quad (3.6)$$

3.7 Data Analysis and Presentation

The various data gathered form the observation guide or checklist was analysed through content analysis. By analysing and quantifying the meaning of words and text, making deductions and conclusions from the data collected by the researcher. The data was also organized with the use of excel spreadsheets and various results were represented using tables and charts in conjunction with plates to further support points made by the tables and charts. These plates were used to describe the immediate environment in the sampled convention centres indicating cooling practices employed with also the energy conservation methods used.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Case Studies

These are established research designs that involves a wide study of a specific subject or subjects within a real world, one of the basic importance of case studies is providing an opportunity for the basic deductions of existing designs and structures which are in similitude to the proposal, and the case studies are listed below:

i. Justice Legbo Kutigi International Conference Centre Minna, Niger State, Nigeria.

ii. Abuja International Conference Centre (AICC) Abuja, FCT, Nigeria.

iii. Kigali Convention Complex (KCC) Kigali Rwanda.

iv. Qatar National Convention Centre (QNCC) Doha, Qatar.

4.1.1 Justice Legbo Kutigi international conference centre Minna, Niger state

Located around a well-planned area along, Bala Shamaki road beside NSCDC suites GRA Minna, Nigeria, it was designed by Ministry of works Minna and the construction was completed in the year 27th May 2011, with size of 32,277m^2 it has a Multi-purpose main hall of 500 delegates, two seminar rooms with a capacity of 25 delegates each, a conference hall that seats about 100 delegates and a 100 capacity exhibition space. It also has two meeting rooms with a sitting capacity of 50 delegates each, the conference centre entertains activities such as wedding receptions, conferences, book launch and other large programs, it also has a pavilion and large space for outside exhibitions, the open pavilion can occupy a total of 50 people and a pool for both young and adults, well paved parking spaces of up to 300 cars and backup generator on site with a water treatment tank, to the west of the site is a hotel building NSCDC suite with a total of 90 rooms for guests.

4.1.1.1 Building orientation

The building has the longer side facing the west and does not conform to the North-South orientation. The main hall is slightly tilted towards North-East and South-West direction with the shorter sides of the building facing North-West and South-East. Although the Givoni angle of tilt suggested buildings should be slightly tilted to face North-East and South-West, taking into consideration the sun path as it moves, thereby using the tilt in the orientation to cut off unwanted solar radiation from directly entering into the building. Plate 3 shows the orientation of Buildings on site.

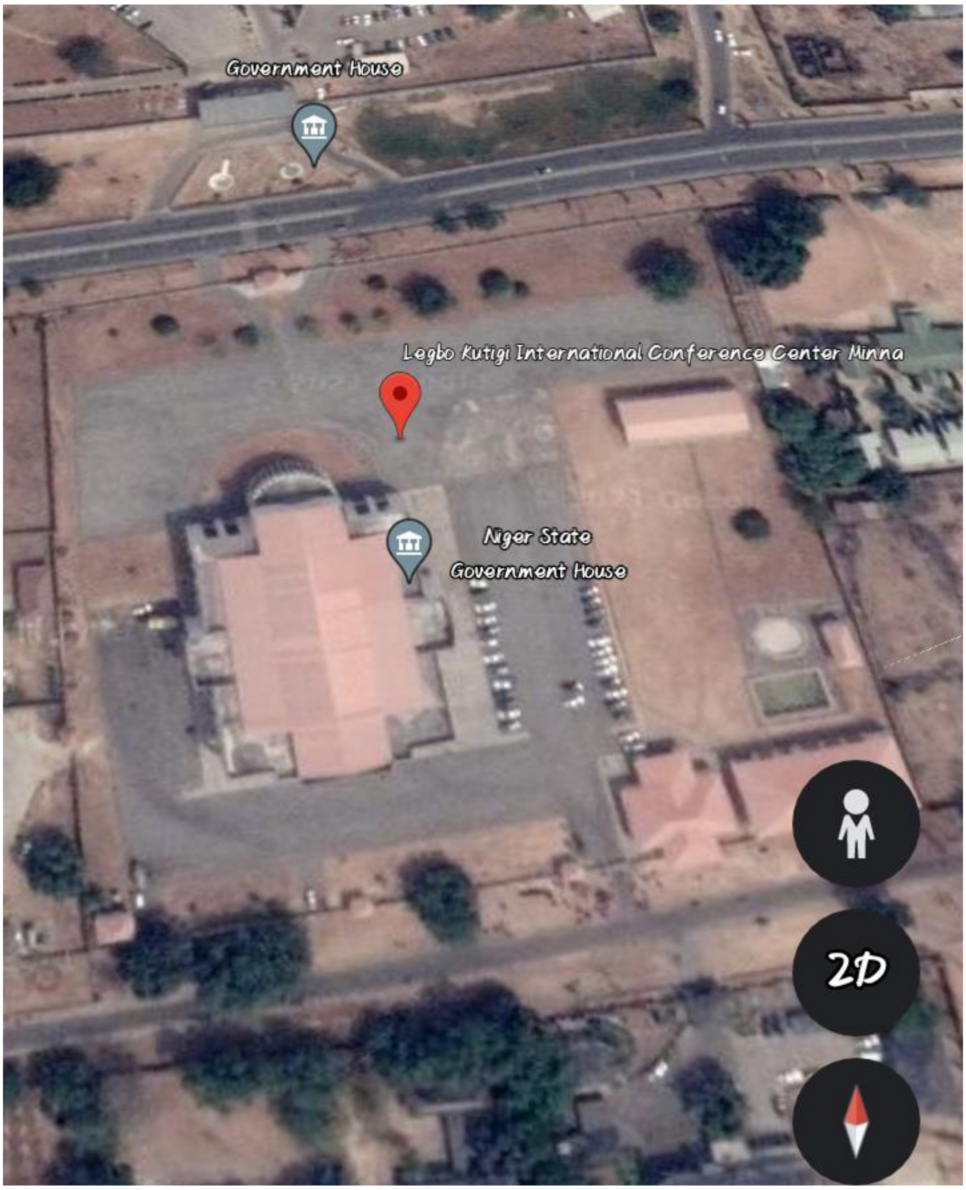

Plate III: Building orientation of Justice Legbo Kutigi international conference centre.
Source: Google Earth (2021)

4.1.1.2 Building form

The building form takes on a simple rectangular shape which defines the longer and shorter sides of the building and constructed with mostly sand-crete blocks. Generally rectangular forms in the buildings automatically provides smaller surface area exposure to solar radiation hence, minimizes the amount of solar heat gains penetrating into the building, Entrance lobby and the main hall is covered with reflective flooring also the main hall is lit with LED bulbs and false ceiling, single banking corridors were also employed at the longer part of the building thereby shading the large glass openings from direct sunlight thereby reducing heat gains, as seen in figure 4.1 and plate IV.

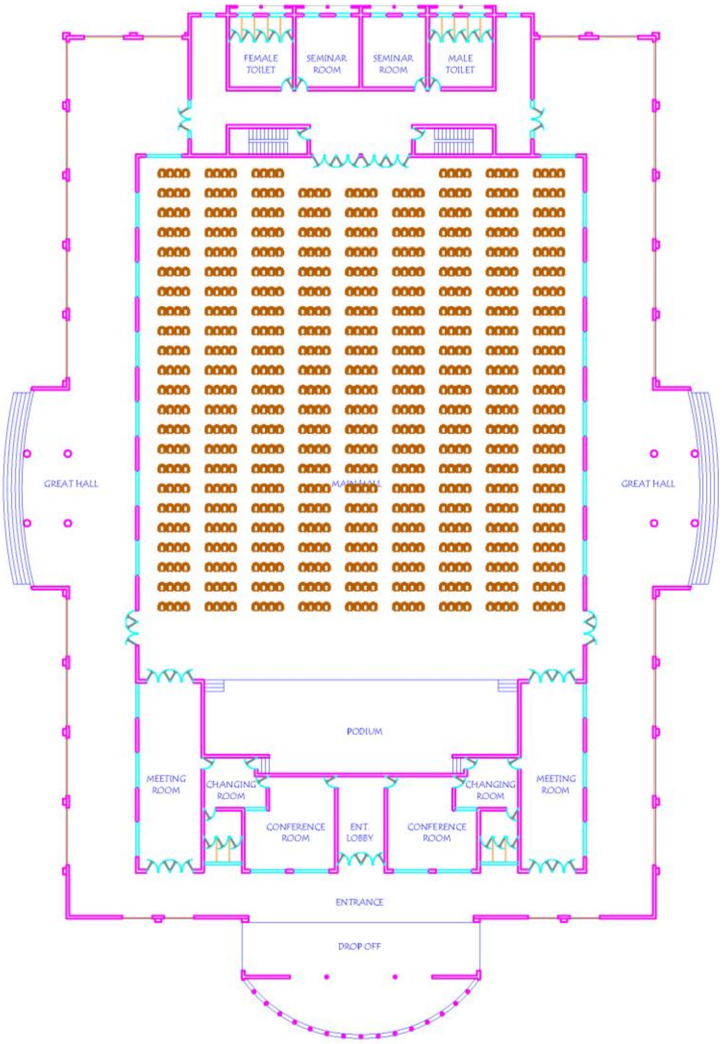

Figure 4.1. Ground Floor plan of Justice Legbo Kutigi international conference centre showing single banking corridor on the longer sides
Source: Author's field work (2023)

Plate IV: Image showing shaded corridor.
Source: Author's field work (2023)

4.1.1.3 Shading devices

External corridors were place on the longer side facing the rising of the sun, the main entrances were also shaded with lobbies and the shorter sides of the building double walling with an adequate recess was used to protect the windows from direct sunlight, curtains were also used in the large hall to shade the windows. Plate V shows shaded entrance into the building.

Plate V: The main entrance into the building with the shaded corridors on both sides.
Source: Author's field work (2023)

4.1.1.4 Openings, windows and vents

Majorly the building was provided with single glazing panels to encourage infiltration. The main hall consists of top fixed long glazed bottom projected windows, with the smaller halls having sliding windows, for the natural lighting of the spaces the windows are adequate but the ratio of opening to the spaces are not adequate for natural ventilation, Plate VI shows the large windows with bottom projected windows.

Plate VI: The side entrance into the building showing large windows with bottom projected windows.
Source: Author’s field work (2023)

Plate VII: Inside the main hall of the building showing large windows and lighting
Source: Author’s field work (2023)

4.1.1.5 Landscaping

Landscaping is one of the visible features around the environment in Justice Legbo Kutigi International Conference Centre. There are different varieties of trees and green landscaping and gardens. The trees were located away from the building, creating a hard land scape round the building used for parking as seen in plate 7 below, the trees and most of vegetal cover are located close to the pool and the auxiliary facilities creating shading and a buffer to the buildings and have also created aesthetically pleasing to one part of the site. Plate VIII, IX and X shows landscaping elements in Justice Legbo Kutigi International Conference Centre, there is also a water body facilitate evaporative cooling.

Plate VIII: The site parking around the building with hard landscape.
Source: Author's field work (2023)

Plate IX: The auxiliary facilities well landscaped with soft and on site pool
Source: Author's field work (2023)

Plate X: The trees and landscape elements at the main gate entrance
Source: Author’s field work (2023)

4.1.2 Abuja international conference centre (AICC) Abuja.

The Abuja International Conference Centre has remained a key landmark in the nation's capital since construction was completed in 1990. Constructed by Julius Berger in record time to host the 1991 OAU Heads of Government meeting in Nigeria, the AICC covers a total land mass of 70,000 sqm, located in Central area, area 11 900 Herbert Macaulay way Garki 1900001 Abuja it has specialized facilities provided for use for both Government and public functions. The International Conference Centre compound is fenced with dwarf concrete walls together with metal grills painted in white Texcote. 2nos. double leaf gates with security posts provide entrance to the compound. The facilities consist of a main conference hall (Africa hall), Committee rooms, Office accommodation, foyer, executive session hall, VIP lounge, mezzanine floor, gallery, banquet Hall/Kitchen and a basement of Niger & Benue halls positioned on the ground floor have complete compliment of conferencing facilities to include presentation screen, projector and individual highly sensitive microphone. When arranged in Committee setting, each can seat about 80 persons otherwise, in a conference formation, Rach hall can hold about 150 persons.

4.1.2.1 Building orientation

The building has the longer side facing the North-East and South-West, the main hall is slightly tilted towards South-West and North-East direction with the shorter sides of the building facing North-West and South-East. The orientation of the building is done in such a way that the larger face of the building is not exposed to direct sunlight, taking into consideration the sun path as it moves, thereby using the tilt in the orientation to cut off unwanted solar radiation from directly entering into the building. Plate XI shows the orientation of Buildings on site.

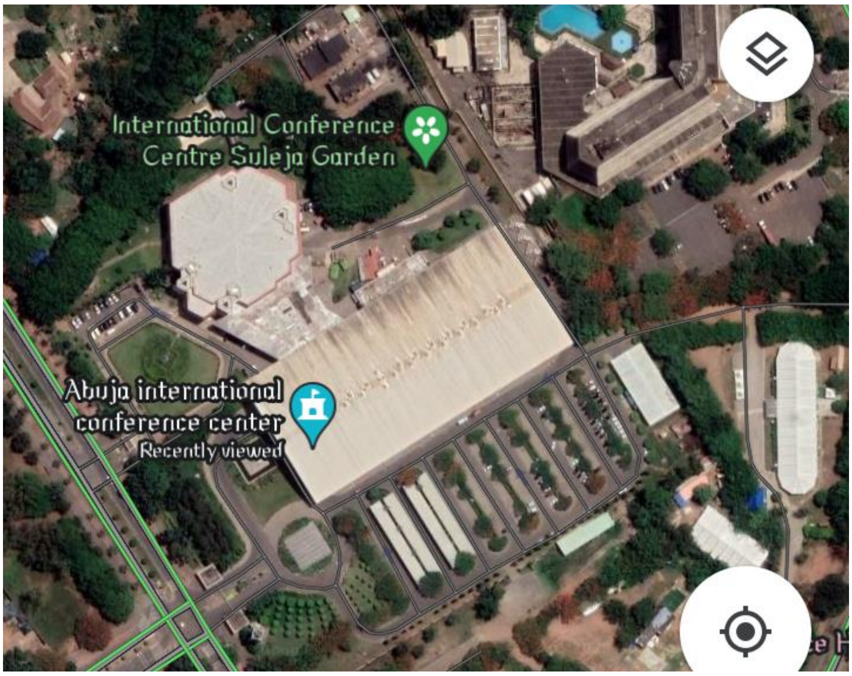

Plate XI: Building orientation of Abuja international conference centre.
Source: Google Earth (2021)

4.1.2.2 Building form

The magnificent conference centre building is rectangular in shape and has a parabolic shaped roof of steel and aluminium sheets with the national Coat of Arms on the fascia and the walls are covered with glass, padded paper, carpet and concrete panels, the form gives the building a strong and firm appearance which is aesthetically pleasing. Plate XII below shows an Ariel view of the main building.

Plate XII: Ariel view showing the rectangular form of the building.
Source: Author's field work (2023)

4.1.2.3 Shading devices

External corridors were place on the longer side facing the rising of the sun, the main entrance to the building has a magnificent long span entrance porch with large columns automatically shading the entrance, with an adequate recess was used to protect the windows from direct sunlight the roof eaves have a wide overhang on all sides, curtains and blinds were also used in the large hall to shade the windows. Plate XIII shows the shaded sides of the building.

Plate XIII: The main entrance into the building with the shaded corridors.
Source: Author's field work (2023)

4.1.2.4 Openings, windows and vents

The swing doors and windows are aluminium glazed glass with 4no. anodized double swing doors providing entrance to the building and the floors are finished in granite, ceramic tiles and rug carpets, The chairs are quite comfortable and the floor is fully carpeted. Majorly the building was provided with double glazing panels to encourage infiltration of light and reduce heat transfer. The main hall consist of top fixed long glazed bottom projected windows, with the smaller halls having sliding windows, for the natural lighting of the spaces the windows are adequate but the ratio of opening to the spaces are not adequate for natural ventilation, Plate XIV shows the large windows with bottom projected windows.

Plate XIV: The side entrance into the building showing large windows with bottom projected windows.
Source: Author's field work (2023)

4.1.2.5 Landscaping

The compound is well landscaped and has a lovely garden filled with historic shady pine trees and well paved driveway, with varieties of ornamental flowers and hedges, an evergreen lawn area, paved compound with asphalt and interlocking concrete blocks, giving it an aesthetically welcoming view from outside, beside the main building on the corridors at specific intervals are concrete planters with varieties of trees and flowers as seen in plate XVI. Other features of the building front include a water fountain tiled in granite and a flag stand directly overlooking the main entrance, this feature helping with evaporative cooling in the building, as seen in plate XV below

Plate XV: The fountain in front of the building well landscaped.
Source: Author’s field work (2023)

Plate XVI: Showing the concrete planters beside the building.
Source: Author’s field work (2023)

4.1.3 Kigali convention complex (KCC) Kigali.

Kigali Convention Complex spans over about 13 hectares, comprises of hotel and a convention centre. The built area is about 80,000 m², which includes the 292 keys Radisson Blu Hotel and Kigali Convention Centre, both managed by Rezidor Hotels Group. Located at highway KN5 in Kigali, 6 kilometres west of Kigali International Airport the complex was designed by Spatial Solutions, Germany, with a capacity of 15,000 delegates the construction was completed in November 2015. The Kigali convention centre has 17 function rooms and an auditorium with state of the art audio visual equipment with configuration flexibility to accommodate the requirement. Comprises of 3 components of set up with balcony seating, retractable seating and 1,257m² flat space, caterers up to 2600 people and various configurations, with interpretation system to support up to 2600 people. Various size of meeting rooms ranging from 31m² to 351m² ideal for boardrooms, meeting, seminar and also banqueting with 3,677m² foyer which will be perfect area for coffee breaks, conference lunches and exhibition.

4.1.3.1 Building orientation

The building has the shorter sides facing the East and West and does follow the North-South orientation principle. The main hall is slightly tilted towards North-West and South-East direction. Taking into consideration the sun path as it moves, thereby using the tilt in the orientation to cut off unwanted solar radiation from directly entering into the building. Plate XVII shows the orientation of Buildings on site.

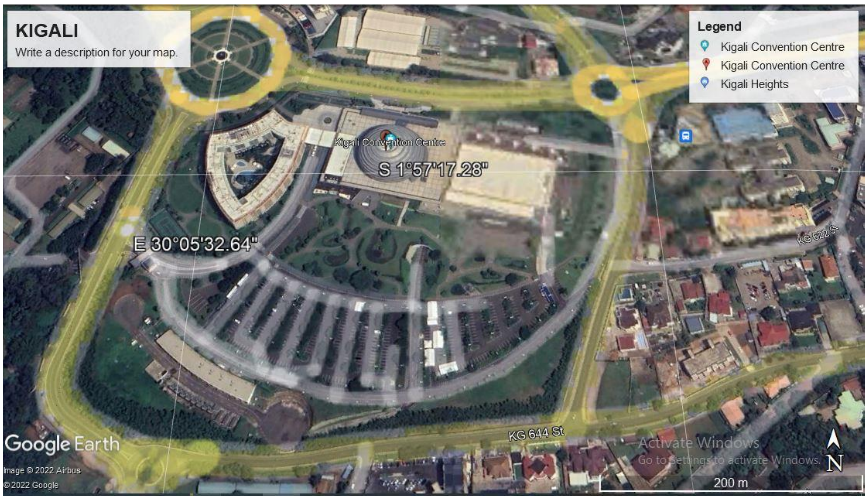

Plate XVII: Building orientation of Kigali convention complex.
Source: Google Earth (2021)

4.1.3.2 Building form

The magnificent conference centre building is rectangular in shape and has a dome shaped roof of steel and double glazing dome to prevent the interior from overheating , interior glass was created using lamellae, located in a very active earthquake region, the steel structure was built as a welded triangular space frame, while the hotel and the office buildings have been designed as skeleton structure of reinforced concrete featuring high flexibility, the form gives the building a strong and firm appearance which is aesthetically pleasing. Plate XVIII below shows a mock 3d of the Ariel view and a section cut through of the dome structure.

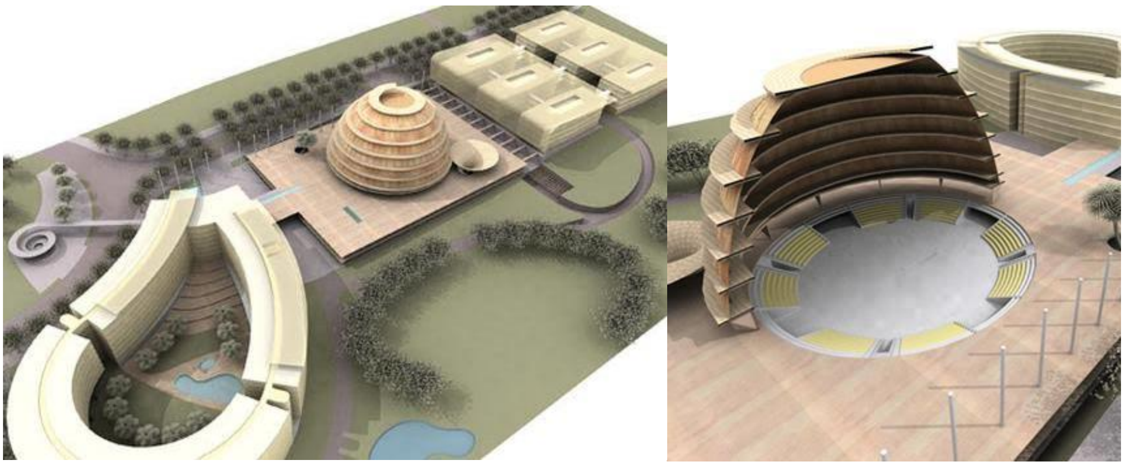

Plate XVIII: Ariel view showing the building form and a section of the dome structure.
Source: Livinspaces.com (2021a)

The hotel is operated by Radisson Blu and this is its very first hotel in Rwanda. With its iconic design, a majestic dome paying tribute to the shape of traditional Rwandan huts, it effortlessly combines Rwandan culture and modernity and is billed to become one of the country's major architectural landmarks. Preciosa has designed a cluster of four chandeliers for the hotel lobby, which are 5.5 meters in length and composed of almost one thousand glass tubes of champagne colour. The ballroom is lit by seven rectangular chandeliers composed of clear glass tubes.

4.1.3.3 Shading devices

The external part of the building is cladded with wood shielding fenestrations with green loggias serving as buffer zone, cooling the air thereby creating a pleasant indoor climate, the gigantic Convention centre, of 53,000 square meters, is the largest in the region. The Universe/Solar System was the inspiration for the dominant lighting installation in the Arena; an amber sphere banked in three rings. The sphere is created from leaves of hand blown Bohemian amber glass inlaid with mica and air bubbles. Three rings of 3, 5 and 7 meters diameter are constructed from 30 cm long glass prisms. Curtains and blinds were also used in various spaces to shade the windows. Plate XIX shows the shading devices used in the building.

Plate XIX: Showing the walkable spiral shape round the dome and the shaded building.
Source: Livinspaces.com (2021a)

4.1.3.4 Openings, windows and vents

The building comprises of various types of windows and opening glazed to encourage infiltration of light and reduce heat transfer. The dome serves as an underlying assembly room admitting natural light into the space from above, the exterior is covered with a glass skin, so to prevent the interior from overheating and the second layer was created using lamellae. This creates an interesting aesthetic of seemingly scattered light on the interior of the dome as seen in plate XX. The convention hotel has a square shaped distorted layout with a generous inner courtyard. Its façade features colourful strips that also aid in shielding the fenestrations and offer and intriguing aesthetic.

Plate XX: The exterior of the dome covered with glass with the walkable spiral shape.
Source: Livinspaces.com (2021a)

4.1.3.5 Landscaping

The compound is well landscaped and has a lovely garden filled with historic shady pine trees and well paved driveway, with varieties of ornamental flowers and hedges, an evergreen lawn area, paved compound with asphalt and interlocking concrete blocks, giving it an aesthetically welcoming view from outside, the inner courtyard in the hotel is planned for plants and greenery and also on the walls are horizontal green with the green loggias serving as buffer zone, cooling down the air and thus creating an indoor climate with two pools adding to the evaporative cooling in the rooms as seen in plate XXI. Other features of the building includes a water fountain tiled in granite and a magnificent statue standing directly overlooking the side entrance, this feature helping with evaporative cooling in the building, as seen in plate XXII.

Plate XXI: The courtyard well landscaped with greenery and pools
Source: Livinspaces.com A (2021)

Plate XXII: The courtyard well landscaped with greenery and pools
Source: Livinspaces.com (2021a)

Both the dome, traditional hut shaped, and the hotel building, rush mat-like façade is inspired by traditional figures. Similarly, landscaping is done to match the "thousand-hill" Kigali natural landscape.

Plate XXIII: The overview of the site well landscaped with trees and various flowers
Source: Livinspaces.com (2021a)

Plate XXIV: The landscaped area with trees round the building serving as buffer zone
Source: Livinspaces.com (2021a)

4.1.4 Qatar national convention centre (QNCC) Doha.

The conceptual design of the QNCC was provided by Yamasaki architects and RHWL, based on a design conceived by Arata Isozaki, this architectural piece presents an impressive facade similar to a tree that symbolizes the Sidra tree. Traditionally, poets, scholars and travellers gathered in the shadow of the cider to exchange knowledge, the tree is the symbol of the Qatar foundation. The Convention Center is located within the Qatar Foundation Campus, in Gharafat al Rayyan, on the Dukhan Highway, so it has excellent communication routes with the rest of the city of Doha, including the new metro line that it is expected to be completed by 2022, the year of the World Cup in the Emirate. It is located next to the Qatar Science and Technology Park, the Sidra Research and Medicine Centre, world-renowned universities and research and technology institution, with a 4000-seat conference room, a multi-level theatre with 2300 seats, 40,000 m² of exhibition space distributed in nine flexible exhibition halls, 10 conference rooms and shows and 52 meeting rooms. It also has 3 staggered auditoriums, VIP lounges, hospitality suites, registration desks, business centre and multimedia rooms to support 7,000 delegates. The place offers facilities that offer five-star catering and parking spaces for 3,200 cars, 43 auto cars and 59 taxis.

4.1.4.1 Building orientation

From the placement on site the building has the shorter sides facing the East and West and does follow the North-South orientation principle. The main hall is slightly tilted towards North-West and South-East direction. Taking into consideration the sun path as it moves, thereby using the tilt in the orientation to cut off unwanted solar radiation from directly entering into the building. Plate XXV shows the orientation of Buildings on site.

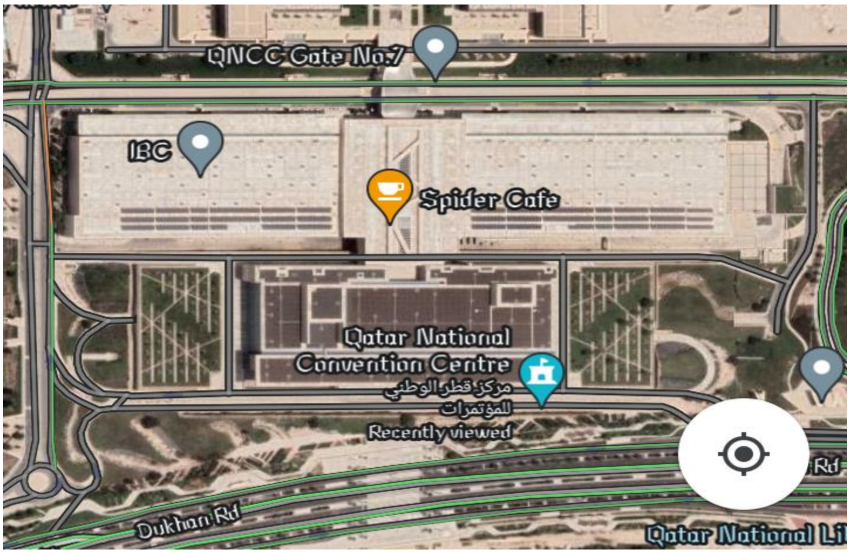

Plate XXV: Building orientation of Qatar national convention centre.
Source: Google Earth (2021)

4.1.4.2 Building form

The convention centre is a rectangular shaped, six-storey structure with a basement measuring about 250m long and 110m wide. The conceptual design of the building incorporates in the main facade a huge organic tree-shaped structure that symbolizes the Cider Tree. Arata Isozaki with its design of giant columns that support the roof of the building refers to Sidrat al-Muntaha, an Islamic sacred tree that is believed to symbolize the end of the seventh heaven. The architects who worked on the project commented that "… The tree is a beacon of learning and comfort in the desert and a refuge for poets and scholars who gathered under their branches to share knowledge …". The building structure was constructed upside down from roof deck to the foundations using Macalloy bars to reduce costs. The 250m-long organic Sidra Tree metal structures were fabricated in Malaysia and shipped for assembly to Doha. The concrete roof deck of the building is at a 40m-long and 30m-wide structure supported by the tree structures. The steel tree structures grow from two concrete bases along the façade and divide into four branches. They are made with structural core of octagonal tubes. The iconic Sidra Tree branch façade will change its colour daily due to six undercoats. It has a built-up area of

150,000m² using about 60,000m² reinforced concrete and 90,000m² of structural steel. The interior wall finishes of the QNCC are Italian marble. The meeting rooms was furnished with Ilboca teak and foyers with timber panelled. The auditoriums has Italian leather seating. The theatres was designed with leather mosaic feature walls. Glass façade was mainly used to clad the building as seen in the plate below.

Plate XXVI: Ariel view showing the building form.
Source: Livinspaces.com (2021b)

4.1.4.3 Shading devices

The rectangular facade of the centre is made of glass and steel. The roof concrete roof is a structure 40 m long and 30 m wide overhang supported by tree structures shading the loner part of the building on one side. Approximately 60,000 m² of reinforced concrete and 90,000 m² of structural steel was used in its construction as seen in the plate below.

Plate XXVII: The roof overhang and Sidra tree concept shading the approach
Source: Livinspaces.com (2021b)

Solar panels located on the roof, occupancy sensors along with LED lights and accessories of low energy consumption and air control systems by areas greatly reduce energy consumption in this gigantic construction. The building is designed to operate efficiently with innovations such as water conservation and energy saving accessories. It also meets the gold certification standards of Leadership in Energy and Environment Design (LEED). The roof has 3,700 m² of panels installed that contribute 12.5% of the total electricity consumption of the building.

4.1.4.4 Openings, windows and vents

The building comprises of various types of windows and opening glazed to encourage infiltration of light and reduce heat transfer. With naturally lite spaces to reduce energy consumption and light colored and reflective coating to enhance cooling of the exhibition spaces, plate XXVIII shows the reflection pool enhancing the cooling of the space in the building, with double glazed glass façade creating a sense of spaciousness by giving incidence of lots of daylight. Through the use of Reynaers slim CW 50 system, the extended curtain wall can let in the maximum amount of light in to the spaces.

Plate XXVIII: The reflective pool enhancing the lighting and evaporative cooling
Source: Livinspaces.com (2021b)

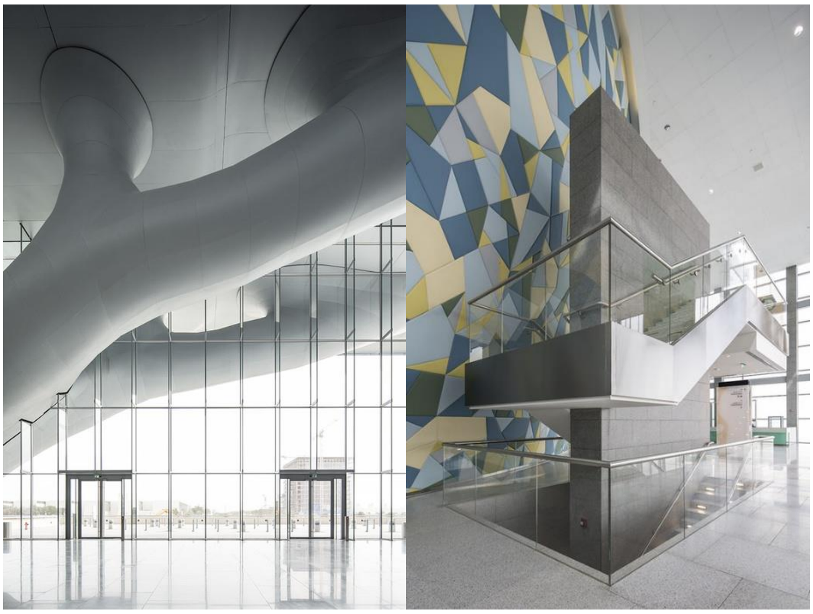

Plate XXIX: The interior space lit naturally and the coloured reflective painting
Source: Livinspaces.com (2021b)

4.1.4.5 Landscaping

The shorter sides of the building has a considerable amount of landscaping serving as buffer zone, with historic shady pine trees and well paved driveway, with varieties of ornamental flowers and hedges, an evergreen lawn area, paved compound with asphalt and interlocking concrete blocks, giving it an aesthetically welcoming view from outside, also cooling down the air and thus creating an indoor climate as seen in plate XXX.

Plate XXX: The landscaped area of the building with flowers
Source: Livinspaces.com (2021b)

4.2 Observed variables across case studies

From the observed case studies as established earlier, the outline variables for the cooling techniques employed in these convention centres and the practices adopted to reduce energy demand in these buildings. The cooling performance emphasizes on the passive and active means, which is the focus of the design. The outlined variables include; Building Orientation, Building Envelope, Shading devices, Ventilation, Landscaping.

4.2.1 Building orientation

A building should be oriented from east to west along the main path of the sun, exposing only smaller façades to high solar radiation at low angles, Openings should be avoided on the west and if they cannot be avoided, they should be adequately shaded by using verandas and tall trees. The buildings observed shows that 80% building orientation were good with two of them using the East West orientation one using the North West to South East orientation and 20% were poorly oriented although the building had a veranda shading it. (See Table 4.1)

Table 4.1: Orientation (N-S, E-W, NE-SW, NW-SE)

Samples	N-S	E-W	NE-SW	NW-SE
Justice Legbo Kutigi International Conference Centre	✓			
Abuja International Conference Centre (AICC)				✓
Kigali Convention Complex (KCC)		✓		
Qatar National Convention Centre (QNCC)		✓		

Source: Author’s field work (2023)

4.2.2 Building envelope

Under building envelop various listed components are: building form, building materials, glazing method

4.2.2.1 Building form

In dry humid climates, larger distances between buildings allow for better air circulation, while in arid climates, compact buildings that are close together expose less façade to the sun and provide shade also energy consumption of rectangular shaped building form is 9-10 % less than the energy consumption of L shaped building form. Building recesses also help to shade building faces. The buildings observed shows that 100% building shape and form were rectangular in shape and 0% didn't use the L-shaped and other forms of building shapes. (See Table 4.2)

Table 4.2: Building forms

Samples	**Rectangular Shape**	**L shaped**	**Others**
Justice Legbo Kutigi International Conference Centre	✓		
Abuja International Conference Centre (AICC)	✓		
Kigali Convention Complex (KCC)	✓		
Qatar National Convention Centre (QNCC)	✓		

Source: Author's field work (2023)

4.2.2.2 Glazing method

Glazing systems have a huge impact on energy consumption. Appropriate glazing choices vary greatly, depending on the location of the facility, the uses of the building, and (in some cases) even the glazing's placement on the building. In hot climates, the primary strategy is to control heat gain by keeping solar energy from entering the interior space while allowing reasonable visible light transmittance for views and daylighting. The buildings observed shows that 80% used double glazing systems and 20% practised single glazing method. (Figure 4.2)

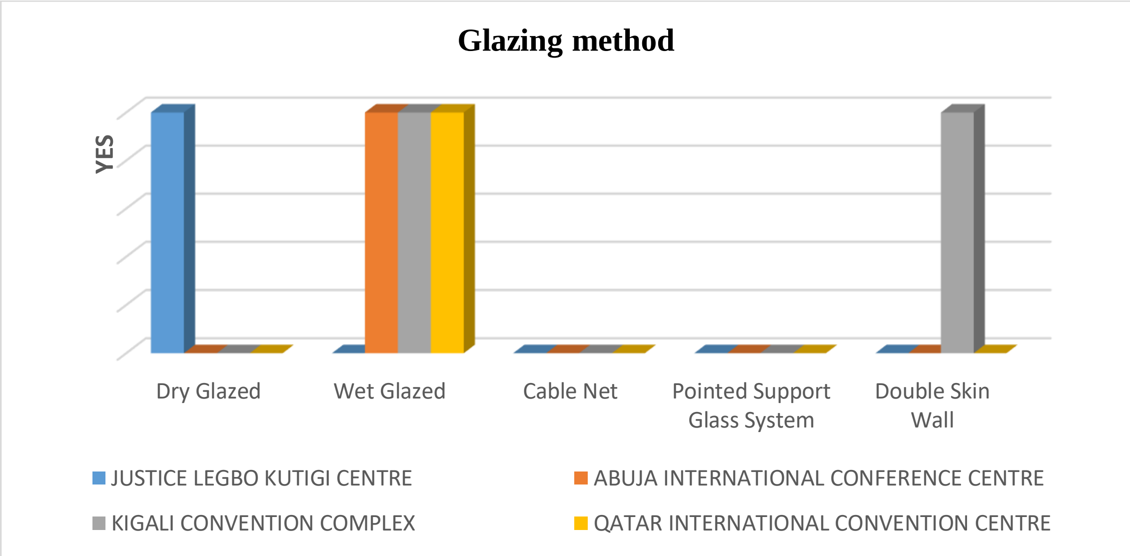

Figure 4.2: Bar chart showing glazing systems used.
Source: Author's field work (2023)

4.2.2.3 Building materials

Good specifications of construction materials and details can reduce heat transfer. Heat transfer across the building envelope occurs as either conductive, radiant, or convective losses or gains. Building materials conduct heat at different rates. Metals have a high rate of thermal conductance. Masonry has a lower rate of conductance; the rate for wood is lower still. Insulating materials, either filled in between framing members or applied to the envelope, resist heat flow through the enclosing wall and ceiling assemblies. (See Table 4.3)

Table 4.3: Building materials

S/N	BUILDING COMPO – NENT	GLASS	BRICK	STONE	BLOCK WALL	+ CEMENT SCREED	CERAMIC TILES	TERRAZO	MOSAIC	CEMENT + RUG	ASBESTOS	WOOD PANEL	PVC	POP	STEEL	ALUMINIUM (LONG SPAN)	CONCRETE
1	WALL																
2	FLOOR																
3	CEILING																
4	ROOF																

LEGEND

- JUSTICE LEGBO KUTIGI CENTRE
- ABUJA INTERNATIONAL CONFERENCE CENTRE
- KIGALI CONVENTION COMPLEX
- QATAR INTERNATIONAL CONVENTION CENTRE

Source: Author's field work (2023)

4.2.3 Shading devices

Shaded openings in the envelope during hot weather will reduce the penetration of direct sunlight to the interior of the building. Overhangs or deciduous plant materials on southern orientations can shade exterior walls to reduce heat gain during warmer seasons. The buildings observed shows that 80% engaged in use of horizontal shading practices and 20% practiced the use of both devices. (See Table 4.4)

Table 4.4: Shading devices

Samples	Vertical	Horizontal	Both	None
Justice Legbo Kutigi International Conference Centre		✓		
Abuja International Conference Centre (AICC)		✓		
Kigali Convention Complex (KCC)			✓	
Qatar National Convention Centre (QNCC)		✓		

Source: Author’s field work (2023)

4.2.4 Ventilation (cross/ one sided/ stack)

Various ventilation methods affect the comfort in spaces, size and location of windows aid proper ventilation and increase the airflow, good location boost ventilation also high windows for daylighting are preferable because, if properly designed, they bring light deeper into the interior and eliminate glare. The buildings observed on both the size and location shows that 60% practiced cross ventilation, 20 % use one sided and 20% use both methods. (See Table 4.5) Figure 4.3 shows the various ventilation elements used.

Table 4.5: Ventilation (cross/ one sided/ stack)

Samples	Cross	One sided	Stack
Justice Legbo Kutigi International Conference Centre	✓		
Abuja International Conference Centre (AICC)	✓		
Kigali Convention Complex (KCC)	✓		✓
Qatar National Convention Centre (QNCC)	✓	✓	

Source: Author’s field work (2023)

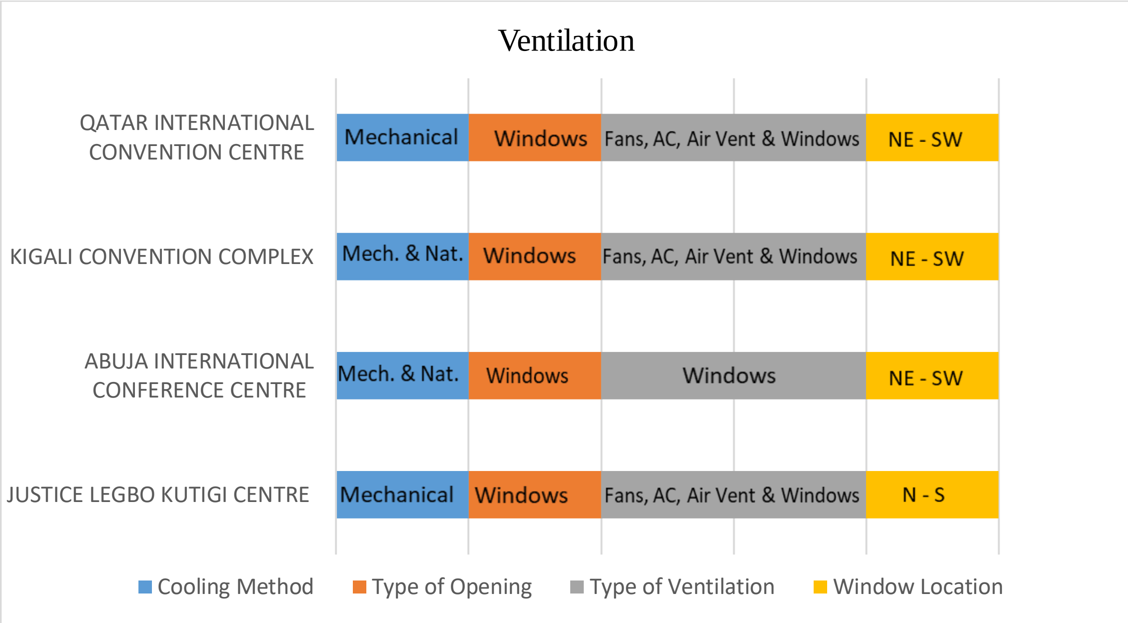

Figure 4.3: The various ventilation elements used.
Source: Author's field work (2023)

4.2.5 Landscape

Landscape and other elements such as overhangs should be integral to a building's performance. Decisions about the envelope need to be coordinated with existing and new landscaping schemes on a year-round basis. Reduce paved areas to lessen heat build-up around the building that will add to the load on the building envelope, consider selection of a paving colour with a high reflectance to minimize heat gain, with considering glare factors. The buildings observed shows that 80% considered less paved areas and 20% did not. (See Table 4.6) Figure 4.4 shows a bar chart of the various elements used.

Table 4.6: Landscape

Samples	Extensive Soft landscape	Extensive Hard landscape	Both
Justice Legbo Kutigi International Conference Centre		✓	
Abuja International Conference Centre (AICC)	✓		
Kigali Convention Complex (KCC)	✓		
Qatar National Convention Centre (QNCC)		✓	

Source: Author's field work (2023)

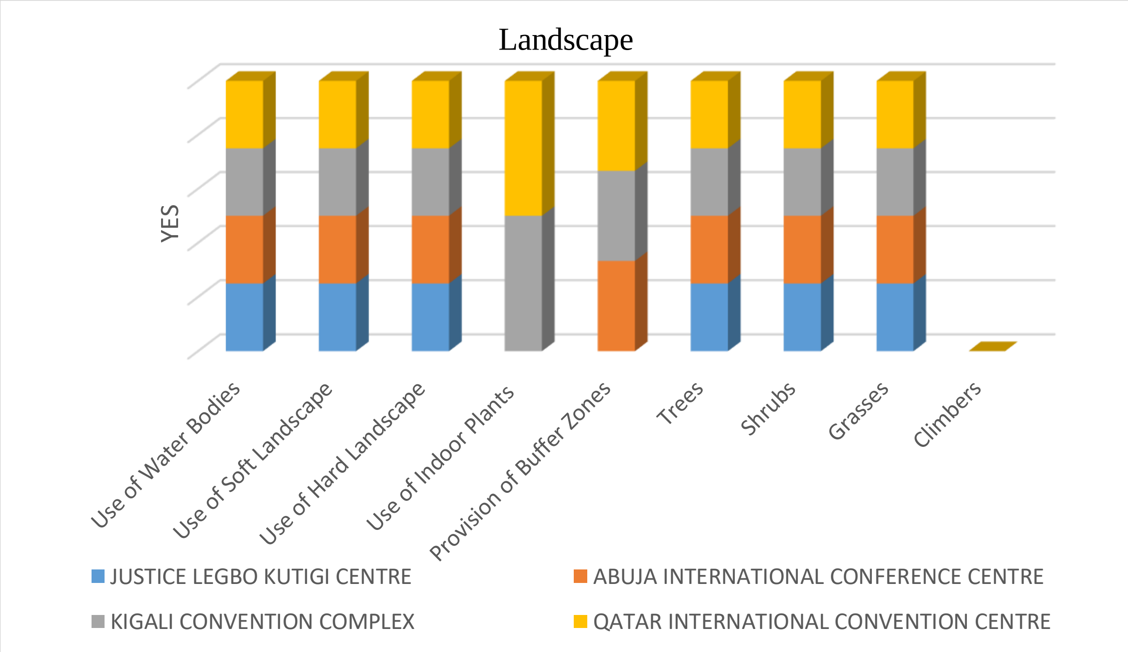

Figure 4.4: The landscape elements used.
Source: Author's field work (2023)

4.2.5.1 Evaporative cooling (natural/ artificial)

Evaporative cooling has been a method that employs the outcome of evaporation as the natural heat dissipater. Sensible heat coming from the atmosphere has been engrossed to be utilized as latent heat needed to become dry out the water, this can be achieved via natural or artificial means. The buildings observed on mode of evaporative cooling shows that 20% use both natural and artificial means and 80% uses artificial mode (air conditioning systems). (See Table 4.7)

Table 4.7: Evaporative cooling

Samples	Natural	Artificial	Both
Justice Legbo Kutigi International Conference Centre		✓	
Abuja International Conference Centre (AICC)		✓	
Kigali Convention Complex (KCC)		✓	
Qatar National Convention Centre (QNCC)			✓

Source: Author's field work (2023)

4.3 Energy Use in Justice Legbo Kutigi International Conference

The Energy usage in a selected convention centre is represented under the following sub-headings:

i. Estimated Energy Supply

ii. Estimated Energy Demand.

4.3.1 Estimated energy supply

Justice Legbo Kutigi International Conference Centre electricity supply is recorded from utility bills documented and back-up supply from a main back-up generator of 500kWh and a substitute of 135kWh. Having minimal power outage due to the eight hours of daily supply from the mains allowing the backup power to work for only four hours straight. Hence, this led to having a higher utility supply per annum compared to back-up supply. Table 4.8 shows the utility and back-up supply for the building.

Table 4.8: Utility and back-up supply for Justice Legbo Kutigi international conference centre.

Electricity supply	Average hours of supply/day (hrs)	Average supply/hour (kWh)	Average electricity supply/day (kWh)	Average monthly electricity supply (kWh)	Average annual electricity supply (kWh)
Utility Supply	8	300.4	3,604.38	14,419.2	173,030.4
Back-up Supply	4	500	2000	8,000	96,000
Total	12	800.4	5,604.8	22,419.2	269,030.4

Source: Author's field work (2023).

Figure 4.5 shows the utility supply covers 66.7% while back-up supply covers 33.3% of the total supply. This shows that the extended supply of electricity from the mains compared to the short back up supply power contributed to the higher percentage.

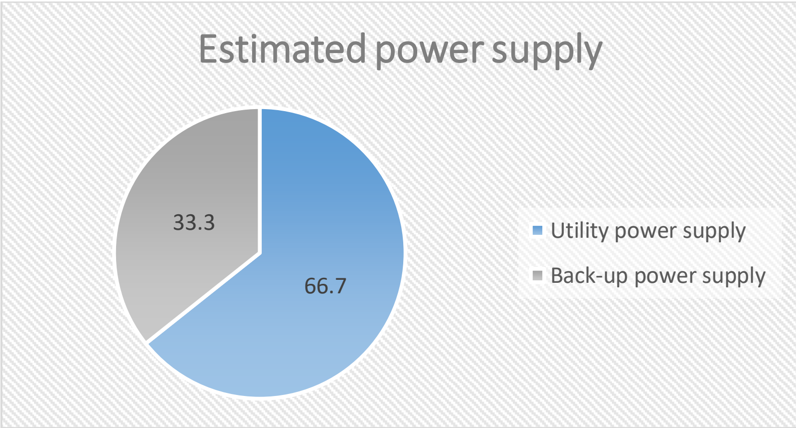

Figure 4.5: Percentages of utility and back-up power supply for Justice Legbo Kutigi international conference centre Minna.
Source: Author's field work (2023)

4.3.2 Estimated energy demand

The estimated energy demand for Justice Legbo Kutigi international conference centre Minna would be calculated using these three (3) factors of cooling and ventilation, lighting and appliances demand to ascertain the energy usage and also the activities that consume the most power in the building.

4.3.2.1 Estimated cooling and ventilation demand

Installed cooling systems in the building are used to estimate the cooling performance which is gotten from an inventory of the various cooling and ventilation systems used in the building. The main hall has 8 nos. of 10hp standing air-condition, with 6 units of 8hp, this cool air is injected into the hall using cooling coils and ducts pipe connected to the external unit. The other spaces in the building contain a 6hp standing units numbering 8nos, with ceiling fans in this spaces Table 4.12 shows the different cooling and ventilation appliances in the building with their ratings and estimated energy consumption using an average of 8hours per day and once in a week.

Table 4.9: Cooling and ventilation demand equipment's with ratings and energy demand

S/N	Appliance	Quantity (Nr)	Energy Rating (kW)	Average hours of usage/day (hrs)	Average Energy consumed/ day (kWh)	Average energy consumed/ month (kWh)	Average Energy consumed/ annum (kWh)
1	Panasonic 10 hp standing unit AC	8	28.1	8	1,798.4	7,193.6	86,323.2
2	LG 8 hp standing unit AC	6	25.1	8	1,204.8	4,819.2	57,830.4
3	LG 6 hp standing unit AC	8	16.1	8	1,030.4	4,121.6	49,459.2
4	Ceiling fans ORL. brands	16	0.08	8	10.24	40.96	491.52
	Total	38	69.38	32	4,043.84	16,175.36	194,104.32

Source: Author's field work (2023)

4.3.2.2 Estimated lighting demand

The various lighting in the building was documented and the lighting demand was estimated using the same method. Table 4.10 shows the different lighting appliances with their ratings, locations both internally and externally and estimated energy used for a period time.

Table 4.10 Estimated lighting equipment's with ratings and energy demand.

S/N	Lighting	Location	Quantity (No)	Rating (kWh)	Average hours of usage/day (hrs)	Energy consumed/ month (kWh)	Energy consumed/ annum (kWh)
1	18 watts T8 fluorescent recessed low glare ceiling light	Main Hall and Meeting Rooms	200	0.06	8	384	20,736
2	18 watts Bollard Light	Garden, walkways and car parks	80	0.04	12	1,152	13,824
3	AKT 18 W energy saving bulbs	Veranda and offices	100	0.018	8	57.6	3,110.4
4	Security Flood light	Property boundary	18	0.2	12	1,296	15,552
5	Halogen security light	Walk ways and building edges	12	0.2	12	864	10,368
Total			410	0.518	52	3,753.6	63,590.4

Source: Author's field work (2023)

For the lighting equipment's in the main building were calculated based on the average hours of operation per day and subsequently multiplied by 4 weeks in a month and 12 months in a year, while the equipment's outside the building were calculated based on the average of 12 hours, 30 days and 12 months in a year.

4.3.3 Estimated appliances demand

The appliances demand would be calculated from equation 3.1. It covers heating appliances, electronics and machines. From Equation 3.1;

$$Qt = Qc + Ql + Qa \qquad (3.1)$$

Where, *Qc* is the cooling and ventilation system, *Ql* is the lighting demand, and *Qa* represents the other appliances in the building.

From equation 3.6, $Qa = Qt - (Qc + Ql)$

Hence, $Qa = 269{,}030.4 - (194{,}104.32 + 63{,}590.4)$ $Qa = 11{,}335.68$

$Qt = 194{,}104.32 + 63{,}590.4 + 11{,}335.68$

$Qt = 269{,}030.4$ kWh (total estimated electricity demand for Justice Legbo Kutigi International Conference Centre Minna)

Figure 4.6 shows that cooling and ventilation system has the highest energy usage in the building followed by the lighting then appliances demand. The lighting demand is minimal due to the fact that the lighting equipment with the highest energy usage are used at night. The substantial energy consumption by cooling and ventilation system is an indication that targeting this end-use will provide significant energy saving.

Table 4.11 End use Average electricity demand per annum

End-use Electricity Demand	Average Electricity Demand (kWh)
Cooling and Ventilation Demand	194,104.32
Lighting Demand	63,590.4
Appliances Demand	11,335.68
Total	269,030.4

Source: Author's field work (2023)

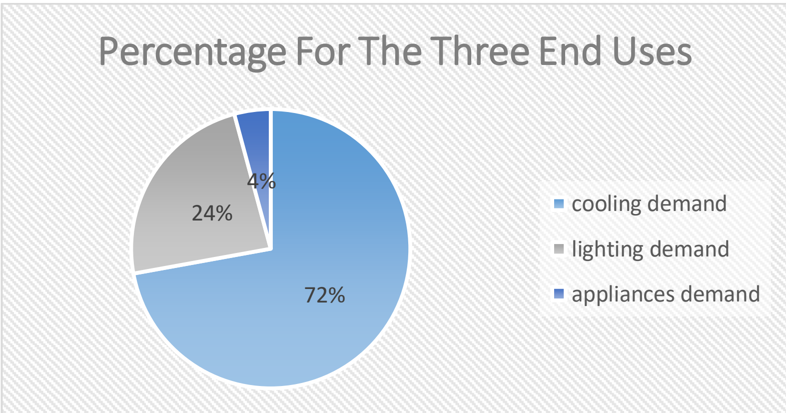

Figure 4.6: Percentages of cooling, lighting and appliances demand.
Source: Author's field work (2023)

With the comparison of the three end uses in the building, it shows that cooling load demand having the highest consumption per annum covers 72% of the total supply followed by the lighting with 24% and appliances with 4%. This indicates that the higher the working hours of the centre, the higher the cooling demand.

4.4 Summary of Analysis and Findings

From the analysis carried out it is seen that an average of 50% of the building being observed generally consumes more energy thereby increasing the energy demand in these buildings, large percentage of analysis is on the negative side of the variables considered for reduced energy use. The energy audit carried out also shows that the buildings cooling load consumes the most energy. In the following, we investigate the advantages and shortcomings of different strategies depending on the local condition, Table 4.12 shows comparison between these cooling methods.

Table 4.12 Comparison between the cooling strategies adopted

Strategies	Installation & maintenance costs	Results	Suitable climate conditions	Disadvantages
Natural ventilation	Very low	i. Can reduce up to 3°C ii. Lower 40% energy cost used by the air-conditioning systems	Low temperature region with available natural air flow	Free entry of dust, pollen, insects & security limitations
Evaporative cooling	Relatively high	i. Can reduce up to up to 3 to 4°C ii. May lower 50% of energy cost used by the air-conditioning systems	Hot & dry atmosphere	May cause an uncontrolled humidity & health hazard due to the development of bacteria

Source: Siddique *et al.,* (2018).

This shows that targeting the natural cooling and ventilation end-use in the design of the convention centre would greatly reduce energy demand and also improve cooling performance thereby providing the building with a substantial energy savings system.

4.5 Proposed Convention Centre for Minna.

4.5.1 The study area

4.5.1.1 Proposed site and its location

The site located in the city of Minna with a 5.3 km drive from the City gate, which is in Minna south of the Chanchaga local Government area, Niger state, Nigeria. Situated along the Western Bypass, the site is close to a rail line to the South West and Christ The Rock Assembly Church to the North.

Figure 4.7: Google earth image of the proposed site
Source: Google Earth (2021)

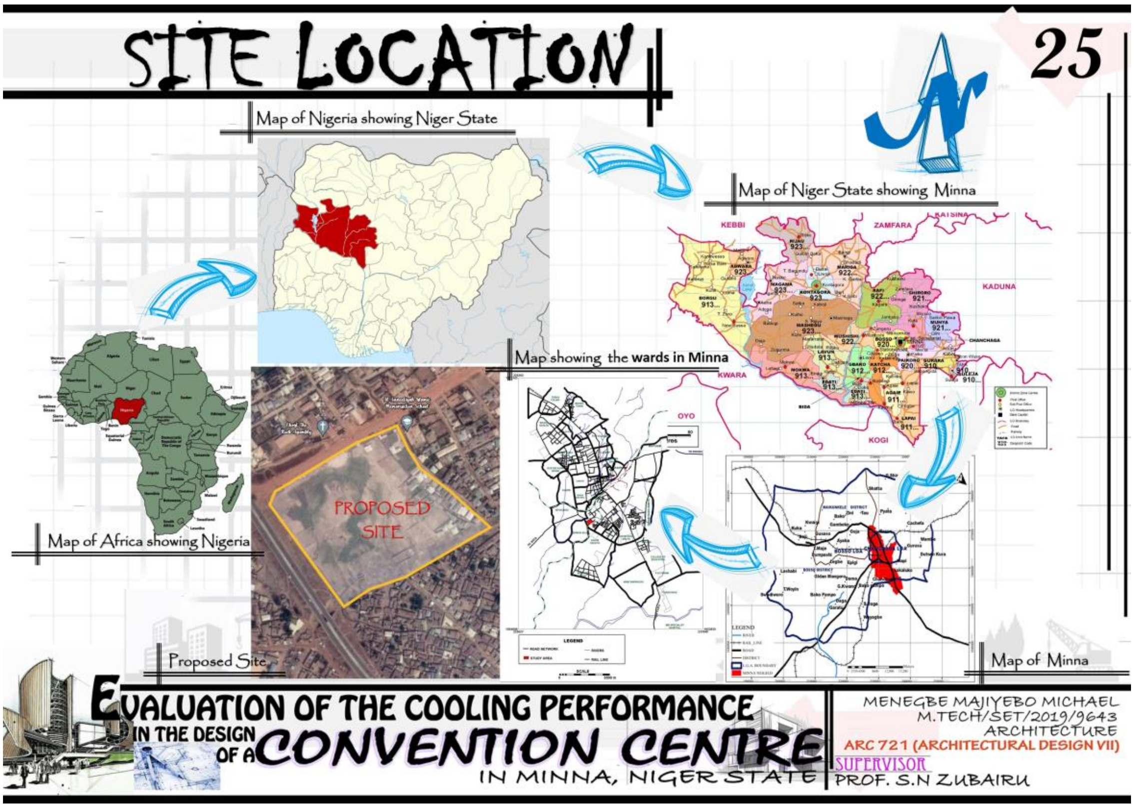

Figure 4.8: Image showing site location.
Source: Author’s field work (2023)

4.5.1.2 Site Selection criteria

From the existing land use map as at 1979, the area left blank is allocated for future development with other land uses also are represented showing both primary and secondary roads with the rail line passing through Minna. Based on the reviewed master plan as at year 2000 the area was still allocated for future development as seen in figure 4.9, due to the proximity of this space to the CBD, rail way station, and western-by-pass the site was chosen as the proposed site for the development, in the selection of the site other criteria’s considered was the site been a focal point for business activities and infrastructural development and that will encourage accessibility from surrounding areas. The area of land within the red rectangle is the proposed area for the development, as allocated for future development in the master plan.

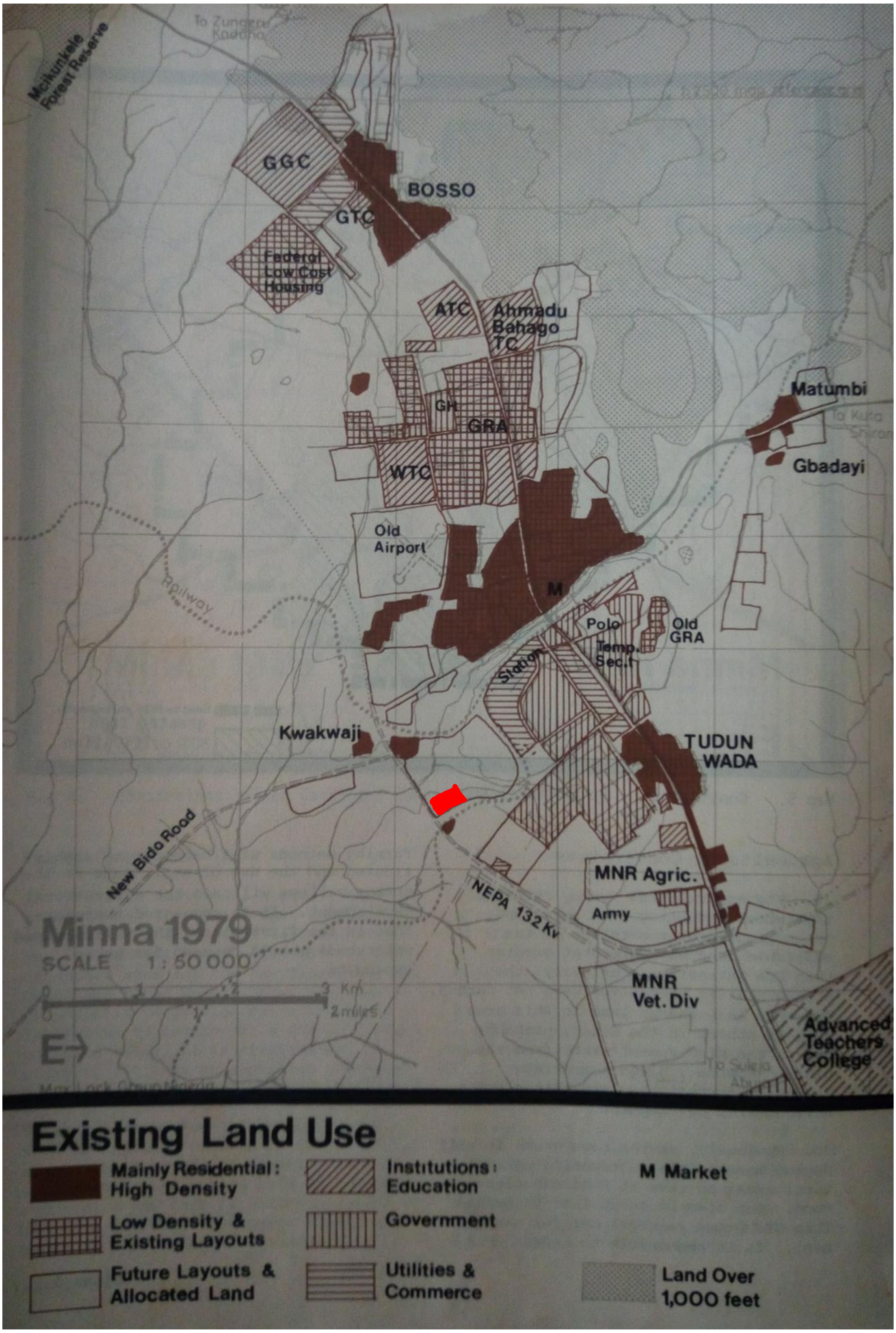

Figure 4.9: Image showing the Minna master plan.
Source: Town Planning Division, Ministry Housing and Environment, Niger State (2021)

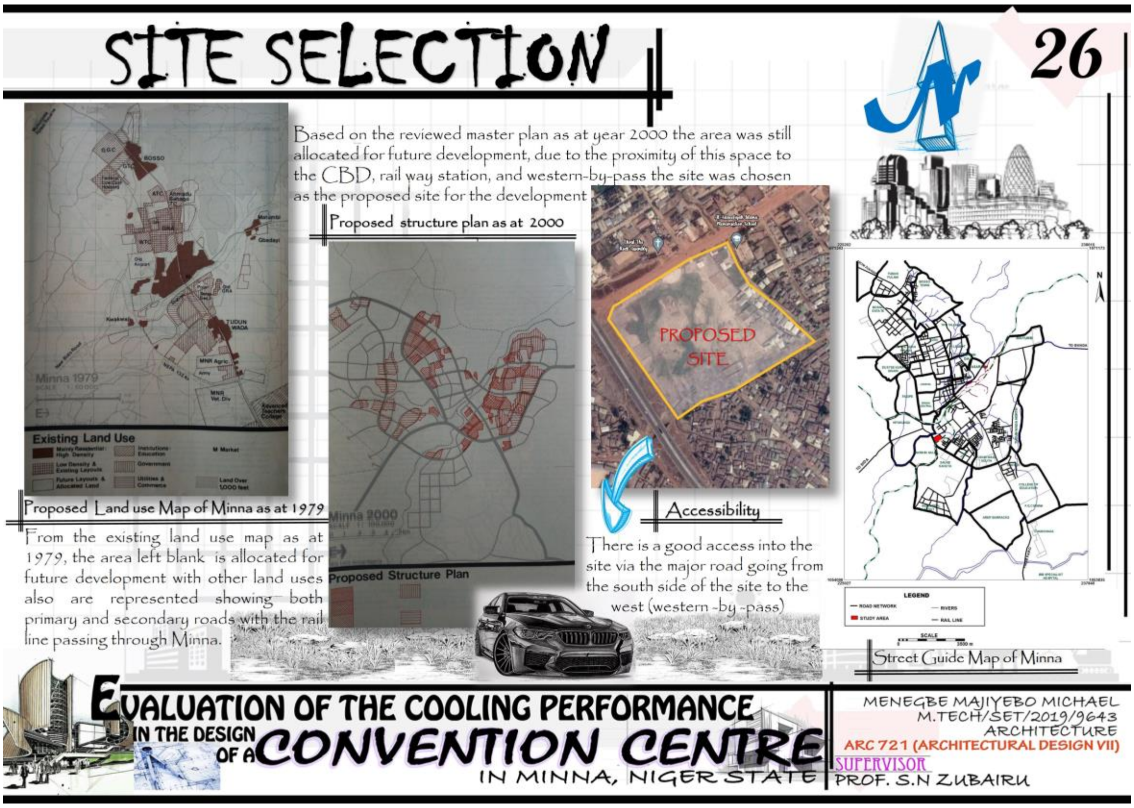

Figure 4.10: Image showing site selection criteria.
Source: Author's field work (2023)

4.5.1.3 Site analysis

After the site was selected a careful evaluation of the site was conducted taking note of the site characteristics, it has the existing access road located to the north, with the site been easily accessible from the western-by-pass to the east, and the site has a gentle slope of 4.4% from the East to West with undulations at intervals as seen in fig 4.11.

Figure 4.11: Google earth image of the proposed site showing the site section
Source: Google Earth (2021)

With a rock formation located at the middle of the site. The vegetal cover is sparse with no trees and little shrubs as well as grasses, trees would be planted to reduce effect of sun and wind directly on the building creating buffer zones and increasing the buildings natural cooling performance. Presence of electric lines as source of power to the building through the power line station opposite the site. Buildings should not be located underneath these lines. With the major winds in Nigeria been the North East trade wind and the South West trade wind. Originating from the Sahara Desert in the north and it accompanied with a characteristic dry atmosphere with dust causing Harmattan. Trees would be planted to break wind effect. With the South West trade from the Atlantic Ocean in the South bringing a cool and moist air, causing the raining season. The temperature in Minna is averagely high during the day with a range of 28^{o}C to 30^{o}C and lower temperatures at night ranging from 19^{o}C to 21^{o}C (Weather spark, 2019).

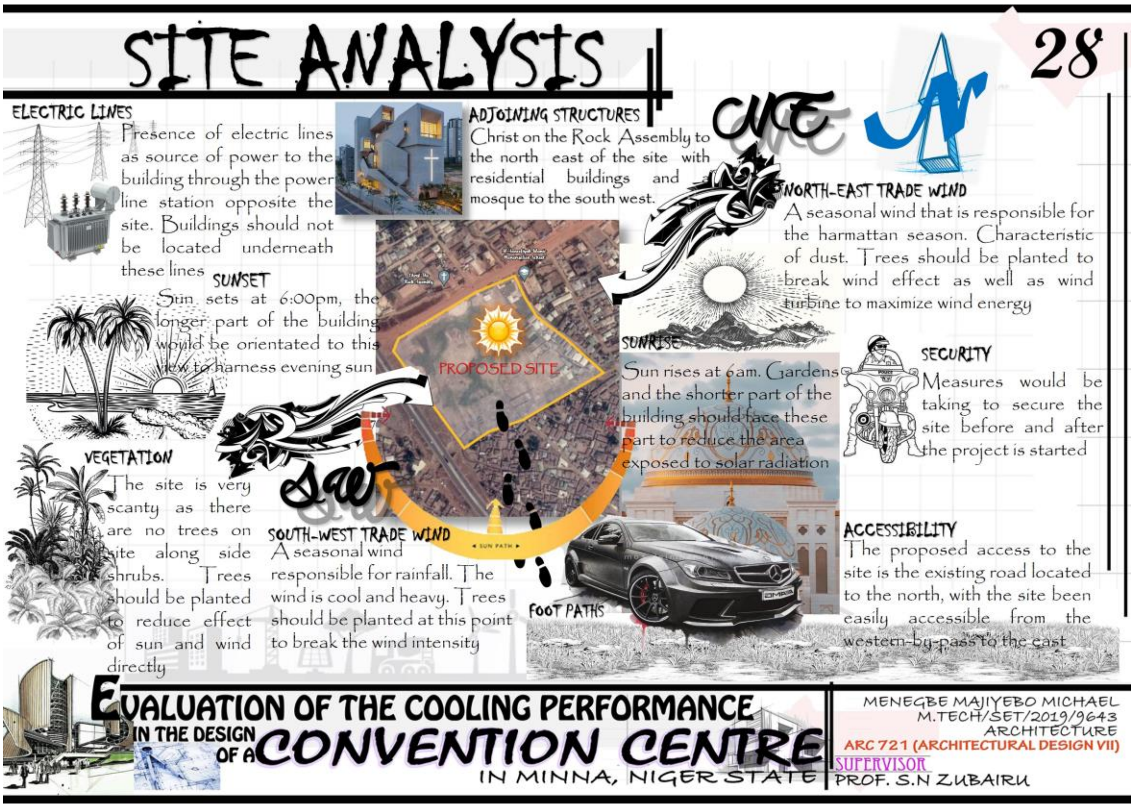

Figure 4.12: An architectural illustration showing site analysis.
Source: Author’s field work (2023)

4.6 Design Report

4.6.1 Design brief

The design task as commissioned by the Niger State government is to provide an appealing state-of-the- art convention Centre as it is an important accelerator of business and communication for the city, the Centre shall consist of an auditorium, multi-purpose halls, accommodation, retail spaces and associated facilities. Buildings are one of the biggest energy consumption tool in the world, accounting for one-quarter to one-third of all energy use and a similar amount of greenhouse gas emission (Council, 2007). Testing the limits of general of cooling performance, sustainable technologies and materials in a building that hosts numerous events with a variety of needs on a daily basis improving. Indoor environment and presents a great environment to test new technologies and materials in a variety of ways. The aim of this thesis is to evaluate various cooling performance and thus reducing cooling demand in buildings, with energy efficiency considerations and use these measures to design a modern, culturally and aesthetically pleasing energy sustainable structure, also from the research process, the following outcomes were implemented

i. Adequate landscaping elements on the site with paved areas, green areas, trees and shrubs so as to purify the outdoor air and enhance a cool environment.
ii. Orientation of the building to harness the effect of the prevailing wind and solar gain, also practicing self-shading.
iii. The use of cross ventilation and stack ventilation as a means of natural cooling.
iv. The adequate spacing of the building sections to enhance natural air flow.
v. The planting of indoor plants for air purification process

4.6.2 Design concept of the proposed convention centre

4.6.2.1 Site concept

The site radiating outwards using the building as the core, is planned to make movement within the site easy and accessible and also to shade the building with trees from the South Eastern and North Western Trade winds. Activities and facilities are connected with flowing pedestrian covered walk-ways helping the guest to interact with spaces and also cherish the full architectural master piece in one go. This concept is aimed at achieving a heightened cooling performance in the design with proper adaptation that enhance natural cooling and reduce energy demand.

4.6.2.2 Building concept

Trees generally cools the air by the process known as transpiration cooling, releasing water into the atmosphere from their leaves via transpiration. Due to the unique shape and netted design of the maple leaf it releases water from the veins and the surrounding air is cooled, it also enhances air flow through its branches. The flow of the building will be based on the radial symmetry with the plan taking the shape of the maple leaf, the shape and the parts of the leaf were adopted and the veins where replaced with basic shape and circles to come up with a form that enhance cooling and easy circulation of natural air. The north façade maximizes north day lighting and wind flow by a skin system of solar control glass and mesh screen.

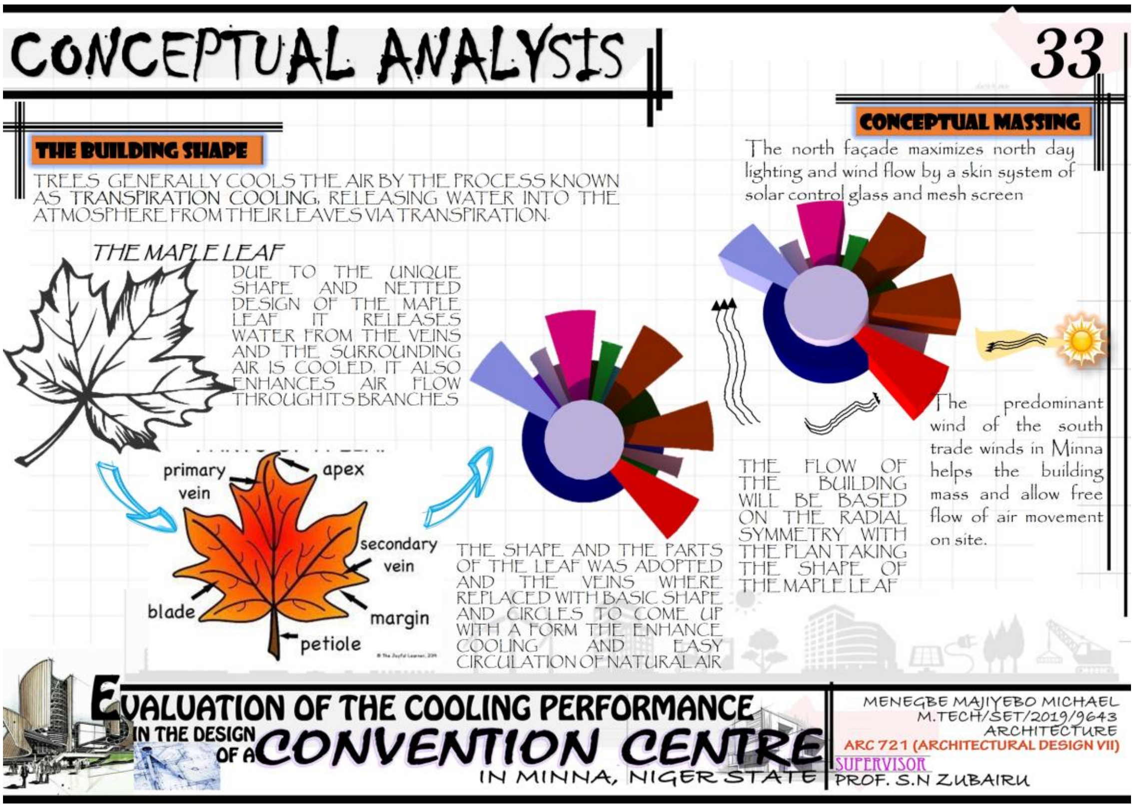

Figure 4.13: An architectural illustration showing design concept.
Source: Author's field work (2023)

4.6.3 Schedule of accommodation

From the brief and consultation of relevant sources both primary and secondary the schedule for accommodation for the design of the convention centre was developed using the standards Table 4.13 shows the schedule of accommodation. Flow and functionality of the design were also shown in the presentation drawings below.

Table 4.13: Schedule of Accommodation for Convention Centre

S/N	Function	Area (m^2)	Units	Total (m^2)
1	Entrance lobby/ Reception	175	1	175
2	Waiting area	145	4	580
3	Snack bar	80	4	320
4	Restaurant/ Bar	190	4	760
5	Male toilet A	13	10	130
6	Female toilet A	12	10	120
7	Male toilet B	5	2	10
8	Female toilet B	6	2	12
9	Kitchen	175	2	350
10	Dry store	11	2	22
11	Cold store	9.5	2	19
12	Chef's office	7.5	2	15
13	Newspaper/ /Magazine store	38	2	78

14	Internet	31	2	62
15	Boutique	30	2	60
16	Souvenir shop	27	2	54
17	Conference hall	135	4	540
18	Speaker rest room	9	8	72
19	Podium/ Back stage	28.5	4	114
20	Project monitor/ lights/ sound	18	4	72
21	Mini conference hall	640	1	640
22	Video conference hall	640	2	1280
23	Banquet hall 1	640	1	640
24	Banquet hall 2	360	1	360
25	Logistics	24	1	24
26	General staff area	234	1	234
27	Chief of staff office	15	2	30
28	Public relation staff office	15	2	30
29	Accounts treasury office	21	2	42
30	Administrative office	15	1	30
31	Printing area	14	1	14
32	Tour/ Personnel shows office	13	1	13
33	Secretary	12	1	12
34	Works proposal	24	1	24
35	Managers office	44	1	44
36	Exhibition hall	195	2	390
37	Convention	820	1	820
38	Podium	44	1	44
39	Male changing room	12	1	12
40	Female changing room	12	1	12
41	Courtyard	380	-	380
42	Lobby	695	-	695
43	Raised floor	235	1	235

Source: Author’s field Work 2023

4.6.4 Integration of cooling techniques

4.6.4.1 Building orientation

Good building orientation helps to reduce penetration of hot sun ray acting on the building, by considering the sun path in relation to the rising and setting of the sun, with these considerations the building was placed on the site. Zoning of facilities within the site with the aim to have scenic view of nature and extensive landscape was also considered. The building was oriented exposing little part of the buildings wall to the sun, with a tilt to allow self-shading due to the nature of the building design elevational hierarchy was also practiced.

Figure 4.14: An architectural illustration showing building orientation on site.
Source: Author's field work (2023)

4.6.4.2 Solar study of the site location

The building concept helps in the ability to make use of the prevailing winds and also harness the sun through the buildings wing and shading strategy. Figure 5.9 shows the building orientation and the response to the sun movement along various times of the day. Building faces that are expose to the elements are shaded and protected using wind breakers and solar shading devices.

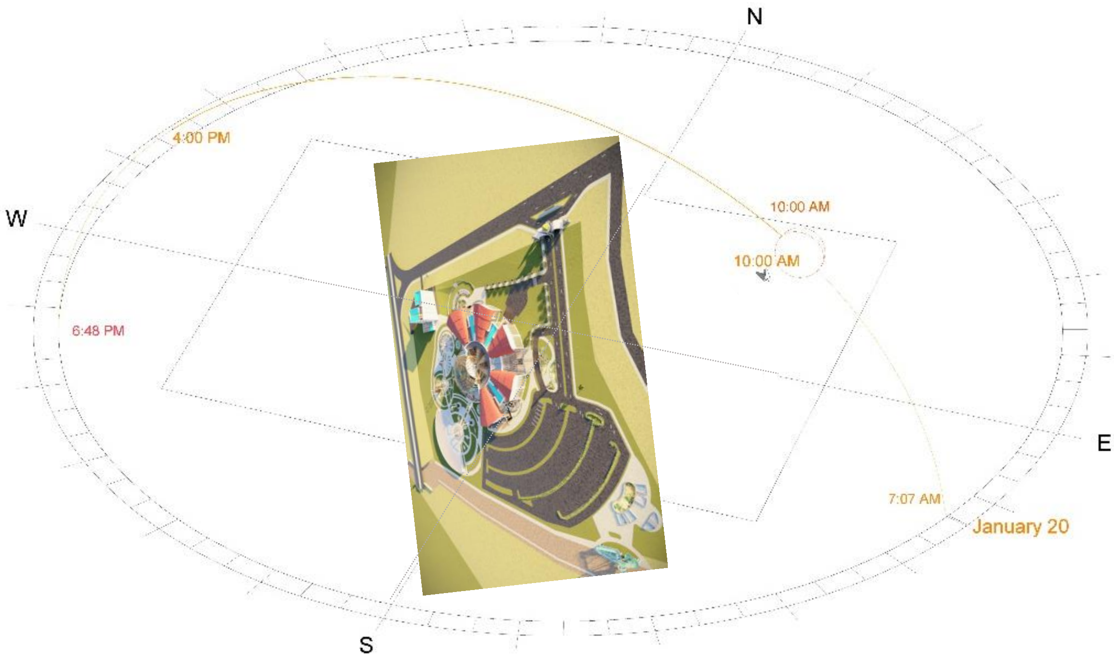

Figure 4.15: An architectural illustration with the solar study of the site.
Source: Author’s field work (2023)

4.6.4.3 Building form/ materials

The form used aides in self-shading, with the building designed in sections to allow optimum ventilation through the buildings wing and shading strategy. Figure 5.10 shows the form of building exposing minimal part to solar glare. In the structural system, post and lintel system was adopted with pad and deep strip foundation. The columns were constructed using the pad foundation method with the beams connected creating a frame structural system, external and load bearing walls were done using the deep strip foundation. Space frame lattice structure was used in the atrium covering, also in the main convention hall creating a large dome structure and the larger building parts. With each of the building frames connected forming a multiple triangulation network spanning great distances.

Figure 4.16: An architectural illustration of the building form on site.
Source: Author's field work (2023)

The building materials for finishes were carefully selected with attention to their cooling and insulating properties to achieve an energy efficient and eco-friendly structure, as the importance in energy reduction cannot be over-emphasized owing to the overall energy consumption of the building. Walling materials used mainly for the external walls has high thermal mass with the purpose of limiting hot air into the interior spaces. Phase change materials were also used in the cladding of the frame structure, red bricks and Innovida fibre composite panels made of polyurethane were also introduced. The composite material is placed between two composite layers giving room for the absorption of the external heat in the environment during the day and release it at night. Ultra white paint for coating of the external walls were also used as it has high ability to reflect the suns heat by 98% thereby enhancing cooling.


Figure 4.17: The finished material on the façade of the building.
Source: Author's field work (2023)

The flooring system was done using hollow block slabs, reducing the process of heat exchange between floors via the process of insulation, hollow floors are designed with earth coupling copper wires passing through them enabling heat exchange between the earth and the hot room temperature, coupled with the use of the UFAD systems.

Sun rays hit the roof directly, cool roof mechanism was adopted with various segments of the building covered with cool dark roof. The main conference hall roofing material used was PTFE (polytetrafluoroethylene) coated fibre glass membrane, these are composed of woven glass fibre base cloth, pre-coated with a silicon layer to prevent moisture absorption, and then coated with liquid PTFE. This process produces a membrane fabric which has low water vapour permeability and excellent UV, anti-adhesive and translucency properties, this creates an interesting aesthetic of seemingly scattered light on the interior of the dome. Figure 4.18 shows the working principle of PTFE, fig 4.19 also shows the characteristics of PTFE

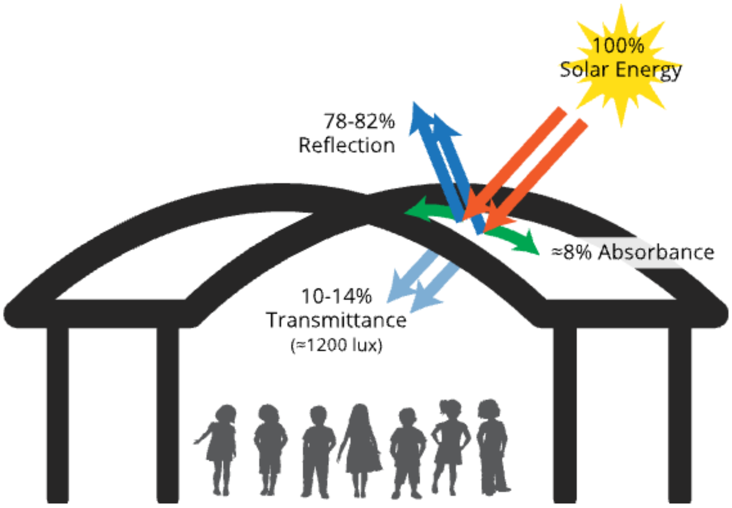

Figure 4.18: An illustration of how PTFE works.
Source: Iten *et al.* (2016)

Means of Fabrication	Heat Sealing
Life Expectancy (years)	45+
Translucency	10-14%
Waterproof	✓
UV Protection	●●●
Cleanability	●●●
Recyclable	✗
Colours Options	White only (after sun bleaching)
Maintains Colour	✓
Price Comparison	●●◖
Additional Options	Top coats in fluropolymers and Ti02 coatings to improve durability & surface cleanliness

Figure 4.19: Characteristics of PTFE Teflon coated Fibreglass.
Source: Iten *et al.* (2016)

Green roofing system has the ability to slow and reduce the impact of the solar radiation on the building by cooling the interior space below it. Green plants on the roof traps sun through photosynthesis and releases fresh clean air into the atmosphere. In designing the use of solar panels thereby trapping and making use of the clean solar energy produced by the scorching sun of this region, reducing the solar radiation around the building.

Figure 4.20: The finished PTFE material on the dome structure of the building.
Source: Author's field work (202)

4.6.4.4 Shading devices

Vertical and horizontal shading devices were used in the building to reduce the impact of the sun radiation on the buildings envelope, use of recesses and staggered elevations. The double glazed areas also had steel rectangular pipes to reduce the suns impact on the façade. Roof overhangs and netted entrance were also used to shade and also allow light pass through with the aim to control heating. By drastically reducing the impact of the suns radiation on the building, energy consumption for cooling and lighting activities were reduces there by affecting the overall energy demand. The shading is seen in figure 4.21 below

Figure 4.21: The various shading devices used in building.
Source: Author's field work (2023)

4.6.4.5 Natural ventilation/air movement

Taking into consideration the hot humid and hot dry climate of Niger State, natural cross ventilation reduces the need for artificial means of ventilation thereby increasing the rate of energy consumption. All spaces are cross ventilated, with use of atriums and courtyard for stack effect and to extract hot air and replace it with cool refined air. With water bodies at some of the interior spaces to achieve evaporative cooling and filter the air, placement of openings at the top part of the building in form of clerestory windows to extract the hot air that rises to the ceiling level, minimizing cooling loads on the building. Use of roof vents were also employed, with double wet glazed system for the curtain walls around major sections in the building and in the exhibition halls the use of foldable blinds was adopted to create a connection with the cool air coming into the building based on the orientation harnessing the South east trade winds. Figure 4.22 shows the roof vents and double glazing used.

Figure 4.22: The roof vents and glazing system.
Source: Author's field work (2023)

4.6.4.5 Landscaping

The use of extensive landscaping with of soft landscape to accommodate green plants with the purpose of cooling the atmosphere. Trees, grasses and shrubs were carefully placed on the site to achieve cooling, with fountains and water bodies placed strategically to filter hot air and cool it down before infiltrating to the building spaces giving a scenic and aesthetically environment.

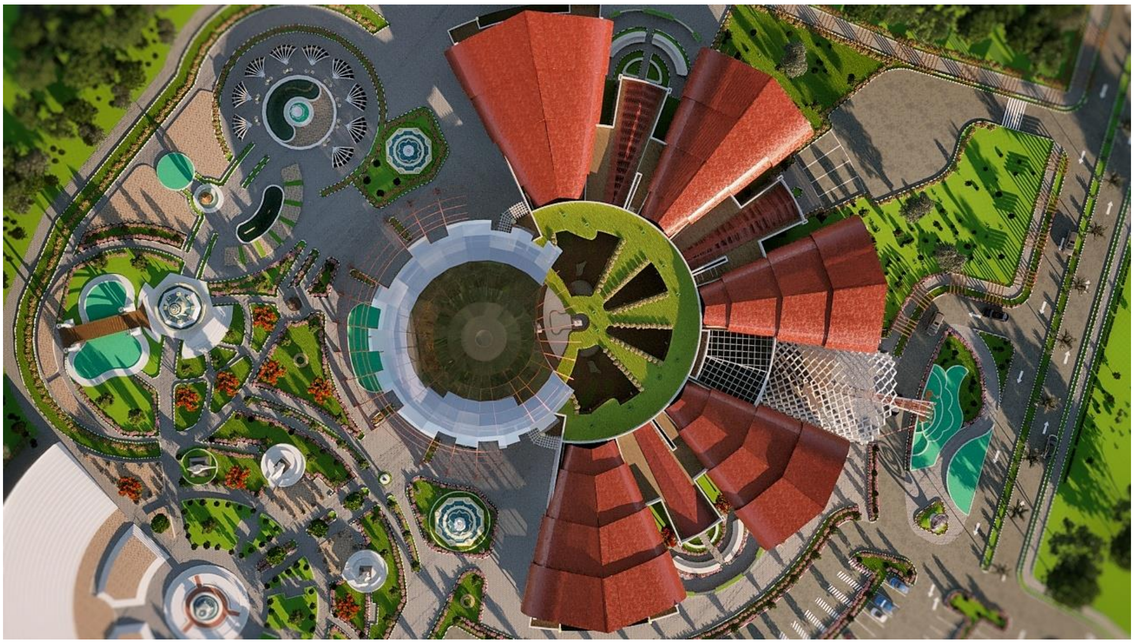

Figure 4.23: Trees, shrubs and water bodies located at the entrance to the site.
Source: Author's field work (2023)

Indoor plants and shrubs in courtyards, atrium and balconies were introduced to produce oxygenated air there by cooling the micro climate around them. To reduce direct ground heating, covered walkways were adopted with green plant climbers on the wooden members reducing the surface area of paved areas exposed to direct sunlight.

Figure 4.24: Covered walkways with shrubs and climbers on the wooden members.
Source: Author’s field work (2023)

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The emerging idea of power-efficient structures has focused many researchers to work towards the reduction of cooling load on the buildings by using cooling techniques. With the developing issues in respect to urbanisation, climate change, diminishing biodiversity, energy use and noise pollution, the need to look back and learn from nature cannot be overemphasized as it has in previous times given a solution to many problems enabling man to deal with these predicaments. In this thesis, different cooling techniques that would be incorporated within the building have been examined. Proper care should be taken for choosing the various cooling methods to be adopted as these cooling methods are climate-specific.

5.2 Recommendations

Envelope design is a one of major factors in determining the amount of energy a building will use in its operation, and decisions about its components play a crucial role in energy costs needed for cooling. Several cooling strategies were considered including insulation, solar shading and ventilation. Members of the design team should coordinate their efforts to integrate optimal design features for every building type to reach the lowest energy for realizing thermal comfort for its occupants, careful study is required to arrive at a building footprint, shape, form, and orientation that work with the building envelope components to maximize energy benefit, and to achieve energy savings. The thesis is highly recommending the proposed cooling performance design checklist to be used by architects for providing them with specific design strategies.

5.3 Contribution to Knowledge

This research evaluated various ways cooling affects the energy consumption in a public buildings and their performances as regards cooling applying it to the design and construction of a convention centre in Minna Niger State. This was achieved by examining existing buildings both in Nigeria and around the world. The survey carried out using an energy audit and an observation schedule which showed that 61.4% of the building being observed generally consumes more energy thereby increasing the energy demand in these buildings. 73.4% of the analysis is on the detriment when it comes to the considerations made for decreased energy use. The energy audit carried out also shows that the buildings cooling load consumes averagely 81.2% of the total energy used.

The major finding of the study is that cooling performance of a building, measured by an index ranging from 80% to 85%, is significantly influenced by pre- and post-design construction strategies. Application of diverse design principles for cooling systems in a specific way is required, without ignoring performance concerns, as is the case with solar cooling and low-energy active technologies. In order to encourage widespread use of accessible guidelines for these systems by architects and construction experts. When planning and developing a convention centre, natural cooling strategies including soft landscaping, proper ventilation, a cool building envelope, the structure's shape, and orientation should all be taken into account. Incorporating all these methods, and utilizing low-energy cooling equipment in public buildings at a rate of 60% or more. The performance restrictions of passive techniques in hot regions, the utilization of renewable energy sources for cooling, or the energy effectiveness of low-energy active systems should all be taken into account.

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APPENDICES

Appendix A: Observation schedule on Evaluation of the Cooling Performance in the Design of a Convention Centre in Minna, Niger State Nigeria:

This section is to be filled by the researcher

PART A: PERSONAL DATA

1. Name of building ____
2. Number of floors (1) One story (2) Two story (3) Three story (4) Others

S/N	SPACES	LOCATION	SIZES	NOS
1	Mini conference hall			
2	Conference hall			
3	Kitchen			
4	Reception area			
5	Entrance			
6	General offices			
7	Video conference hall			
8	Multipurpose hall			
9	Convention hall			
10	Lobby			
11	Waiting area			
12	Banquet hall			
13	Exhibition hall			
14	Entrance lobby			

PART B: COOLING STRATEGIES IN COVENTION CENTRE

15. Method of cooling	(1) Mechanical (2) Natural (3) Both
16. Type of openings	(1) Atrium (2) Courtyard (3) Windows
17. Type of ventilation system	(1) Fans (2) AC (3) Air vent (4) Windows
18. Location of windows	(1) N-S (2) E-W (3) NE-SW(4) NW-SE
19. Use of water bodies	Yes/No
20. Use of soft landscape	Yes/No
21. Use of hard landscape	Yes/No
22. Use of indoor plants	Yes/No
23. Provision of buffer zones	Yes/No
24. Double banking of spaces	Yes/No
25. Use of insulating materials	Yes/No

ARCHITECTURAL DESIGN CONSIDERATION USED FOR COOLING

26. Building orientation	(1) N-S (2) E-W (3) NE-SW (4) NW-SE
27. Provision of sun shading devices	Yes/No
28. Type of shading devices	(1) Vertical (2) Horizontal (3) Both
29. Type of Vegetation	(1) Trees (2) shrubs (3) grasses (4) climbers
30. Type of Evaporative cooling	(1) Natural (2) Artificial (3) Both
31. Head rooms within spaces	(1) 3-4m (2) 4-5m (3) 5-6m (4) 6m and above
32. Provision of recesses	Yes/No
33. Glazing method	(1)Dry Glazed (2) Wet Glazed (3) Cable Net (4) Pointed Support Glass Systems (5) Double Skin Wall

34. Building material

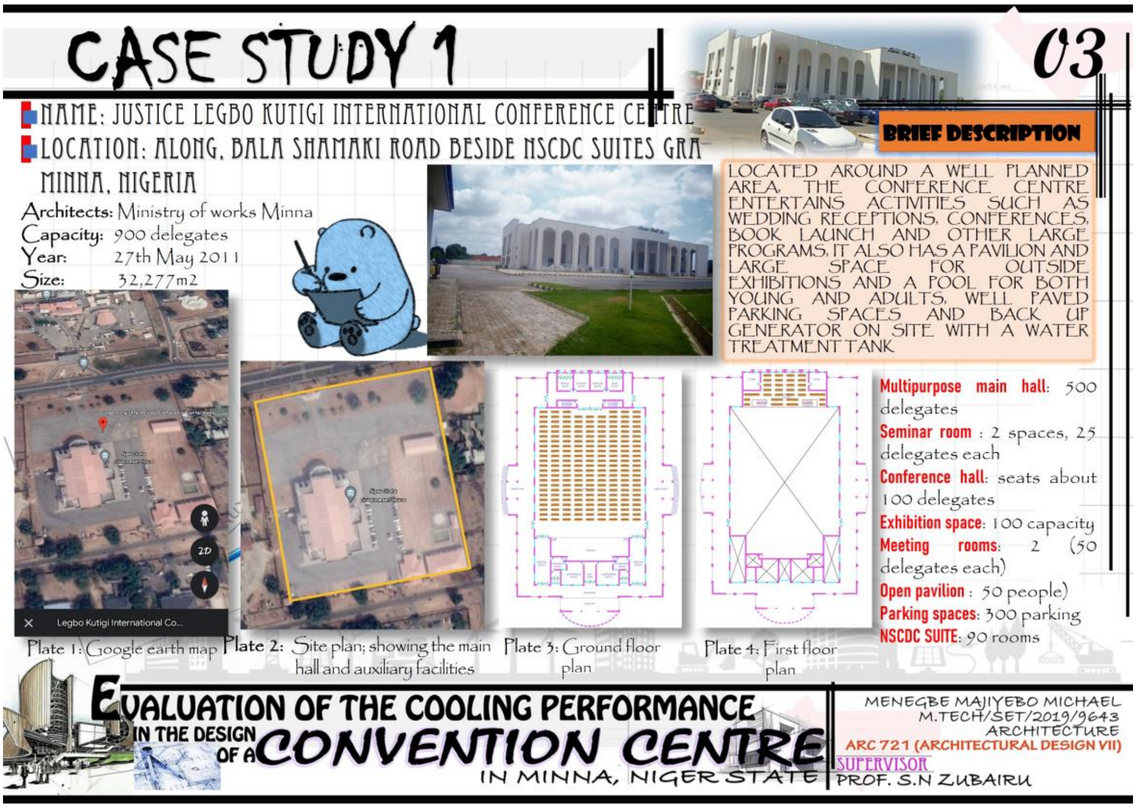
S/N	BUILDING COMPONENT	MATERIALS																	
		GLASS	BRICK	STONE	BLOCK WALL	CEMENT-SCREED	CERAMIC TILES	TERRAZO	MOSAIC	CEMENT + RUG	CEMENT + CARPET	ASBETOS	WOOD PANEL	PVC	POP	THATH	ZINC	ALUMINIUM (LONG SPAN)	CONCRETE
1	WALL																		
2	FLOOR																		
3	CEILING																		
4	ROOF																		

PART C: PART C; ENERGY CONSUMPTION IN CONFERENCE CENTRE.

1. ENERGY CONSUMING EQUIPMENT/FACILITIES

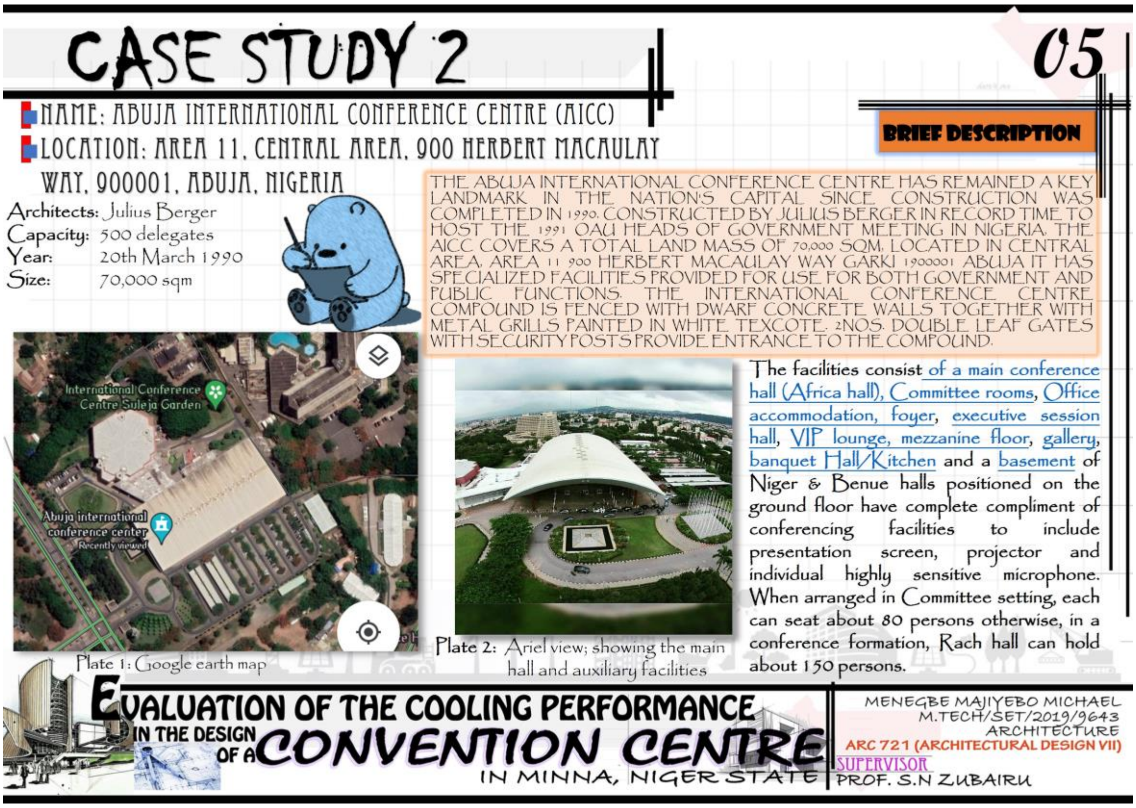
Equipment	Number Available (No.)	Capacity (kW)	Average time of usage/day (h)	Electricity Consumption (kW/h)

Appendix B: Case Study 1 (sheet 1)

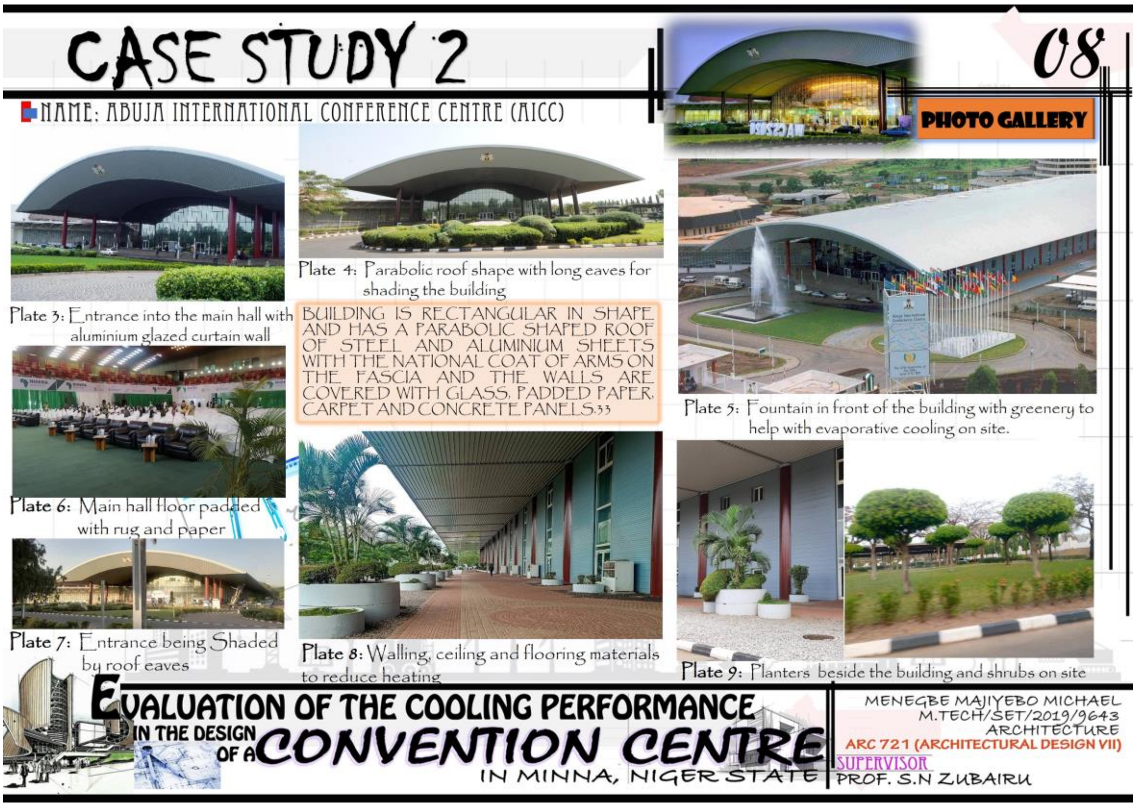


Appendix C: Case Study 1 (sheet 2)

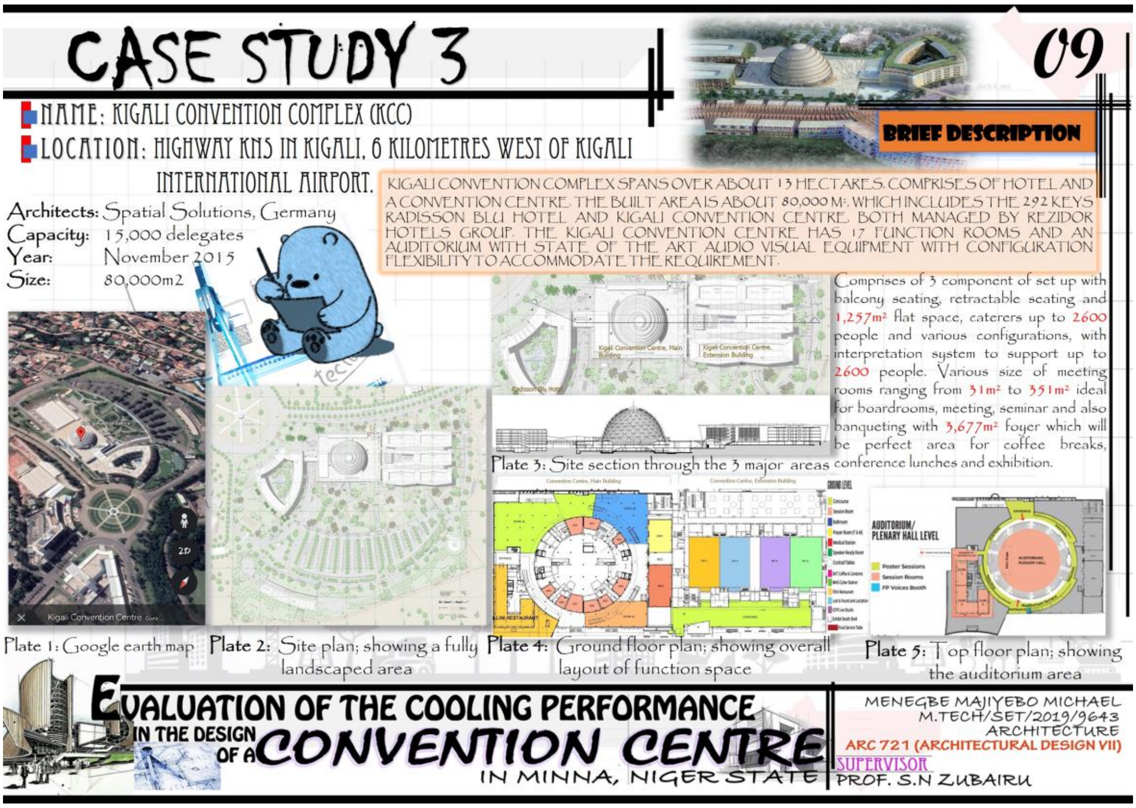
Appendix D: Case Study 2 (sheet 1)



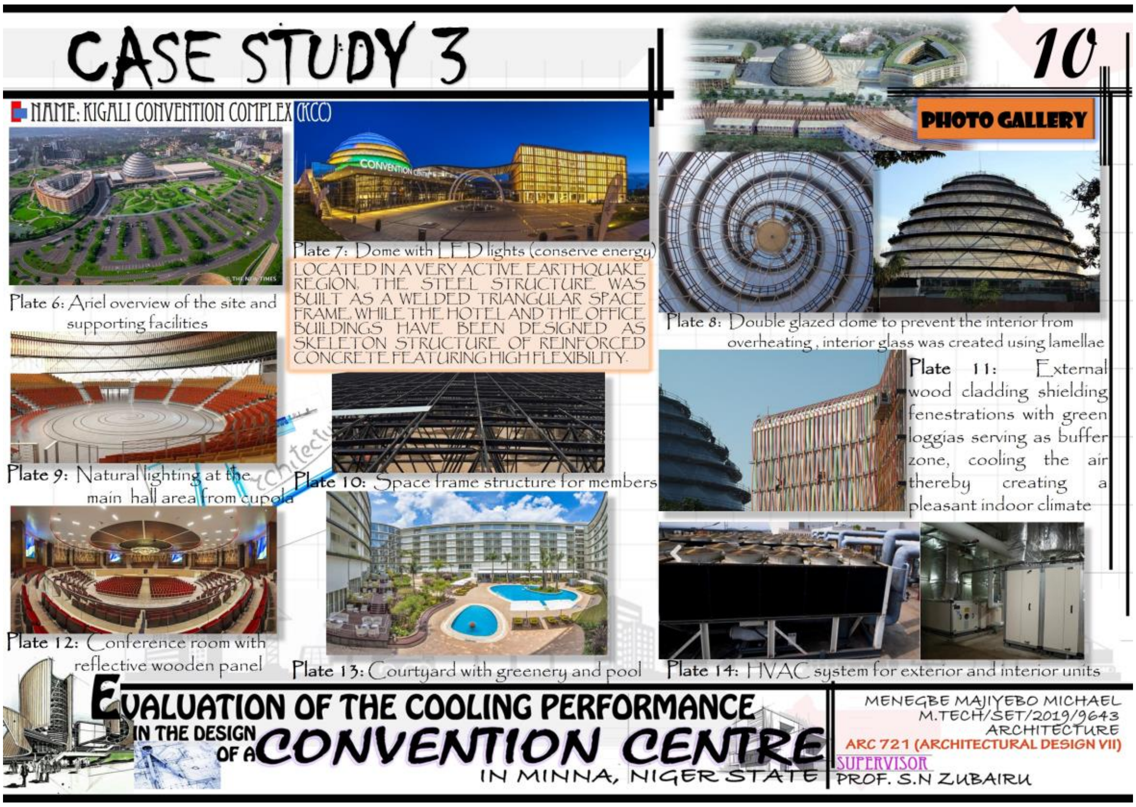
Appendix E: Case Study 2 (sheet 2)



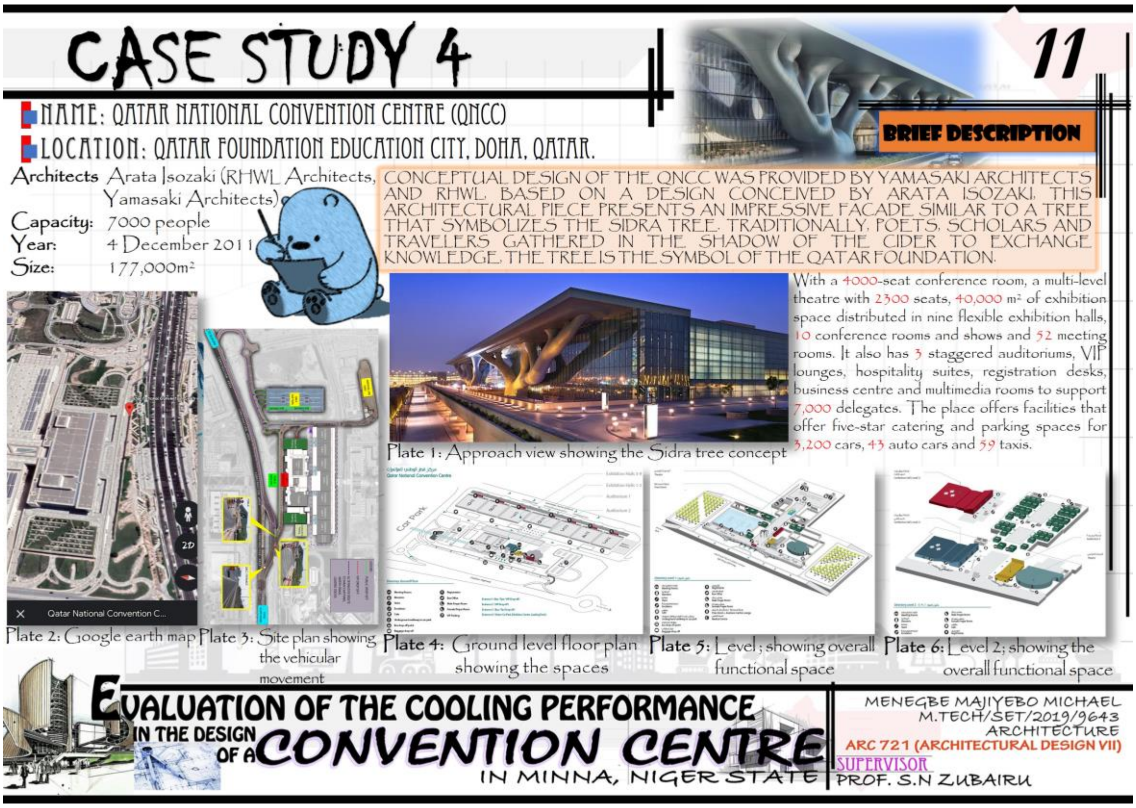
Appendix F: Case Study 3 (sheet 1)



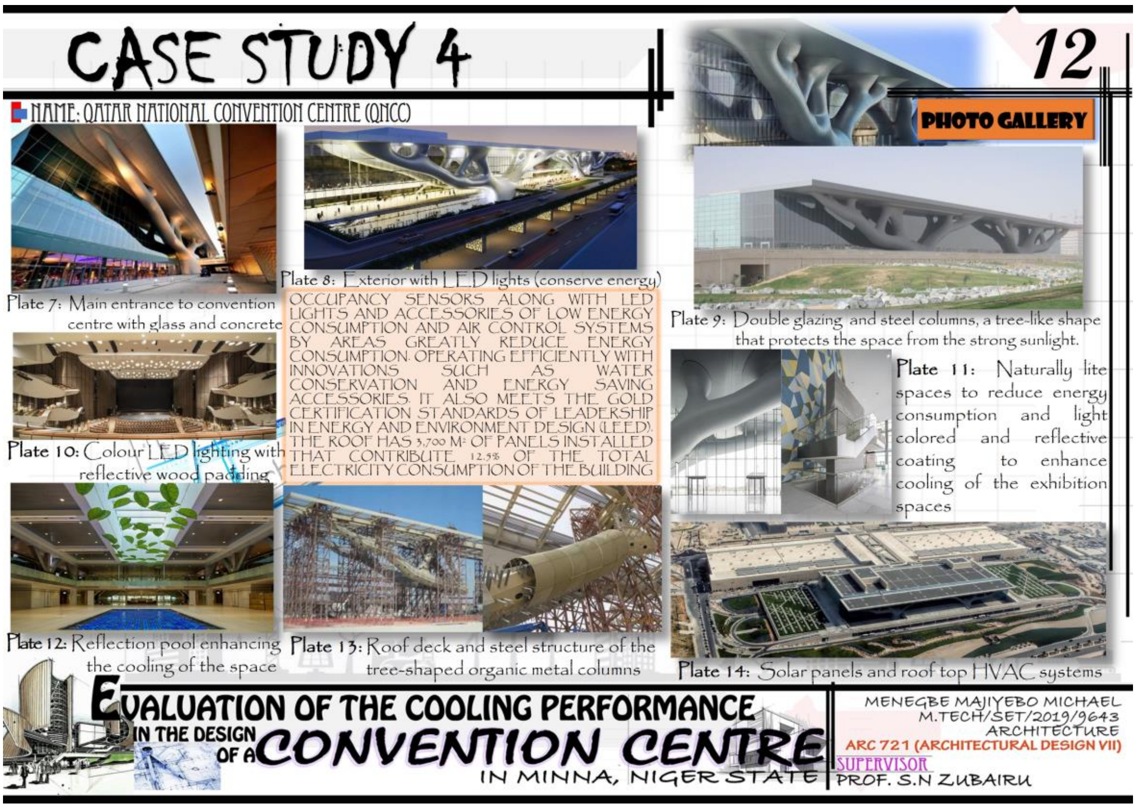
Appendix G: Case Study 3 (sheet 2)



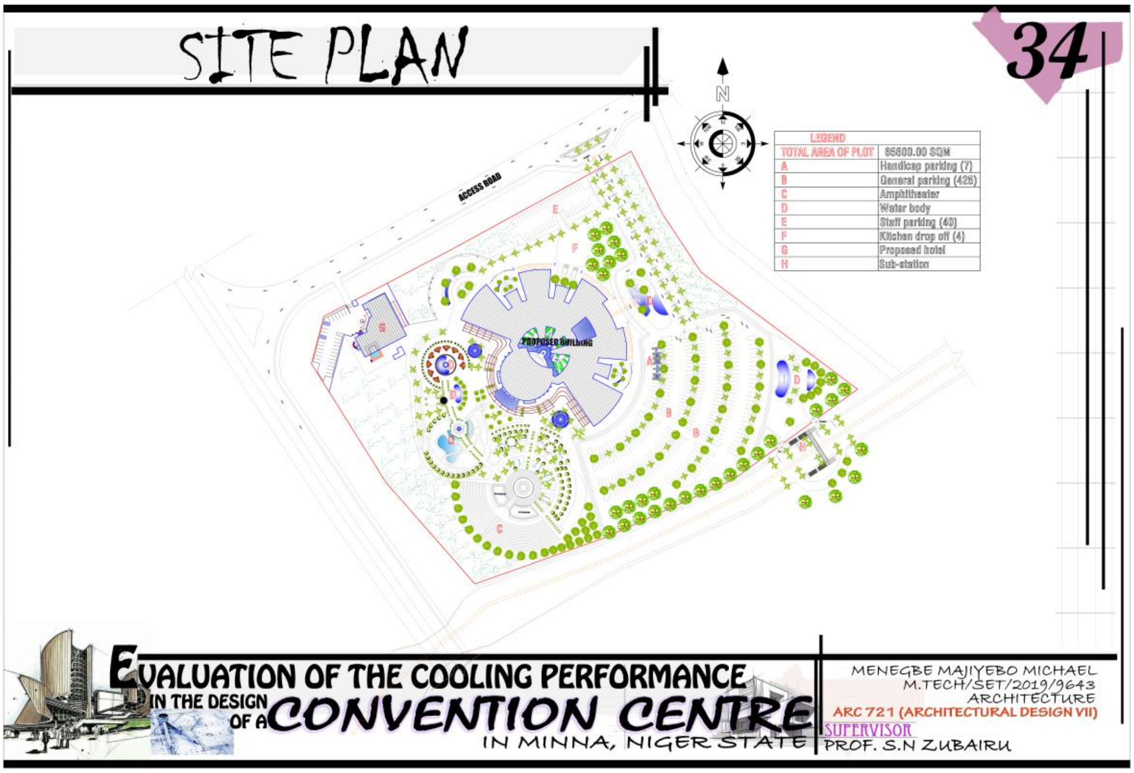
Appendix H: Case Study 4 (sheet 1)



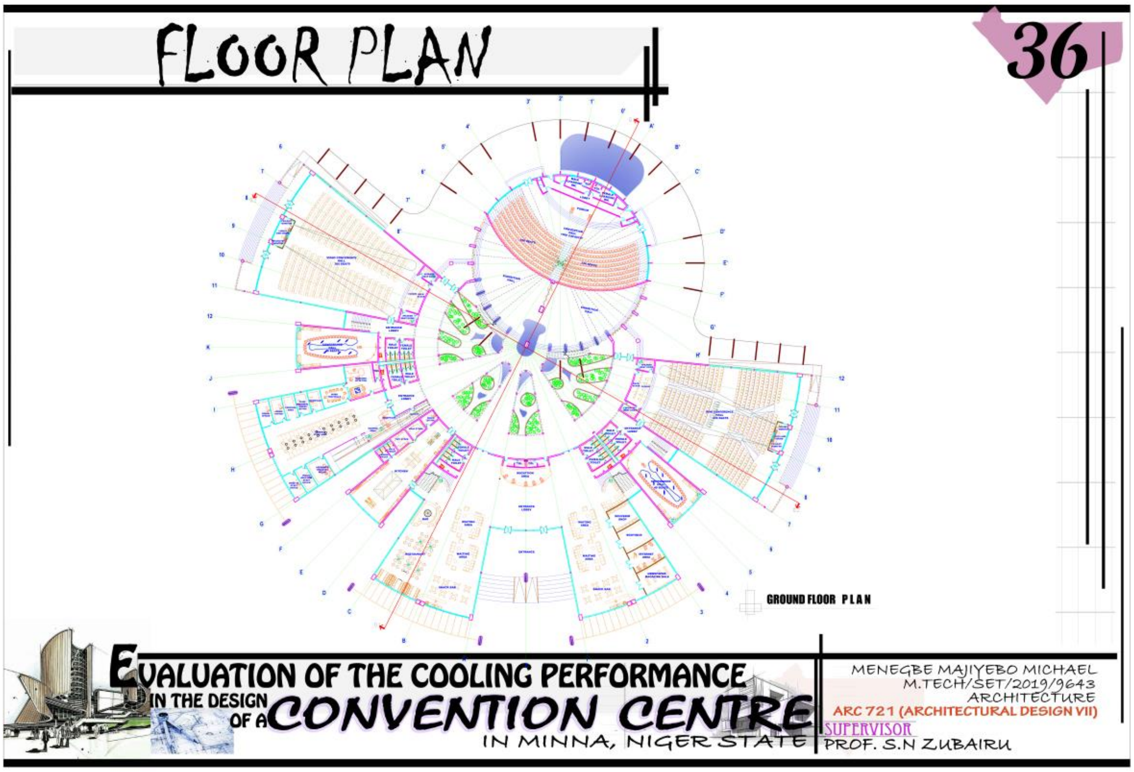
Appendix I: Case Study 4 (sheet 2)



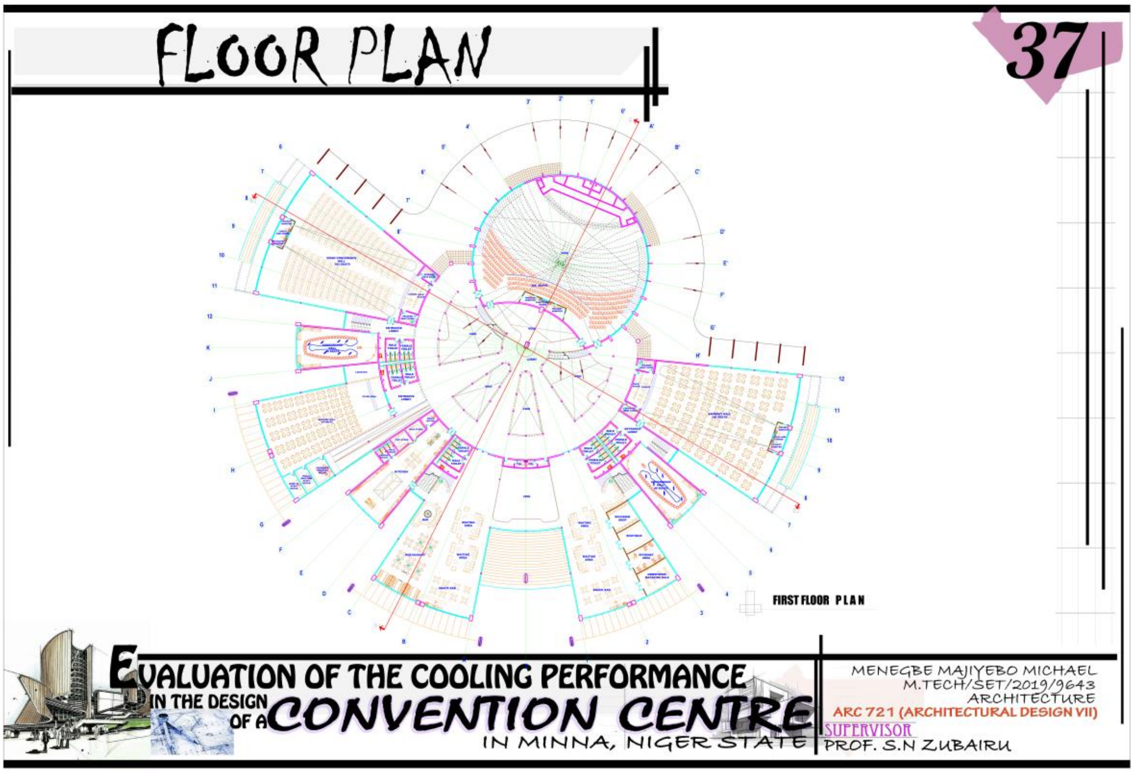
Appendix J: Site Plan



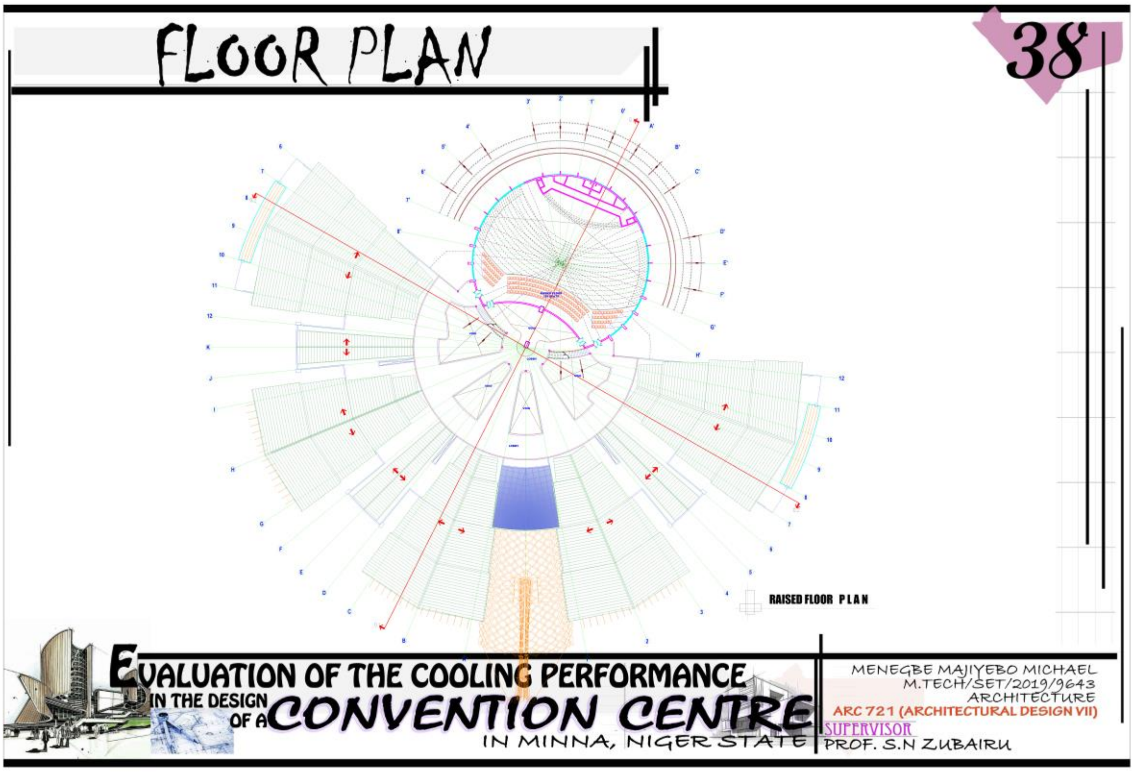
Appendix K: Floor Plan (ground floor)



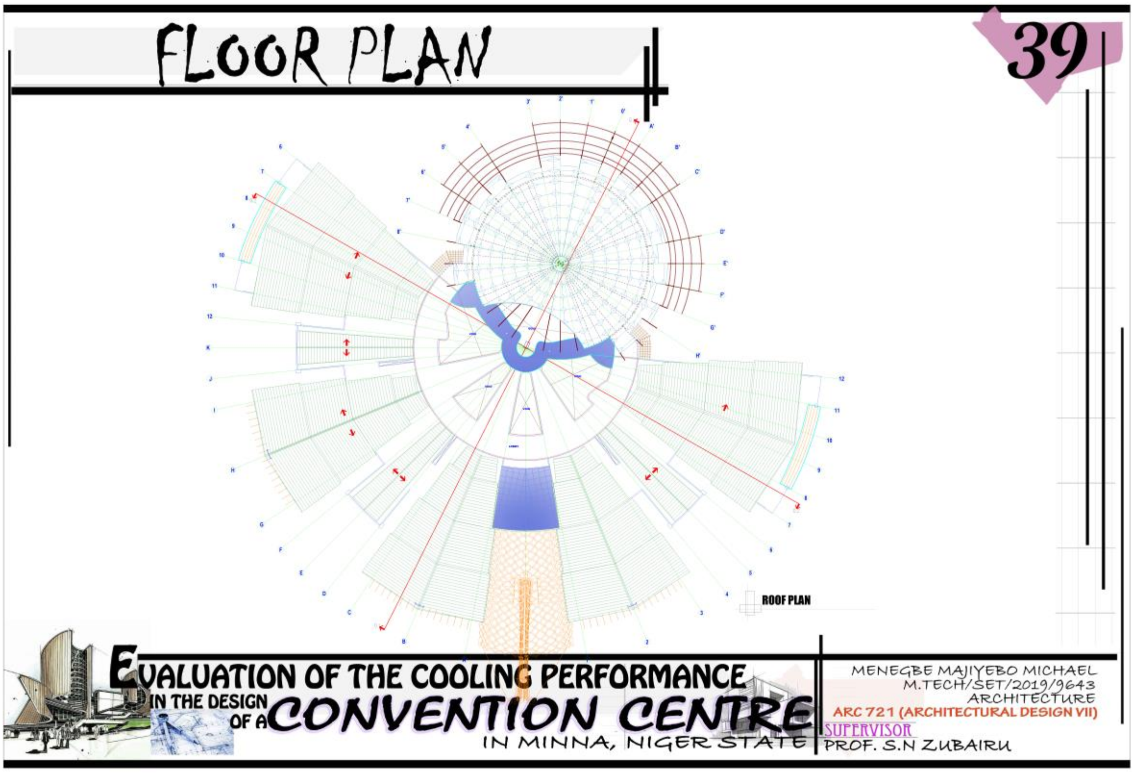
Appendix L: Floor Plan (first floor)



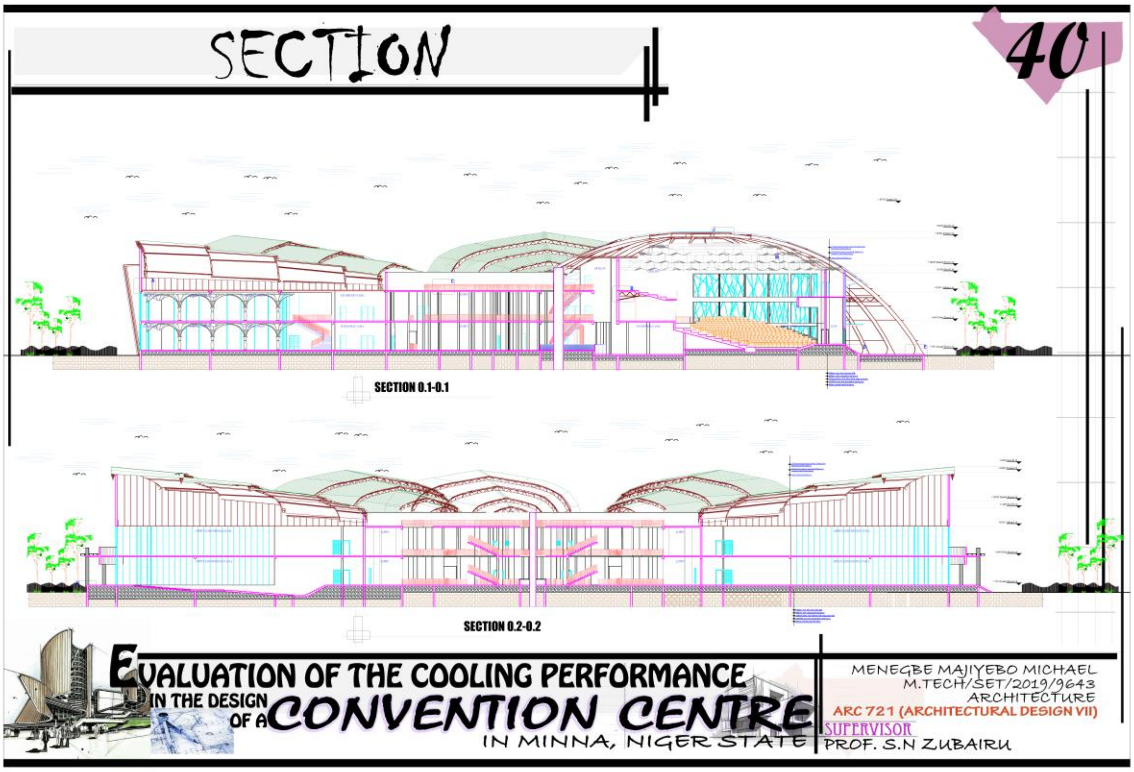
Appendix M: Floor Plan (raised floor)



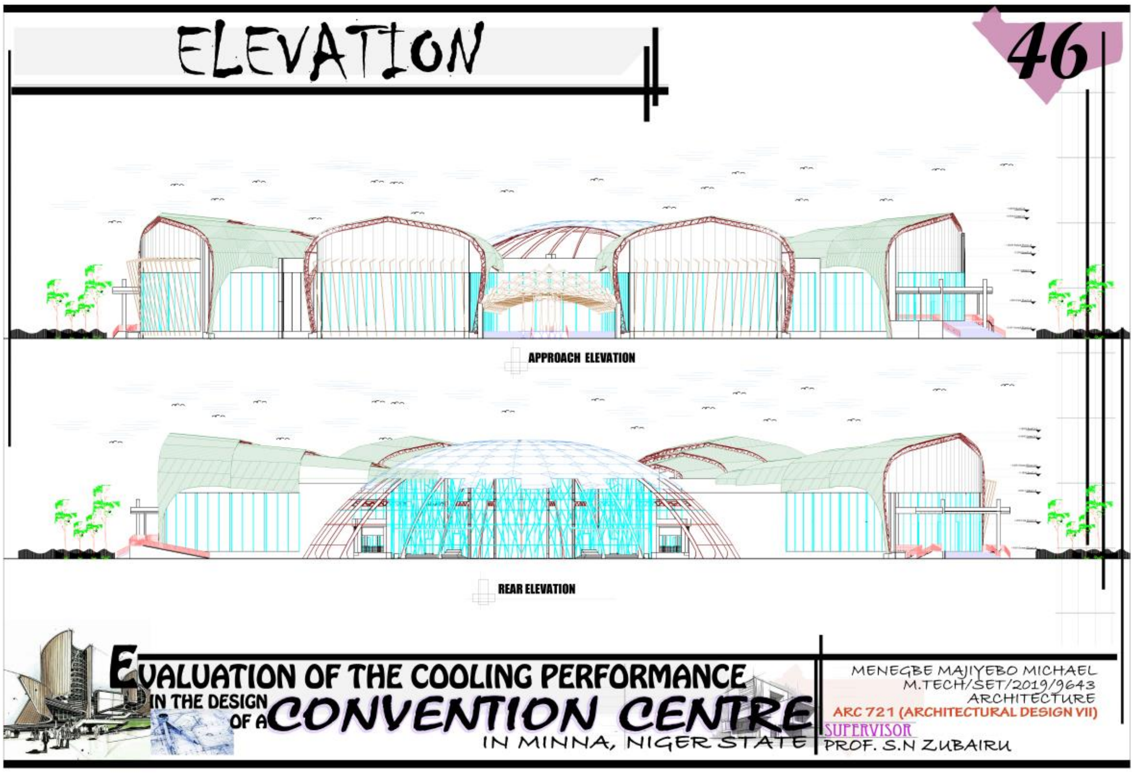
Appendix N: Roof Plan



Appendix O: Sections



Appendix P: Elevations



Appendix Q: Elevations

Appendix R: **Perspectives (Sheet 1)**

Appendix S: **Perspectives (Sheet 2)**