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Optimizing Energy Efficiency of Office Buildings in Tropical Composite Climatic Belt of Abuja, Nigeria

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Abstract

The reduction of energy use in the built environment via optimizing building energy efficiency is a strategic research challenge. The aim of this study is to reduce energy for cooling in office buildings using passive cooling strategies and at the same time putting thermal comfort into consideration. This was achieved through evaluating the cooling energy consumption demand of some selected office buildings in tropical composite climatic belt of Nigeria. Energy Use Intensity (EUI) of the buildings was measured against bench marks developed in South Africa. A mixed method approach was used to achieve the research aim. These methods include physical observation and computer based simulation. A case study selection criteria was developed for the purposive selection of cases. Three buildings were purposively selected namely: Rachel court, Capital centrum and Rivers house offices respectively. Simulation results predicts that despite the usage of certain passive strategies for cooling on the buildings such as: solar shading devices, building orientation, air and moisture tightness and low window to wall area ratio, they still exhibit high energy demand in cooling the buildings. More also, the result shows that yearly, indoor comfort temperatures were achieved for a maximum of 20%, 7% and 18% respectively for the cases within the period of occupancy. This suggests an inevitable use of other cooling approaches including Heating Ventilation and Air Condition (HVAC) systems. Furthermore, the EUI was measured to be 207.9 kwh/ m²/yr, *468.2*kwh/ m²/yr *and 219.7*kwh/ m²/yr *for the three cases respectively. An enhanced passive cooling strategy for the three cases demonstrated a significant reduction of 19.1%, 27.6% and 19.5% respectively in energy consumption. The study concludes that the optimized energy method could become more strategic for applicability inexisting buildings that already have high performance building systems, where other improvement interventions are not passively energy efficient.*

Keywords: *Energy efficiency, Mixed Method, Passive Cooling Strategies, Nigeria, Office Buildings*

1.0 INTRODUCTION

The eco-system is at an unprecedented crossroad; ranging from greenhouse gasemissions to the depletion of the ozone layer, increased sea level and many more. Cortese (2009) asserted that despite all the work that has been done on environmental protection, all living systems are declining at an increasing rate. Today, buildings are responsible for more than 40 percent of global energy used, and as much as one third of global greenhouse gas emissions, both in developed and developing countries (Levine et al, 2014). This implies that use of energy efficient buildings will offset the global energy demand by 40 percent which could have emanated from the housing sector (Asdrubali, Cotana,Messineo, 2012).

Thus, the architect plays a strategic role in the process of mitigating this menace. Architects are primarily responsible for the transposition of the natural environment into the built

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environment.

The research efforts concerning building energy efficiency are continuously making progress through a wide variety of multiple issues. These include:
Kahu (2014) conducted a research on the design of large scale office building in Hot-dry climate of Nigeria, paying attention to energy efficiency enhancement. The study tried to evaluate the level of energy usage in existing large scale office buildings in hot-dry tropical region of Nigeria. It also tried to suggest recommendations for cost effective measures vis-à-vis reduction of energy consumption using principles of energy efficient design.

The research adopted a case study approach and data were elicited primarily through visual survey. Analyses of data were carried out through visual survey checklist and computer simulation tool. The study concluded that investment on energy efficient measures in large scale office buildings will demonstrate how the building industry contributes to the economy of a country through cutting cost for energy delivery.

Abdullahi (2015) on the other hand focused on using passive solution to increase energy efficiency in the design of a shopping mall in Abuja. The study assessed passive parameters that will enable the achievement of energy efficiency in a shopping mall in order to provide thermal comfort with less energy.

The research also adopted a case study approach and primary data were obtained via structured interviewed schedule and an analytic comparative study of few commercial building types. The study concluded that energy efficiency enhances optimum utilization of material usage and construction which in turn reduces cost on energy.

Mitterer, Kunzel, Herkel, & Holm (2012) focused on optimizing energy and occupant comfort with climate specific design of the building. The research paid attention to using principle of climatedependingdesigntodevelopandevaluateanenergycontrolforasetofnet-zeroenergyhouses in Dubai. These concepts were based on building envelope optimization and the development of an efficient building service system through the use of renewable energy.

The study concluded that a combined comfort and energy demand monitoring is of value, to gain profound understanding of the reaction of a building to the specific climate as well as of users' behavior or user acceptance.

Most of the recent works explored above focused on energy efficiency enhancement using various methods and principles; including passive design, energy efficient design and climate specific design principles. But a crystal clear lacuna exists in integrating the use of passive design and thermal comfort parameter to deliver energy efficient office buildings in tropical composite climatic belt of Nigeria (i.e. setting thermal comfort criteria and minimizing energy usage in delivering thermal comfort).

The aim of this study is to reduce energy for cooling in office buildings (in tropical composite climatic belt of Nigeria) using passive cooling strategies and at the same time putting thermal comfort into consideration.

2.0 ENERGY EFFICIENCY OF A BUILDING

The energy efficiency of a building is the extent to which the energy consumption per square meter of floor area of the building measures up to established energy consumption benchmarks for that particular type of building under defined climatic conditions (Vladimir, Albert, Beth & Michel, 2009).

Benchmarks are applied mainly to heating, cooling, air-conditioning, ventilation, lighting, fans, pumps and controls, office or other electrical equipment, and electricity consumption for external lighting(Federal Ministry of Power Works and Housing (FMPWH), 2016). The benchmarks used vary with the country and type of building.

2.1 The Need for Energy Efficient Buildings

Governments have a responsibility to ensure that there is secure supply of energy to ensure economic growth. In many developing countries there is normally very little margin between existing power supply and electricity demand(FMPWH, 2016). With increasing electricity use from existing consumers and new connections, new interventions need to be brought on line to meet increasing demand. (Sustainable energy regulation and policymaking for Africa, 2011).

The main benefit from measures to improve energy efficiency in buildings is to lower energy consumption (Sustainable energy regulation and policymaking for Africa, 2011).

2.2 Benchmark for Energy Consumption in Office Buildings.

The Lack of reliable data for office and residential buildings makes it difficult to set local benchmarks in Nigeria (FMPWH, 2016).
Benchmarks developed in South Africa where office construction is similar to Nigeria and where consumption of energy is mainly in the form of electricity, are as follows:

i. Under 130 $kWh/m^2/yr.$ – best practice air conditioned office,
ii. 130-210 $kWh/m^2/yr.$ – good practice air conditioned office,
iii. 210-320 $kWh/m^2/yr.$ – typical existing air conditioned office,
iv. Over 320 $kWh/m^2/yr.$ – poorly performing air conditioned office (Green Building Council South Africa (GBCSA), 2012).

2.2 Passive Control Strategies for Cooling

Passive cooling strategies prevent the building from overheating by blocking solar gains and removing internal heat gains (Vladimir et al., 2009).
Passive cooling strategies are often coupled with passive ventilation strategies, and the cooling function is achieved by increased passive ventilation air flow rates during periods when the outdoor air temperature is low enough to flush heat from the building.
Elements that contribute to passive cooling include the following: building orientation, Fixed/operable external shading, thermal mass, low window to wall area ratio, nocturnal cooling, stacked windows, passive evaporative cooling and earth-tempering ducts (Vladimir et al., 2009).

2.3 Thermal Comfort Model

The thermal comfort model used for this study was the Humphrey's "adaptive comfort" model as shown in equation 1. Using an upper temperature band of 34°C and 18°C for lower temperature band in the formula:

$$Tc = 0.534\,(T_{mean}) + 11.9 \quad \text{(Equation 1)}$$

Were $T_{c=}$ is Comfort Temperature, the comfort temperature was deduced to be 25.7 °C. $T_{mean=}$ Annual Mean temperature.

2.4 Climatic Conditions of the Study Area

Abuja climatic conditions can be described as a mixture of hot-humid and a hot dry climate (tropical composite Climate). The climate is characterized by two seasons; dry and rainy seasons. In between the two seasons, there is a brief interlude of harmattan occasioned by the North East trade wind, with the main feature of dust, haze, intensified coldness and dryness(Nigerian Metrological Agency(NIMET, 2010). The rainy season begins around March and runs through October when daytime temperatures reach 28-30°C and night time hover around 22-23 °C.

The dry season spans between October and March. Recorded daytime temperatures reaches as high as 40°C and night time temperatures reducing up to 12°C resulting in chilly evenings (NIMET, 2010). The city experiences an average of 11-12 hours of daylight and 7 hours of sunshine all year round but with some overcast skies during the rainy seasons (NIMET, 2010).

3.0 RESEARCH METHODOLOGY

The pivotal idea of this research methodology is to develop an enhanced passive cooling approach with thermal comfort criteria in order to enhance energy efficiency of office buildings in tropical composite climatic belt of Nigeria. The methodology applied to fulfill the research objective involves a mixed method comprising of qualitative and quantitative type of research. In other to achieve this, a case study approach was used.

The case study approach provided a unique opportunity to examine the study area in a way that has been largely unexplored. As such multiple case methods was used.

Physical observation was used to get buildings physical properties (passive cooling strategies adopted). Subsequently, an environmental simulation software (ECOTECT) was used to replicate existing situation of cases and their corresponding impact in energy demand. This enabled the elucidation of numerical or quantitative data.

A purposive selection method was applied in selecting the buildings for the case study. Since the selected buildings constitute the unit of assessment, it is essential that they are similar in all respect as much as possible (Lam, Wan, & Yang, 2008). The purposive selection method consists of four areas - these are: Building, occupancy, Passive control elements, HVAC strategy and Energy use. For a building to be selected and used as a case study in this research work, it must satisfy all the criteria.

A total number of twelve office buildings in Abuja were selected and approached to participate as case studies in the study. Three were responsive, three declined and six did not respond at all. Those that were responsive constituted the cases under evaluation. These buildings are:

1. Rachel Court Office Complex (case 1)
2. Capital Centrum Office Complex (case2)
3. Rivers House Office Complex (case 3)

Analysis of data was carried out in two ways; descriptive analysis and computer based simulation evaluations. Data collected via physical observation was analyzed descriptively. This method of evaluation is common particularly in the field of social science and has also been applied within the architecture discipline (Groat& Wang, 2012).

The second part engaged a more contemporary method of applying computer based simulation for the evaluation. Although this method requires some level of expertise in both running the simulation and result interpretation, it was considered appropriate as it is inexpensive and less time consuming compared to real-time construction of the buildings and monitoring the results of applied interventions. The computer simulation was applied

to evaluate the impact and relative importance of the dependent variables (passive cooling strategies identified from the case study) having significant correlation with the independent variables(building energy use and thermal comfort parameters.
Pre-defined input parameters for the simulation analysis were categorized and inputted into the simulation software. These parameters serve as the existing operational conditions in which the cases will be simulated (see table1).

***Table 1**: Pre-defined input parameters for simulation.*

S/No.	INPUT PARAMETER	OUTPUT PARAMETER
1	Abuja weather data file	Annual Climatic conditions of Abuja
2	Occupancy Schedule	All-days (Monday-Fridays), apart from weekends and public holidays
3	Cooling Strategies	Mixed-mode strategies
4	Comfort band temperature	Adaptive comfort model for the location (25.7 ºC).
5	Hours of building operation	Nine Hours (08:00am-05:00pm)
6.	Nature of activity in the spaces	Sedentary
7	Internal gains (values for both lighting& small power loads per unit floor area).	Sensible gains and latent gains

***Source:** (Authors, 2017)*

3.1 Case1

Physical observation (see plate I and fig. 1) carried out revealed that, the total floor area was measured to be 4609.04 m². Also, horizontal type of shading devices was identified. This was used in two different forms: recesses in wall with attachedmetallic blinds for smaller openings and Floor slab projections with an attached metallic grill at intermittent floor levels (used for larger openings). Both were measure to be 650mm in projection. Shading devices were positioned on eastern and western facades. More also, there were no visible cracks noticed all around the building. Also with respect to Building façades orientation, longer façade facing east & west while shorter façade facing north and south respectively as shown in fig. 1.

With respect to the percentage of glazed façade, it was deduced to be 35% and 65% respectively for both glazed & unglazed façade. Furthermore, Electricity billings system was identified to fall under the prepaid metering protocol.The building has an operational period of Nine hours (08:00am-05:00pm).

***Plate i:** A view of Rachel court office complex.* ***Figure 1:** Site plan of Rachel court office complex.*
***Source**: Authors (2017)* ***Source**: Authors (2017)*

3.2 Case2

Physical observation (see Plate ii and fig. 2) carried out revealed that, the total floor area was measured to be 6292.98 m^2. Also, Horizontal type of shading devices was identified (450mm). Cantilevered beams were used to achieve the horizontal projections. These were positioned on the south eastern and north western facades. More also, there were no visible cracks noticed all around the building. Also with respect to Building façades orientation, longer façade faced east & west while shorter façade facing north and south respectively as shown in fig. 2.

With respect to the percentage of glazed façade, this was deduced to be 37.8% and 62.2% respectively for both glazed & unglazed façade. Furthermore, Electricity billings system was identified to fall under the prepaid metering protocol. The building was observed to have operational period of Nine hours per day (08:00am-05:00pm).

Plate ii: *A view of Capital centrum office complex.* ***Source****: Authors (2017)*

Figure 2: *Site plan of Capital centrum office complex.* ***Source****: Authors (2017)*

3.3 Case 3

Physical observation (see Plate iii and fig. 3) carried out revealed that, the total floor area was measured to be 4450.98 m^2. Also, shading devices were absent all-round the building.

There were no visible cracks noticed all around the building. Also with respect to Building façades orientation, the longer and shorter façade faces the north west- south east and north east- south west orientation respectively.

With respect to the percentage of glazed façade, this was deduced to be 25.3% and 74.6% respectively for both glazed & unglazed façade. Furthermore, Electricity billings system was identified to fall under the prepaid metering protocol. The building was observed to have operational period of Nine hours per day (08:00am-05:00pm).

Figure 3: *Google map of Rivers house office complex* ***Plate iii:*** *Perspective View ofHouse Building.*
Source*: Authors (2017)* ***Source****: Authors (2017)*

3.4 Established Passive Elements and Parametric Inputs

Having identified various passive cooling elements from the cases, parametric inputs of these elements was developed and used for the simulation analysis. Table 2, 3 and 4 shows the aforementioned relationship for each of the cases under consideration.

Table 2: *parametric input for simulation of case study one.*

S/ No	Passive Element/ principle	Observation	Parametric input	Unit
1.	Building Orientation	Longer and shorter façade faces the east-west and north south orientation respectively.	180	º
2.	Window to Wall Area Ratio	U value of 230mm sandcrete block wall with 15mm plaster(internal & external surfaces) & 10mm marbletile(external).	2.689	W/m² ºK
		U value of single paneled transparent glass with aluminum frame.	5.77	
		Window to wall area ratio	35 (glazed façade) & 65 (unglazed façade).	%
		Window total shading Coefficient	0.3	-
3.	Solar Shading	Horizontal shading device on eastern and southern façade respectively	650	mm
4.	Air and moisture Tightness	Infiltration	0.4	ACH

Source*: Authors Analysis (2017).*

Table 3: parametric input for simulation of case study two.

S/ No	Passive Element/ principle	Observation	Parametric input	Unit
1.	Building Orientation	Longer and shorter façade faces the east-west and north -south orientation respectively.	180	º
2.	Solar Shading	Horizontal shading device on south eastern and north western façaderespectively.	450	mm
3.	Air and moisture tightness	Infiltration	0.5	ACH
4.	Window to Wall Area Ratio	U value of 230mm sandcrete block wall with 15mm plaster (internal & external surfaces) & 0.9mm Aluco-bond (external).	2.722	W/m² ºK
		U value of single paneled transparent glass with aluminum frame.	5.77	
		Window to wall area ratio	37.8(glazed façade) & 62.2 (unglazed façade).	%
		Window total shading coefficient	0.4	-

Source: *Authors Analysis (2017).*

Table 4: parametric input for simulation of case study three.

S/ No	Passive Element/ principle	Observation	Parametric input	Unit
1.	Building Orientation	Longer and shorter façade faces the north west- south east and north east-south west orientation respectively.	180	º
2.	Window to Wall Area Ratio	U value of 230mm sandcrete block wall with 15mm plaster(internal & external surfaces).	2.725	W/m² ºK
		U value of single paneled transparent glass with aluminum frame.	5.77	
		Window to wall area ratio	25.3% glazed façade & 74.6% unglazed façade.	%
		Window total shading coefficient	0.5	-
3.	Air and moisture Tightness	infiltration	0.4	ACH

Source: *Authors Analysis (2017).*

4.0 RESULTS AND ANLYSIS

The test simulation of the three cases showed that cooling load of the buildings accounted for the bulk energy consumption of the respective buildings. See table 5 for load consumption break down.

Table 5: *Cooling energy requirement result from the simulation of case studies.*

MONTH	CASE ONE COOLING LOAD (wh)	CASE TWO COOLING LOAD (wh)	CASE TWO COOLING LOAD (wh)
Jan	11055655	75455655	21790236
Feb	118760576	193876559	220361140
Mar	195086805	799088785	206874078
Apr	170598605	690598667	181443000
May	150096676	395096634	74687400
Jun	120506077	247980098	61458431
Jul	95687746	190697789	61603452
Aug	58853778	129873767	51045619
Sep	26745786	99805789	36750786
Oct	6906873	59590878	23034565
Nov	2078675	27107676	17404534
Dec	1938977	9923889	21478042
TOTAL	**958,316,229**	**2,919,096,186**	**977,931,283**

Source: *Ecotect Analysis (2017).*

4.1 Energy Demand Breakdown(EDB).

From the three cases, proper building orientation with respect to the Abuja climate was poorly considered. The three buildings have their longest sides exposed directly to the east and west cardinal points respectively. From the simulation analysis, Spaces with east and west direct exposure have the highest total energy requirement for cooling (see fig. 4, 5, and 6).

Though the simulation test performed for three cases made use of three different walling material composition, and same type of glazing panels, their impacts on the respective building energy demand was overwhelming. As indicated in fig. 4, 5 and 6, walling material and type of glazing panel contributed to 40%, 49% and 43.2% of the cooling load demand of the respective cases(i.e. cases one, two and three respectively).

The simulation result revealed that, the provision of horizontal shading devices with 650mm depth and tilt angle of ninety degrees for the Rachel court building had a great impact on the cooling requirement of the building. This may have resulted to a conscious adoption of a passive cooling approach in shading some areas with large panel windows. Energy requirement for cooling was reduced by 20% of the total annual cooling energy. On the other hand, the provision of horizontal shading device on the south eastern and north western façades of case two had no impact on the cooling requirement of the building.

Furthermore, all the three buildings were observed to have no visible cracks on the walling and glazing materials. Also construction and expansion joints were properly sealed. As such a value of 0.4 Air Change per Hour (ACH) was used. As indicated in fig. 4, 5 and 6, the infiltration and exfiltration contributed a little proportion of the cooling energy demand of all cases under review.

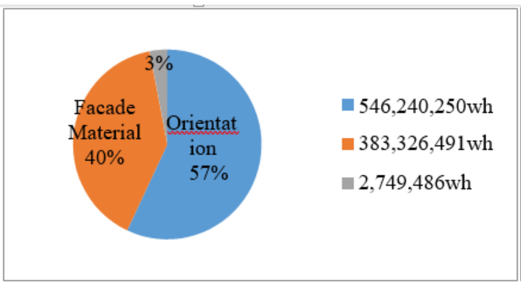


Figure4: *EDB(casestudy1)*
Source: EcotectAnalysis (2017).

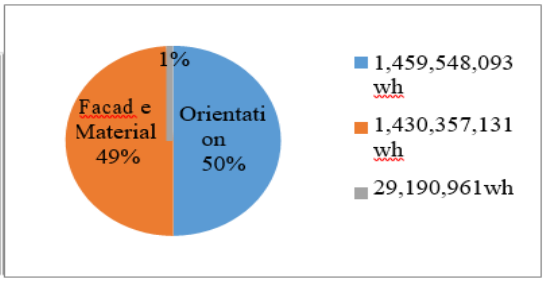


Figure 5: EDB (case study2)
Source: Ecotect Analysis (2017).

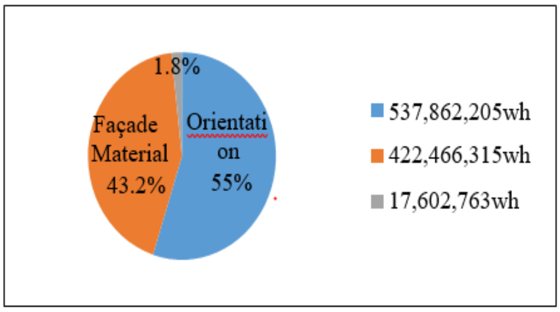
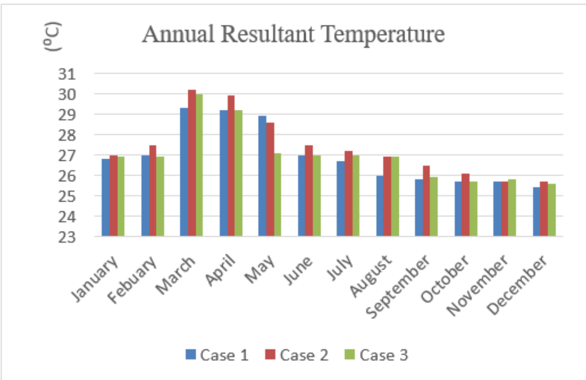


Figure6: EDB (case study 3)
Source: Ecotect Analysis (2017).

4.2 Thermal Comfort Duration

The simulation result as depicted in fig. 7 and 8 revealed that the accepted comfort temperature range is obtained annually at a maximum of 20%, 7%, and 18% of the buildings occupied periods for cases one, two and three respectively.



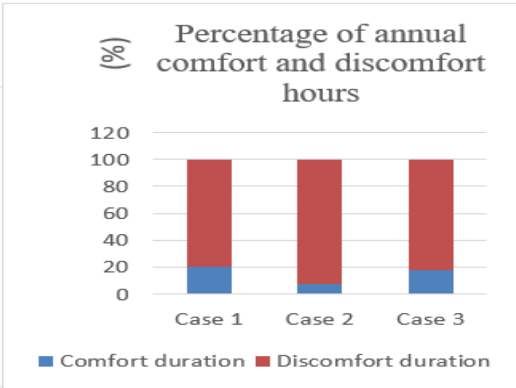


Figure 7: Annual resultant temperature of cases
Source: Ecotect Analysis (2017).discomfort hours.

Figure 8: Percentage of annual comfort
Source: Ecotect Analysis (2017).

This suggests that rest of the 80%, 93% and 82% occupied periods respectively for the three cases under consideration can be characterized by temperature ranges outside the boundaries of human adaptive capabilities. This further suggests that other HVAC systems may be necessary for these periods.

4.3 Energy Use Intensity

The simulation results revealed that the Rachel court office building fell under good practiced air conditioned office (130-210 kwh/m²/yr) with an energy use intensity of 207.9 kwh/m²/yr for cooling. On the other hand, Rivers house office complex was a bit higher and was computed to fall under typical existing air conditioned office (210-320 kwh/m²/yr) with an energy use intensity of 219.7kwh/m²/yr. Capital centrum office building had the highest energy use intensity for cooling of about 468.2kwh/m²/yr. This positioned the building on poorly performing air conditioned office (over 320 kWh/m²/yr).

4.4 Enhanced Scenery ofCases.

A base line model of each case study will be used with a varying parametric assumption inputted. Each passive cooling element adopted by the cases will be used in this context as shown in Table 6.

Table 6: *Parametric input for simulation of all cases.*

S/ No	Passive Element/ principle	Definition	Parametric input	Unit
1.	Building Orientation	Longer and shorter façade faces the north-southern and East-western orientation respectively.	180 aligned from north	º
		Longer and shorter façade faces the north east - South west and south- east - North western orientation respectively.	45 aligned from north	
2.	Building envelope	U value of 230mm sandcrete block wall with 15mm plaster(internal & external surfaces) & 10mm marble tile (external).	1.14(hollow wall), 0.69(polystyrene insulated wall)	W/m² ºK
		U value of double paneled transparent glass with aluminum frame.	4.32, 3.51, 3.04	
		Window to wall area ratio	Glazedfaçade 30, 35, 40	%
		Window total shading Coefficient	0.3, 0.4,0.5	-
		Infiltration	0.3	ACH
3.	Solar Shading	Horizontal shading device on south western and north eastern façade respectively.	650, 750, 900 20º, 35º, and 45º angle between the bottom of the window and edge of overhang	Mm

Source: *Authors Analysis (2017).*

4.5 Implications

These will be discussed based on the variables under consideration

4.5.1 Building orientation

It was observed that the 180º alignment of all the three buildings from the north created a huge impact on the overall cooling energy requirement of the buildings (see table 7 & 8). A reduction of 5.3%, 7% and 6.4% cooling energy demand was recorded for case study 1, 2 and 3 respectively

4.5.2 Building envelope
Little cooling energy was required below the 35% window to wall area ratio in the entire case models. This is because there are no internal heat gains. If there were internal heat gains a slight cooling energy requirement may be observed. A combination of 30% window to wall area ratio, polystyrene insulated scenario of walls, double glazing with a reduced U-value 3.04 W/m² °K and a shading coefficient of 0.4 displayed a significant reduction in cooling energy demand. The percentage reduction is displayed in table 7 & 8.

4.5.3 Shading devices
The shading device had the greatest impact on the southwest and the North East facade paces. Horizontal shading with shade angles less than 20° (shade depths less than 650mm) had little impact on the overall space cooling energy.
Shading devices with shade angles greater than 35° eliminated the cooling energy requirement in the North-east facade space. The percentage reduction is displayed in table 10 & 11.

Table 7: *Reduction in energy demand*

Enhanced features	CASE 1	CASE 2	CASE 3
Building Orientation	-5.3%	-7%	-5.9%
Building Envelope	-8.2%	-12.5%	-8.8%
Shading devices	-5.6%	-8.1%	-4.8%

Source*: Authors Analysis (2017).*

Table 8: *Total reduction in energy demand and energy use intensity.*

Case Study	Percentage reduction (%)	Energy consumption (kwh/yr)	Building floor area (m^2)	Energy use intensity (kwh/ m^2/yr)
Case 1	19.1	776, 236	4609.44	167
Case 2	27.6	2,119,096.2	6234.07	258.2
Case 3	19.5	737,931.3	4450.99	162.7

Source*: Authors Analysis (2017).*

4.5.4 Thermal comfort duration
The simulation result for the enhanced scenario of cases as depicted in fig. 9 revealed that the accepted comfort temperature range was appreciably achieved within the buildings occupancy period. A 22.5% increment was recorded for the annual comfort hours duration of Rachel court office building. Rivers house building followed next in hierarchy with a 15.2% increment. Capital centrum building offered the least increment in annual comfort hours of occupied period with a 13% increment.

This suggest that incorporating other passive cooling strategies will pave way for the increment of comfort hour duration of the buildings occupied periods and also the reduction of energy demand for cooling.

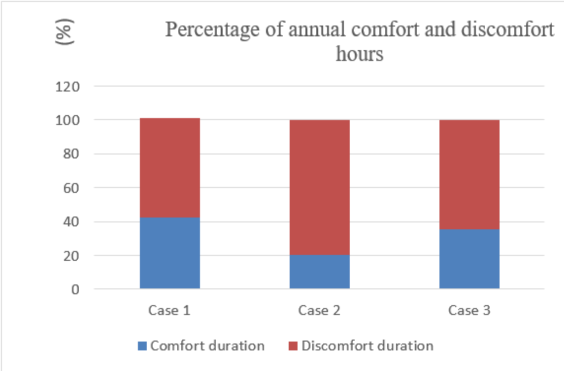


Figure 9: *Percentage of annual comfort discomfort hours (enhanced scenery).*
Source: *Ecotect Analysis (2017).*

5.0 Conclusion

This study has evaluated three building for energy demand analysis with respect to cooling. The simulation results for the three case studies revealed that though certain passive strategies for cooling were used for the buildings, they still exhibited high energy demand for the accomplishment of the cooling purpose. More also, the result shows that indoor comfort temperatures are achieved annually for a maximum of 20%, 7% and 18% respectively for cases one, two and three respectively. This suggests an inevitable use of other cooling approaches (including air conditioning and other mechanical ventilation systems). An enhanced passive control strategy for the three cases demonstrated a significant reduction of 19.1%, 27.6% and 19.5% respectively in annual cooling energy demand. These reductions in energy consumption resultantly brought down the energy use intensity of the cases under evaluation. It also recorded an appreciable increase in the annual indoor comfort temperature duration with 22.5%, 15.2% and 13% increments for cases one, two and three respectively.

More also, the research results suggest that, while given consideration to the usage of passive cooling strategies in buildings, a conscious effort should be made towards testing the applicability of such strategy to suite our micro-climatic conditions. This will involve the usage of advance computer tools such computer simulation software and advance weather data applications.

Finally, the study suggests that the enhanced energy efficiency method could become strategic for applicability in the future. In particular, the efficacy increases if this strategy is applied to those relatively new existing buildings that already have high performance building systems, where other improvement interventions are not passively energy efficient. An important future development of the research will consist of the implementation of the enhanced strategy and other passive cooling measures on a proposed office development. This will pave way in quantifying the effective energy savings and its corresponding users comfort.

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