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Evaluation of the Cooling Performance in Convention Centres; Thus Reducing Energy Demand in Buildings in Nigeria

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Abstract

A lingering energy demand in buildings has become a difficult issue 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 been concerned about keeping the space warm, whilst countries with high temperatures are worried about keeping their spaces cooler. With exceptional increase in the utilization of artificial cooling mechanisms such as; air conditioning system, air coolers and fans for cooling in buildings. Increased energy consumption being 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; thus reducing energy demand in buildings in Nigeria, with a hypothesis placed 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 research therefore embarked upon an empirical study of a convention centre in Minna Niger state with the view to explore the challenges of energy use with its antecedent challenges of both the building owners and the users, using qualitative research approach. This entail 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 (Air-Conditioning (A/C), Air handling units, Ceiling fans) which requires a power source, creating adverse effect on the environment by increasing energy used by these buildings, The research recommends that in designing for convention centres, the use

of natural cooling methods and practices in buildings is least expensive, and it would mainly depend on interaction of building and its surrounding thereby reducing energy demand in buildings.

***Keywords**: Cooling Performance, Energy Demand, Environment*

Introduction

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. Very large venues, suitable for major trade shows which are sometimes known as exhibition centres (Gentry, 2000) stated the advantages of this type of development as its being convenient and a comfortable provision of a live-play-work and retail/commercial environment.

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.

Buildings are one of the biggest energy consumption tool in the world, accounting for onequarter to one-third of all energy use and a similar amount of greenhouse gas emission (UN Habitat, 2014). 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 (Griffith *et al*., 2007). However in Minna, Nigeria large buildings mainly rely on mechanical means of cooling based on the nature of their climate, therefore the need to proffer architectural solution in reducing or eliminating this trend. The study seeks to explore the cooling requirements of convention centres and 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.

LITERATURE REVIEW

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)

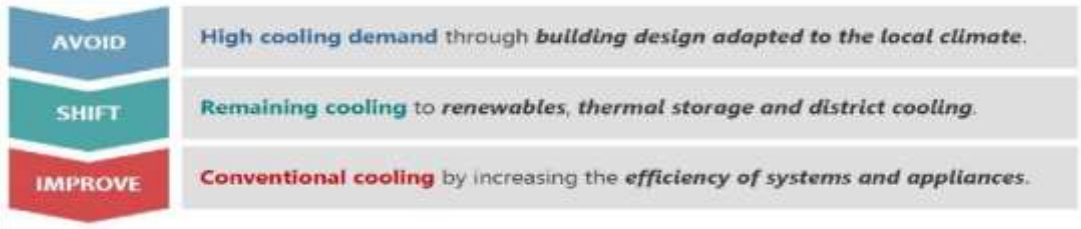


Figure 2.1. Steps for low carbon buildings
Source: PEEB. (2019). Based on: Kovacic and Zoller (2015)

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.

According to the International Energy Outlook 2016 (IEO2016) 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 OECD (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.

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).

Wind-driven cross ventilation

This 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. 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 Fig. 2.2)

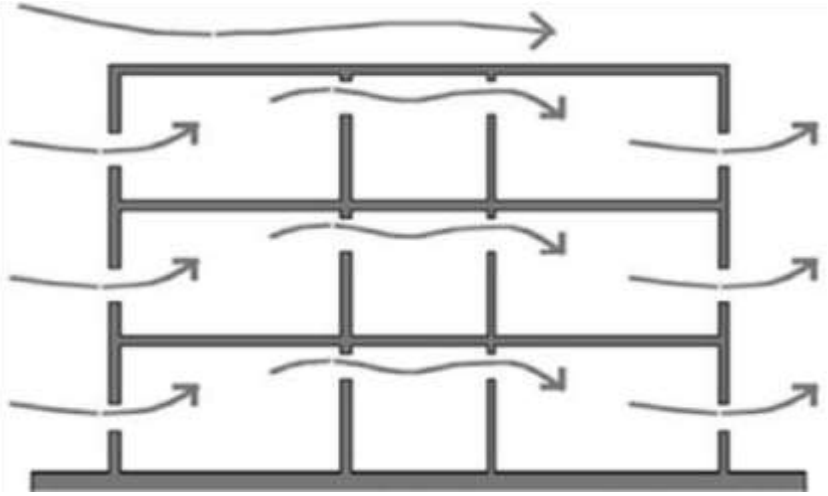


Figure 2.2. The line diagram of wind driven cross-ventilation
Source: Chetan *et al.,* (2020).

Evaporative Cooling

Evaporative cooling is a method that employs the outcome of evaporation as the natural heat dissipater. 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. (Ananda *et al.,* 2021).

Evaporative cooling air conditioning systems use the cooling of the evaporation of liquid water to cool an airstream directly or indirectly. This 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 2.3.

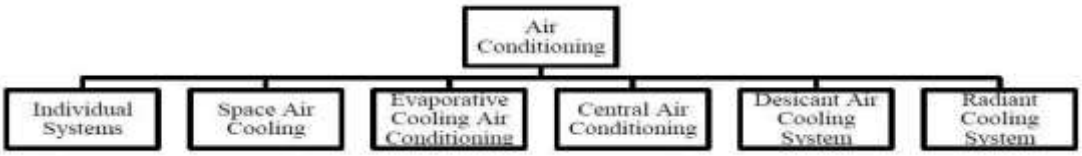


Figure 2.3. Categorization of air-conditioning systems
Source: Ananda *et al.* (2021).

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).

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).

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).

Glazing.

Making usage of double glazing (Figure 2.4) increases the rate of flow to 11-17 percent. 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.

Below is Fig. 2.4 with various glazing methods.

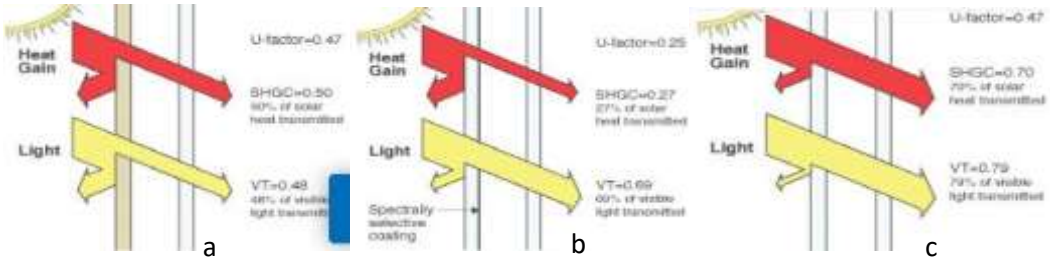


Figure 2.4. a. Double glazing with bronze tint, b. Low solar gain low-E double glazing c. Clear double glazing Source: Ananda *et al.*, (2021).

Walling and Roofing Material.

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, while in dry climates, reverse is the case. (Kovacic and Zoller. 2015).

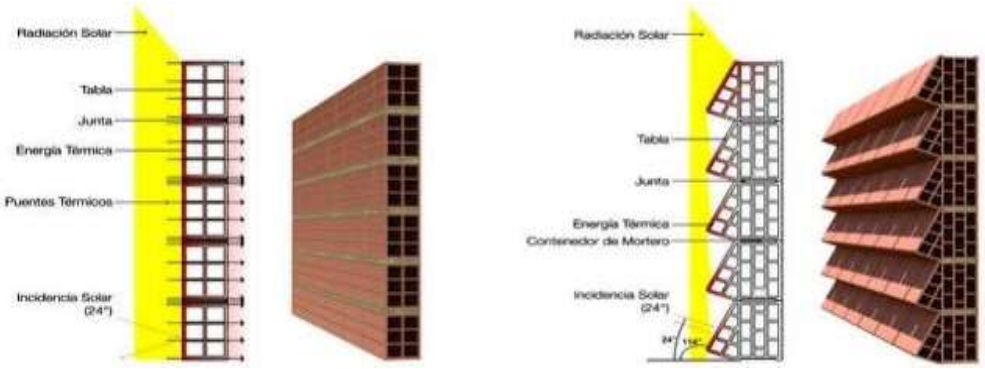


Figure 2.5. Bricks at an angle reducing the area exposed to solar radiation Source: Chetan *et al.*, (2020).

Additionally, the aluminium fins and capillary tubes were used incorporation with the thermal mass for increasing the process of heat transfer. Insulated roofs also referred to as cool roofs are designed to reflect more sunlight and absorb less heat than a standard roof.

(See Fig. 2.6)

Figure 2.6. Showing Cool roof mechanism and Cool dark colour roofs
Source: American roof tile coatings (2020)

Shading.

For reducing a direct gain of solar radiation shading is used, it is an effective technique. 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. (See Fig 2.7)

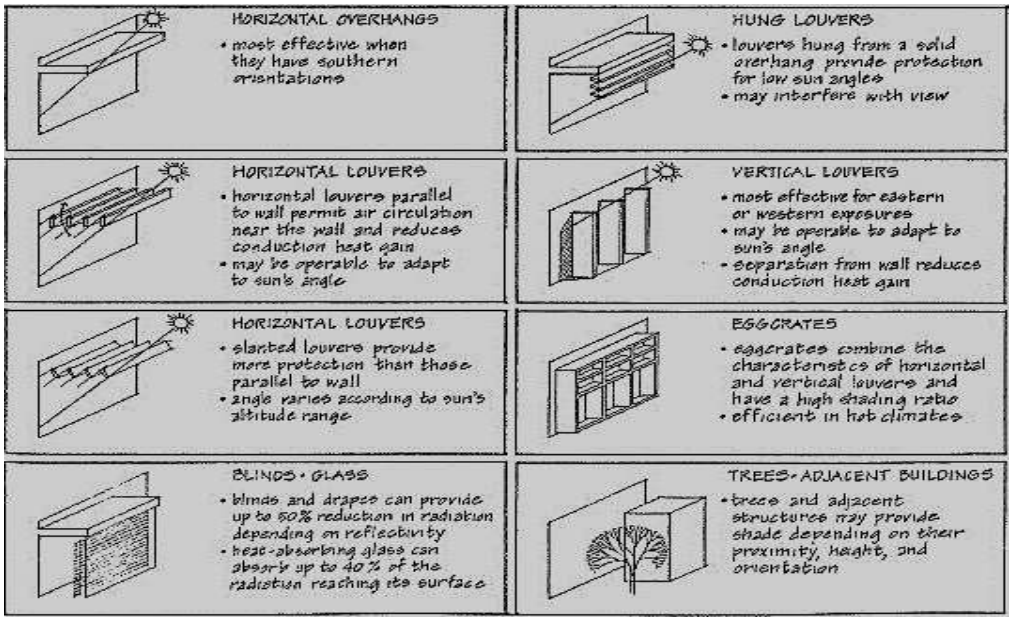


Figure 2.7. The various forms of shading devices

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

Figure 2.7 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 (2019).

Orientation and Site Adaptation Orientation

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. Fig 2.5 shows how building should be placed.

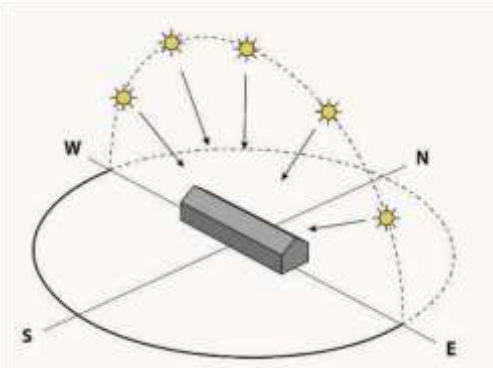


Figure 2.8. Orientation according to the sun
Source: PEEB. (2019). Based on: Kovacic and Zoller (2015)

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). Simpson and Macpherson (2003) have shown that tree shades can reduce annual energy for cooling by 10% -50%.

METHODOLOGY

Qualitative research method was mainly used in this study; involving a descriptive research employed as a scientific method that is used to observe and describing the nature of a subject. A desk study was done on relevant materials related to cooling performance with focus on reducing energy demand in buildings especially convention centres. Case studies were latter carried out as a primary source of data collection method, were relevant information was obtained through physical observation. An observation guide was developed by the researcher, aiding the researcher collect relevant information for analysis with the needed parameters and factors to observe and record. Table 3.1 outlines the parameter that were observed

Table 3.1. Checklist for observation and assessing sampled convention centres
Source: Author's field work

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 Using non-random sampling techniques specific samples relevant to the study were selected to be subjected to observation by the researcher in view of the drafted observation schedule, in order to gather information relevant to the study. The following are listed samples (convention centres) selected to be observed as shown in table 3.2.

Table 3.2: List of Samples
Source: Author's field work

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	Calabar International Convention Centre (CICC)	Calabar, Akwaibom State Nigeria	August 2015
4	Kigali Convention Complex (KCC)	Kigali Rwanda	November 2015
5	Qatar National Convention Centre (QNCC)	Doha, Qatar.	December 2011

DATA ANALYSIS

Due to the qualitative nature of this research, data gotten have been analysed using qualitative data analysis principles. The data gotten by the researcher using the observation guide was analysed using the Microsoft excel software. Afterwards, the results were presented using plates and figures.

Ventilation (cross/ one sided)

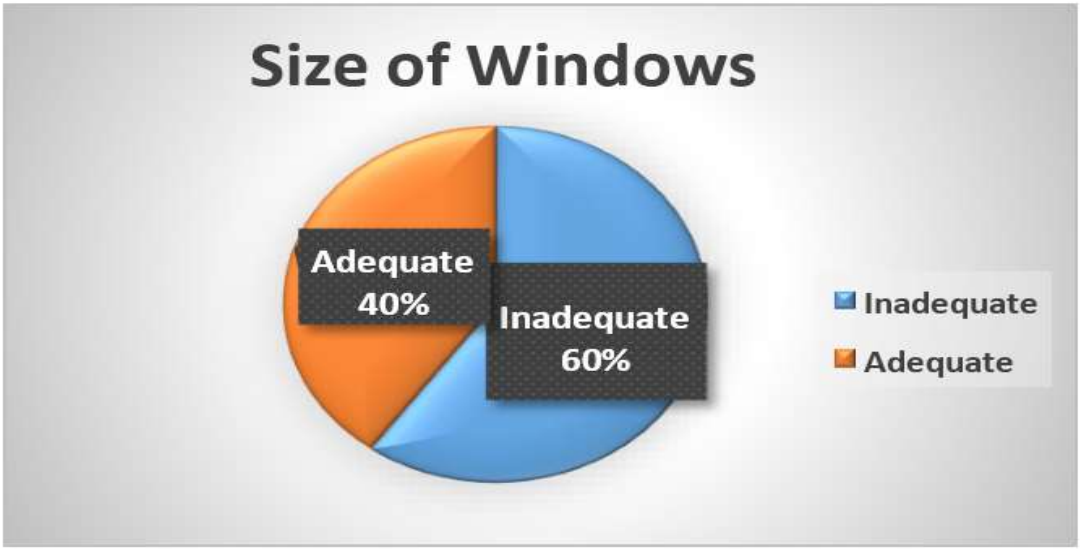
i. Size and location

Size and location of windows in various spaces aid proper ventilation and increase the airflow, adequate window sizes and 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% has adequate and large openings (windows) with their location and 40% don't have. (See fig.4.1 and 4.2)

Table 4.1: Size of Windows
Source: Author's field work

Samples	Adequate	Inadequate
Justice Legbo Kutigi International Conference Centre		□
Abuja International Conference Centre (AICC)	□	
Calabar International Convention Centre (CICC)		□
Kigali Convention Complex (KCC)	□	
Qatar National Convention Centre (QNCC)		□



Source: Author's field work

Table 4.2: Location of Windows
Source: Author's field work

Samples	Adequate	Inadequate
Justice Legbo Kutigi International Conference Centre	□	
Abuja International Conference Centre (AICC)	□	
Calabar International Convention Centre (CICC)		□
Kigali Convention Complex (KCC)	□	
Qatar National Convention Centre (QNCC)		□

Source: Author's field work

ii. 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 100% engage shading practices and 0% don't practice. (See fig.4.3)

Table 4.3: Shading Devices

Source: Author's field work

Samples	Adequate	Inadequate
Justice Legbo Kutigi International Conference Centre	□	
Abuja International Conference Centre (AICC)	□	
Calabar International Convention Centre (CICC)	□	
Kigali Convention Complex (KCC)	□	
Qatar National Convention Centre (QNCC)	□	

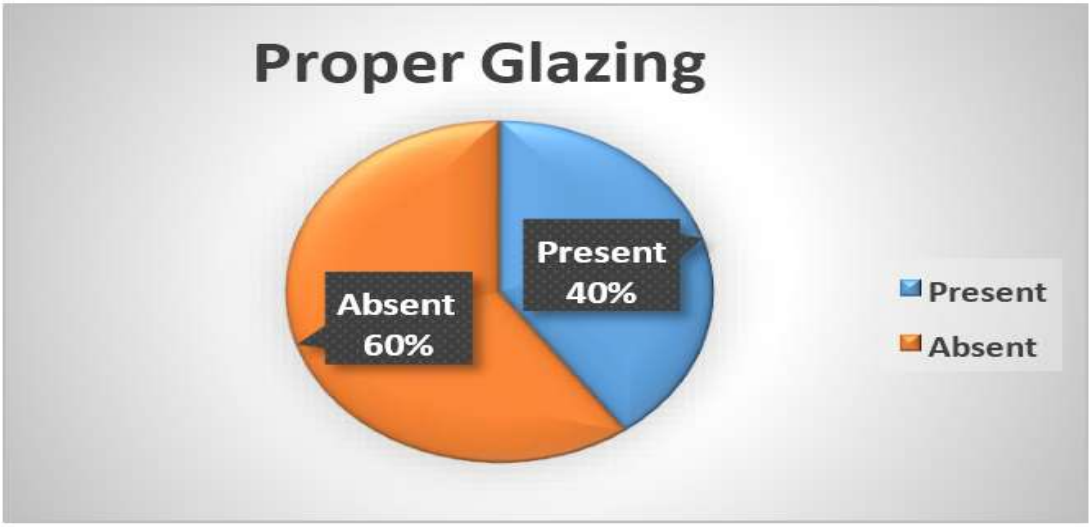
Source: Author's field work

iii. Proper Glazing

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 40% has proper glazing systems and 60% don't not have. (See fig.4.4)

Table 4.4: Proper Glazing
Source: Author's field work

Samples	Present	Absent
Justice Legbo Kutigi International Conference Centre		□
Abuja International Conference Centre (AICC)		□
Calabar International Convention Centre (CICC)		□
Kigali Convention Complex (KCC)	□	
Qatar National Convention Centre (QNCC)	□	



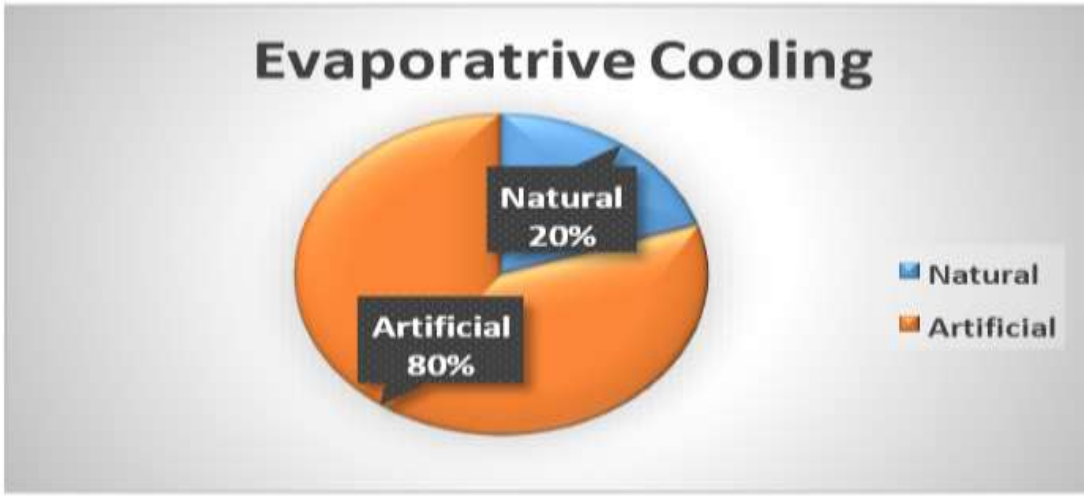
Source: Author's field work

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 natural means and 80% uses artificial mode (air conditioning systems). (See fig.4.5) Table 4.5: Evaporative Cooling (natural/ artificial)

Source: Author's field work

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



Source: Author's field work

Building envelope

i. Provide construction and insulating materials to resist heat transfer

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. The buildings observed shows that 60% considered various insulation and construction materials and 40% were not adequately considered. (See fig.4.6)

Table 4.6: Construction and Insulation

Source: Author's field work

Samples	Adequate	Inadequate
Justice Legbo Kutigi International Conference Centre		□
Abuja International Conference Centre (AICC)		□
Calabar International Convention Centre (CICC)	□	
Kigali Convention Complex (KCC)	□	

Qatar National Convention Centre (QNCC)	□

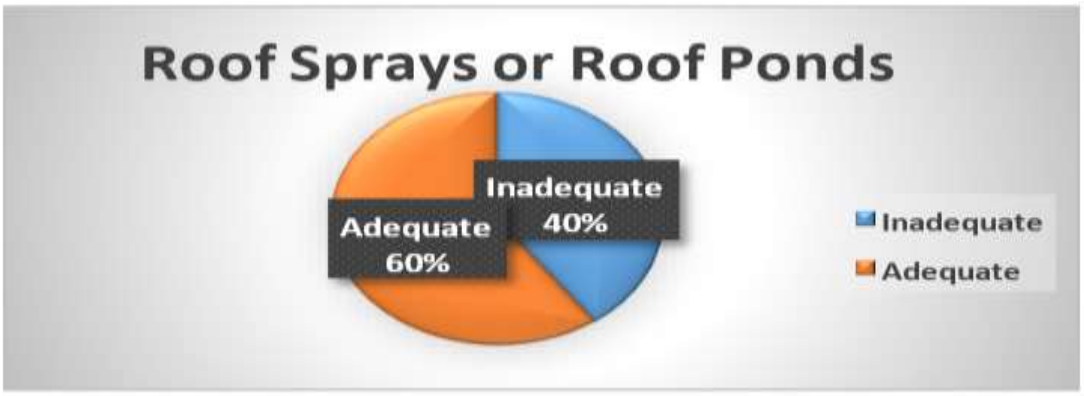
Source: Author's field work

ii. Use roof spray or roof ponds for evaporative cooling to reduce heat gain

Building roofs and roof slabs of adequate thermal resistance is essential to provide human comfort and energy efficiency. Insulating roofs through roof spray or roof ponds, are very beneficial for energy saving and efficiency. The buildings observed shows that 40% considered use of roof spray, cool roofs and roof ponds and 60% were not adequately considered. (See fig.4.6)

Table 4.6: Roof Sprays or Roof Ponds
Source: Author's field work

Samples	Adequate	Inadequate
Justice Legbo Kutigi International Conference Centre		□
Abuja International Conference Centre (AICC)		□
Calabar International Convention Centre (CICC)	□	
Kigali Convention Complex (KCC)	□	
Qatar National Convention Centre (QNCC)	□	



Source: Author's field work

Building orientation and Site Adaptation

i. Control Shape, Form and 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. 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 also energy consumption of rectangular shaped building form is % 9-10 less than the energy consumption of L shaped building form. The buildings observed shows that 80% building orientation shape and form were good and 20% were poorly oriented. (See fig.4.7)

Table 4.7: Control Shape, Form and Orientation Source: Author's field work

Samples	Good	Poor
Justice Legbo Kutigi International Conference Centre		□
Abuja International Conference Centre (AICC)	□	
Calabar International Convention Centre (CICC)	□	
Kigali Convention Complex (KCC)	□	
Qatar National Convention Centre (QNCC)	□	

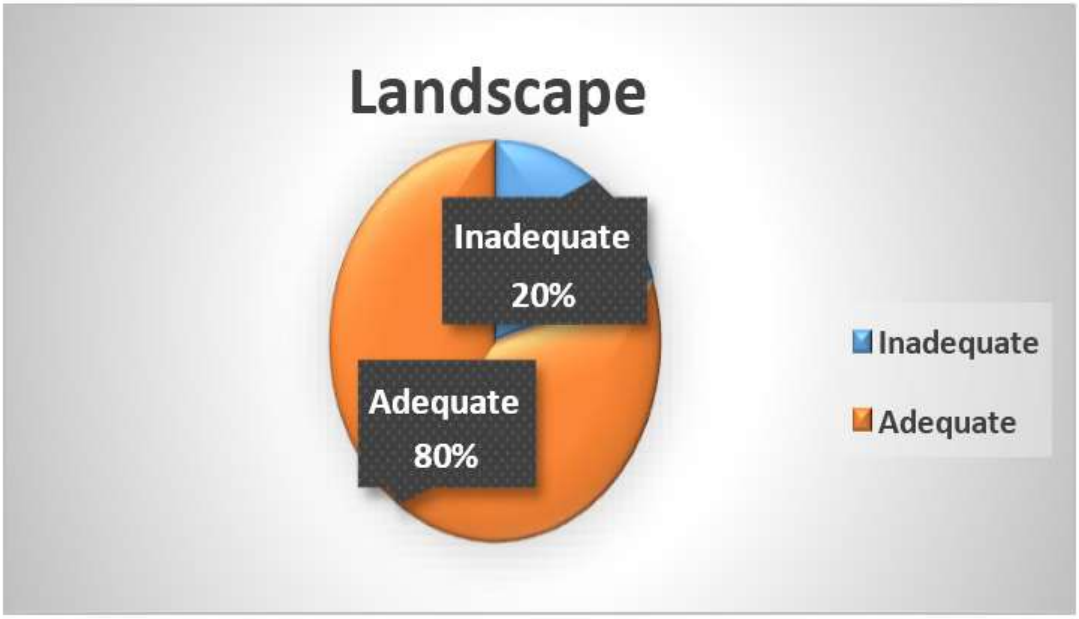
Source: Author's field work

ii. Coordinate with existing, new landscape and other elements

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. The buildings observed shows that 80% considered existing, new landscape and other elements and 20% did not. (See fig.4.8)

Table 4.8: Landscape
Source: Author's field work

Samples	Adequate	Inadequate
Justice Legbo Kutigi International Conference Centre		□
Abuja International Conference Centre (AICC)	□	
Calabar International Convention Centre (CICC)	□	
Kigali Convention Complex (KCC)	□	
Qatar National Convention Centre (QNCC)	□	



Source: Author's field work

iii. Reduced paved areas to lessen heat build-up around the building

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 fig.4.9)

Table 4.9: Landscape
Source: Author's field work

Samples	**Adequate**	**Inadequate**
Justice Legbo Kutigi International Conference Centre		□
Abuja International Conference Centre (AICC)	□	
Calabar International Convention Centre (CICC)	□	
Kigali Convention Complex (KCC)	□	
Qatar National Convention Centre (QNCC)	□	

Source: Author's field work

SUMMARY OF ANALYSIS AND FINDINGS

From the analysis carried out it is seen that most of the buildings 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. In the following, we investigate the advantages and shortcomings of different strategies depending on the local condition, table 4.10 shows comparison between these cooling methods.

Table 4.10 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)

CONCLUSION AND RECOMMENDATION

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. In this particular paper, different cooling techniques that may be put on to 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. The climate at different locations

will be varying like Dry, Hot, Warm, Sunny, Cold, and Humid conditions. Envelope design is a major factor 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. 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, and 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 paper is highly recommending the proposed cooling performance design checklist to be used by the architects for providing them with the principles and design strategies.

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