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Reducing the Operational Energy Demand in Shopping Malls Buildings within Abuja, through Passive Design Approach

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ABSTRACT
Buildings are responsible for at least 40% of energy used in most countries. In Nigeria construction activities has pervaded most urban centres as in the case of Abuja, buildings are design and build without considering the principles of passive design that will be peculiar to the local climate of the region. The following methodology were followed, all the selected 3 case studies were visited for a field survey, interviews were conducted photographs were taken, notes and sketches were collected. Ceddi Plaza Abuja and Silverbird Entertainment Centre Abuja (i.e. Case study 1 and 2) were modelled and analysed with the aid of Autodesk Ecotect Analysis simulation software to determine the annual operational energy demand of the buildings. The simulation results show that case study 1 and 2 has a total annual operational energy consumption of 192.497kwh per square meter and 164.134kwh per square meter respectively, this results indicate that case 2 is more apply more passive design principles than case study 1. Furthermore, at the end of the research the proposed shopping design was simulated and the results indicate a decrease in the annual operational energy demand by 36.3% and 24.3% with respects to case study 1 and 2. Therefore building simulation and investigating the performance of the building virtually in the pre-construction stage will help architects and other consultants to apply suitable passive design principles that will suit a particular local climate and reduces the building annual operational energy demand.
Keywords: Operational Energy Demand, Passive Design, Energy Consumption, Natural Ventilation, Shopping mall, Sustainability.

INTRODUCTION
Buildings are responsible for at least 40% of energy used in most countries (Roux & Alexander, 2007). The absolute figure is rising fast as construction booms, especially in counties such as China and India (Roux & Alexander, 2007). It is essential to act now, because buildings can make major contribution to climate change and energy use. Olotuah (2009) Opined that

incremental construction has pervaded most urban centres in Nigeria. Many of such buildings are inhabited with the barest facility in place. Although sustainability is fast assuming a global trend, the position of architecture in actualizing passive design goals in developing countries is not encouraging. In recent times, most buildings design in Nigeria trend towards mix-use functions as in the case of shopping malls where shopping, entertainment and recreation fall under the same roof. As a result of that, high energy demand which has not been adequately met since the country faces constant power disruption due to insufficient supply of power (Esther & Sagada, 2014). On the other hand, most shopping malls in Nigeria fulfil this cooling requirement with the help of air conditioning and cooling units which are not sustainable in terms of energy efficiency.

Abreu (2012) in her reaction called for global sustainability where all countries commit to sustainable development and the "greening" of their economic systems with clean technology, innovation, and sound science. According to her, for the proposed sustainable development goals to be effective, there should be a call for international scientific cooperation and coordinated research on major passive design challenges, building on, and working with existing programs. Here, among other disciplines, architecture finds a striking relevance. The primary role of the Architect is to create places from existing spaces. In doing this, he must ensure he factors in sustainability values. The goal of passive design is to improve living standards and the quality of people's lives, both now and for future generations. Rour and Alexande (2007) observed that "careful selection of environmentally sustainable building materials is the easiest way for architects to begin incorporating passive design principles in buildings". It is worthy of note that the erection of building structures, however small, involves several activities that have negative impact on the environment if sustainable measures are not considered, which results in 50% of all carbon dioxide emissions worldwide. Right from the conceptual design stage to its erection, the impact of these activities on the environment should be checked. Shopping malls have been developed everywhere with trends like theme parks, sport arenas, indoor leisure sites, centre parks, multiplex cinemas and or musical theatres. These centres, often dedicated to a special theme, combine different leisure functions with retail trade and entertainment. Because of their huge size, growing number and needful catchment areas, their spatial impacts are immense. Reducing the consumption of electricity in shopping malls is very important especially on air conditioning and lighting systems.

This paper tends to address this issue of passive design approaches that reduce the annual energy demand which poses as a challenge in shopping malls especially in hot-humid climate of Nigeria.

LITERATURE REVIEW

What Is Passive Design?

Passive Design regards the particular way to construct a building using the natural movement of heat and air, passive solar gain and cooling in order to maintain a good internal comfort. Through the use of passive solutions it is possible to eliminate, or at least reduce, the use of mechanical systems and the energy demand by 80% as well as the CO_2 emissions.Building a passive house takes careful planning, which includes the introduction of five basic principles: Orientation, Overhangs and shadings, Insulation, Double or triple glazing, Thermal mass (Passive Design Introduction Theory, 2015).

The Core Principles of Passive Design Fitted for Shopping mall Design

- **Avoid heat gain**
  - Orient the building to reduce exposure to midday sun, particularly summer sun.
  - Use materials with low thermal mass (as a general rule).
  - Shade walls and windows, particularly any walls with high thermal mass.
  - Use glazing on windows that cannot be effectively shaded.
  - Use insulation, light colours and heat reflective surfaces.
- **Encourage natural ventilation**
  - Orient the building and windows towards prevailing easterly winds.
  - Include open able windows and ceiling vents that enable the building to naturally ventilate.
- **Make use of natural light**
  - Install shaded windows.
  - Install shaded skylights, light tubes and other natural lighting devices.
- **Create cool outdoor areas**
  - Use verandas and deep balconies to shade and cool incoming air.
  - Use landscaping to provide shade without blocking cooling breezes and use planting to reduce ground temperature and minimize reflected heat. (Cairns Reginal Council, 2011)

Key Features of Passive Design

The key elements of passive design are: building location and orientation on the site; building layout; window design; insulation (including window insulation); thermal mass; shading; and ventilation. Each of these elements works with others to achieve comfortable temperatures and good indoor air quality. The first step is to achieve the right amount of solar access enough to provide warmth during cooler months but prevent overheating in summer. This is done through a combination of location and orientation, room layout, window design and shading. Insulation and thermal mass help to maintain even temperatures, while ventilation provides passive cooling as well as improving indoor air quality. All of these elements work alongside each other and therefore should be considered holistically. For example, large windows that admit high levels of natural light might also result in excessive heat gain, especially if they cast light on an area of thermal mass. Similarly, opening windows that provide ventilation will also let in noise. Alongside passive design features, designers should also consider other factors such as views, covenants and local authority restrictions, and building owners' preferences(Branz D, 2015).

Ventilation

Natural or forced ventilation is paving way of reducing the cooling load in building. Natural ventilation is caused by pressure difference in the inlets and outlets of a building envelope, as a result of wind velocity and stack effects (Aziz & Adnan, 2010)

Day lighting

Daylight is very important for people inside buildings physiologically and psychologically. The natural light can be capitalized by the use of windows, light shade, atria etc. Highly reflective wall coverings indirectly make the space feel lighter. What the interior need is ambient daylight without the radiant heat and glare which is called cool daylight / diffuse daylight. When daylight enters a room through windows, the illumination near the windows will be high and it reduces quickly as it gets further into the depth of the room. Designers should always try to create a better uniformed daylight distribution into a space. The simplest and most often used strategy to improve the daylight penetration to the back of the room is by having high level windows or clerestory window, where the lower window is for vision and the higher level window is purely for daylight. A light shelf between the upper and lower window would help to distribute daylight deeper into the room by bouncing lights of the shelves to bring illumination deeper into the room (Aziz & Adnan, 2010).

What is Passive Cooling?

Before energy was plentiful and air-conditioning omnipresent, designers came up with ingenious techniques for letting the forces of nature keep their buildings cool. Today's designers are relearning those techniques. And coming up with a few more As much as possible. Controlling the heat a building gains from its environment is what passive cooling is all about. It is also what passive heating is about, and the relation between those two functions is crucial. Keeping unwanted heat out in the summer and drawing it in during winter are issues that should in fact, must be addressed hand in hand, for the simple reason that in either case the design of the building itself is the climate-control mechanism. There are designers, who define passive cooling techniques as strategies which literally introduce coolness into a building without mechanical assistance, a definition that excludes design strategies which stop heat before it can enter and become part of the cooling load. While it's a definition that has real meaning, especially in its opposition to active mechanical cooling strategies, even its proponents agree that controlling heat gain is the essential first step in any attempt to cool buildings naturally, passively, through design itself (Passive cooling; Designing natural solution to summer cooling loads, 2012).

Sustainable Approaches in Contemporary Shopping Malls

Shopping malls are fast becoming one of the most dominating structures in Nigeria cities, considering the number, the body structure and the area of shopping malls, the importance of passive design approaches in shopping malls design have become more important aspect to be studied in Nigeria. Contemporary shopping malls should also follow those design criteria as well:

1. Avoid restricting natural conditions reaching their internal spaces that would be of positive benefit to their occupants. For example, buildings should be designed to maximize the use of daylight over artificial light; likewise buildings should aim to be naturally ventilated with fresh air rather than be controlled through energy consuming heating and ventilation systems.
2. Assist in the collection and storage of received energy sources, particularly solar energy, and then utilize this when and where required. Buildings should also be designed so that they consume far less energy.
3. Should respect their local surroundings environmentally. Not only should they minimize internal energy consumption; they should also aim not to create external demands or induce negative environmental effects. Local energy cycles can be utilized, but should not be altered or used in an unsustainable way (Gissen, 2003).

RESEARCH METHODOLOGY

The data is collected through multiple instrument of data collection. All the selected case studies are visited by the researcher for field survey, interviews were conducted, photographs were taken, notes and sketches were collected. Cedi plaza Abuja and Silverbird Entertainment Centre Abuja (i.e. case study 1&2) were drawn, modelled and analysed with the aid of Autodesk ECOTECH software to test for the non-physical variables i.e. annual energy consumption. According to figure 1 below after providing the drawing plans and materials specifications of the case study buildings, zones must be formed for creating various parts of the building. Without creating zones in Revit architecture, energy of the building's various spaces cannot be modelled. In fact, the file cannot be exported to Ecotect software. After creating zones, for exporting the simulation file from Revit to Ecotect, the gbXML based export must be used. This is the way that can export all building's specifications defined in Revit to Ecotect. By choosing gbXML based export, some basic and necessary assumptions for energy modelling such as location and types of the building must be established. After considering essential assumptions, the file is exported to the Ecotect software for energy modelling and analysis. In Ecotect, after establishing some additional assumptions, such as activity, type of system, and environmental temperature range for comfort of the building as shown in table 1, the baseline building annual operational energy use is calculated.

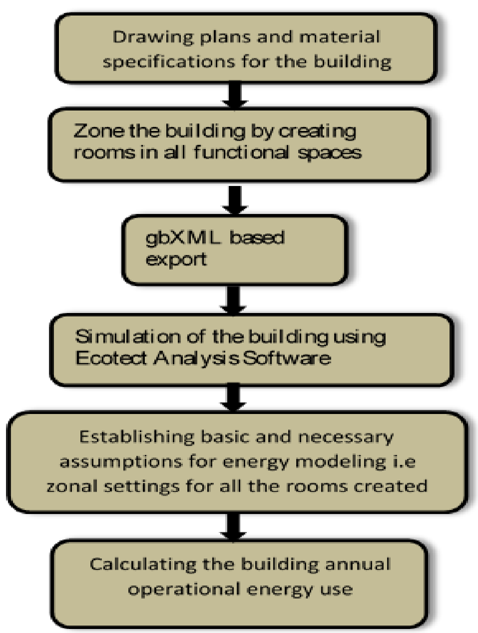


Figure 1**Hierarchy of the Stimulation study**

Table 1: **Basic assumption of zones for case study buildings**

BASIC ASSUMPTION OF THE ZONES IN THE ANALYSIS OF ENERGY CONSUMPTION FOR THE CASE STUDIES							
					THERMOSTAT RANGE		
FUNCTIONAL SPACE	LIGHTING LEVEL	NUMBER OF PEOPLE	ACTIVITY	TYPE OF SYSTEM	LOWER BAND	UPPER BAND	HOURS OF OPERATION
Shopping Area	900lux	5	Walking slow 115w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Hyper-market	900lux	70	Walking slow 115w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Cinema Hall	50lux	100	Resting 45w	Full Air Conditioning	18°C	22°C	8:00AM-1:00AM
Basement	400lux	20	Walking 80w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Stair case	50lux	15	Walking slow 115w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Toilet	50lux	8	Resting 45w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Control Room	50lux	3	Walking slow 115w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Circulation Area	900lux	150	Walking slow 115w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Office	400lux	3	Reading 55w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Amusement / Games and Bowling Section	600lux	20	Exercise 1100w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Pantry / Food Court	300lux	35	Resting 45w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Event Hall	300lux	150	Resting 45w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM

CASE-STUDY BUILDINGS SIMULATION RESULTS

Ceddi Plaza Abuja (Case Study 1)

Ceddi Plaza is owned by Ceddi Corporation and is located in the Central Business Area of Abuja. The Plaza consists of 10,000 square meters of retail and office space. The tenant mix is made up of three floors of retail (eateries, fashion boutiques, entertainment and services) and three floors of corporate office space. The construction material was in situ, reinforced concrete, and the exterior walls were hollow block render walls. The windows were double-glazed glass with aluminium frames. Table 2 shows the components and types of materials used, and Fig. 1 shows the building's floor plan.

Table 2: Types of materials used for each building component (Case Study 1)

Building Component	Type of Materials
Walls	Hollow Block Render
Windows	Double Glaze Aluminium Frame
Roof	Concrete Roof Asphalt
Floors	Concrete Tile on Ground

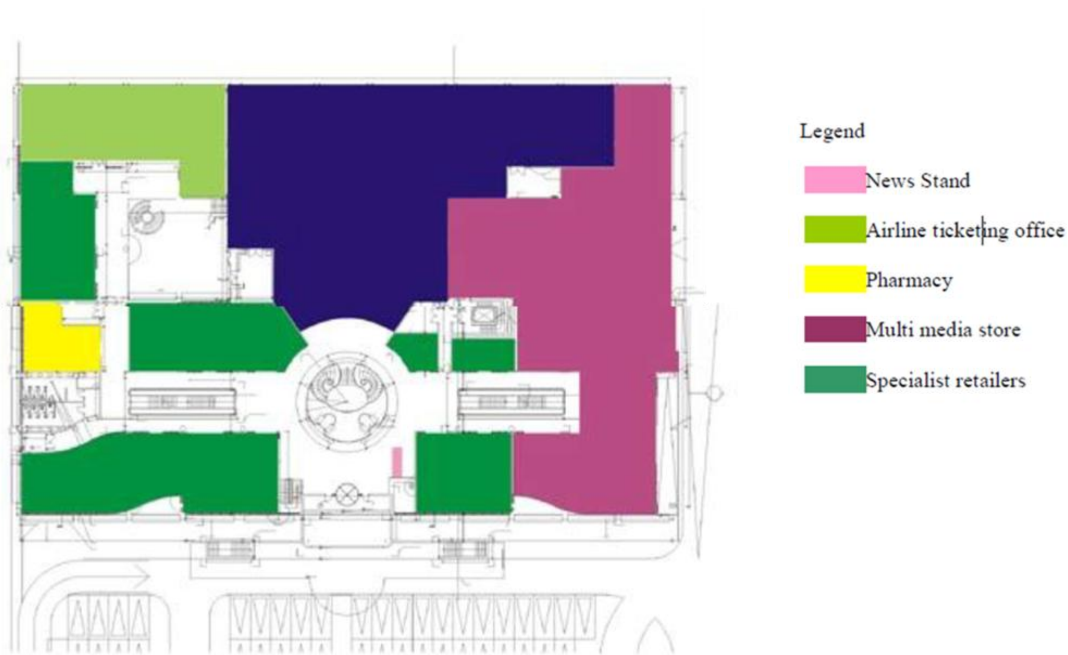


Figure 2: **Ground Floor Plan**

Baseline design cooling energy consumption for case study 1 (Ceddi Plaza Abuja)

The baseline design of the case-study building involves concrete block render for the walls, double glaze aluminium frame for the windows, and concrete roof asphalt for the roof and concrete tiles on ground for the floors as shown in table 2. By considering all months, it is seen that the energy used throughout the year to keep the building's temperature between 18°C and 22°C based on these materials was 192.497kwh per square metre. There is just a cooling load for all months of a year due to the location of the building in Abuja Nigeria, which is a very hot and humid area. The highest amount of energy consumption occurs on. 7 March as shown in table 3.

Table 3: Monthly heating and cooling loads of case study 1

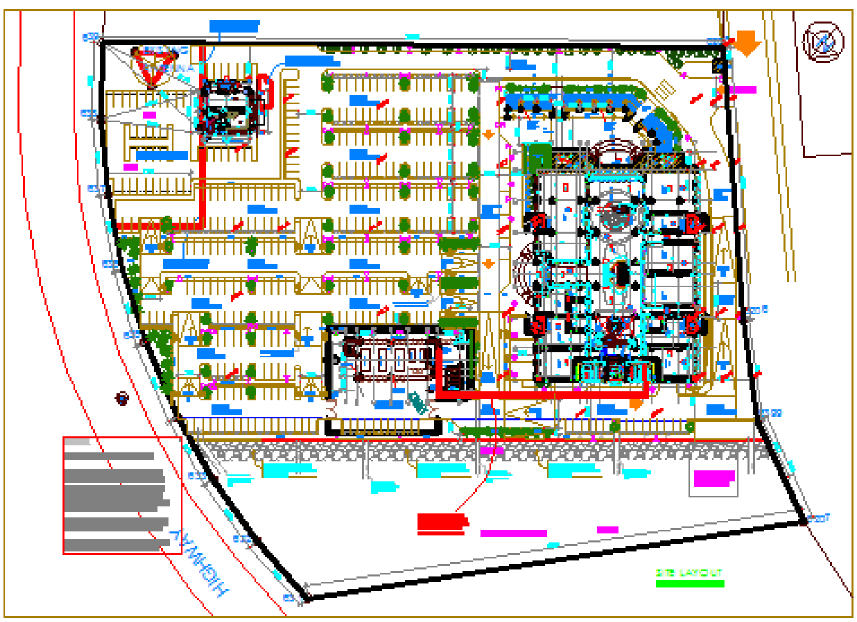
MONTHLY HEATING/COOLING LOADS			
All Visible Thermal Zones			
Comfort: Zonal Bands			
Max Heating: 0.0 C - No Heating.			
Max Cooling: 637128 *W* at 13:00 on 17th March			
	HEATING	COOLING	TOTAL
MONTH	(kWh)	(kWh)	(kWh)
Jan	0	127574.258	127574.258
Feb	0	136152.703	136152.703
Mar	0	161372.297	161372.297
Apr	0	139615.234	139615.234
May	0	129342.023	129342.023
Jun	0	108567.242	108567.242
Jul	0	102736.891	102736.891
Aug	0	102626.547	102626.547
Sep	0	95019.32	95019.32
Oct	0	117258.016	117258.016
Nov	0	112941.531	112941.531
Dec	0	117468.766	117468.766
TOTAL	**0**	**1450674.875**	**1450674.875**
PER M^2	**0**	**192.497**	**192.497**
Floor Area:	7536.083 m2		

Silverbird Entertainment Centre Abuja (Case Study 2)

Silverbird Entertainment Centre Abuja is owned by Silverbird group and is located at plot 1161, Memorial Drive, By Musa Yar'adua Centre, and Central Business District Abuja. Silverbird Entertainment Centre consists of 30,000 sq m retail space, luxury shopping, 12 screen cinema, VIP balconies, Food court, Spa, clothing, supermarket, lifestyle, entertainment etc. The construction material was in situ reinforced concrete, and the exterior walls were hollow block render walls. The windows were double-glazed glass with aluminium frames. Table 4 shows the components and types of materials used, and Fig. 3 shows the building's Site floor plan.

Table 4: Types of materials used for each building component (Case Study 2)

Building Component	Type of Materials
Walls	Hollow Block Render
Windows	Double Glaze Aluminium Frame
Roof	Corrugated aluminium Roof
Floors	Concrete Tile Suspended



Baseline design cooling energy consumption for case study 2 (Silverbird

Figure 3: Site Floor Plan

Entertainment Centre Abuja)

The baseline design of the case-study building involves concrete block render for the walls, double glaze aluminium frame for the windows, and corrugated aluminium roof for the roof and concrete tiles suspended for the floors as shown in table 4. By considering all months, it is seen that the energy used throughout the year to keep the building's temperature between 18°C and 22°C based on these materials was 164.134kwh per square metre. There is just a cooling load for all months of a year due to the location of the building in Abuja Nigeria, which is a very hot and humid area. The highest amount of energy consumption occurs on 21 February as shown on table 5, and the comparison result of case study 1 and 2 is shown in figure 4.

Table 5: Monthly heating and cooling loads of case study 2

MONTHLY HEATING/COOLING LOADS			
All Visible Thermal Zones			
Comfort: Zonal Bands			
Max Heating: 0.0 C - No Heating.			
Max Cooling: 2024370 *W* at 13:00 on 21st February			
	HEATING	COOLING	TOTAL
MONTH	(kWh)	(kWh)	(kWh)
Jan	0	426001.219	426001.219
Feb	0	452451.656	452451.656
Mar	0	536288.188	536288.188
Apr	0	461655.531	461655.531
May	0	425635.656	425635.656
Jun	0	352604	352604
Jul	0	334173.188	334173.188
Aug	0	330767.219	330767.219
Sep	0	306816.469	306816.469
Oct	0	385199.375	385199.375
Nov	0	378815.531	378815.531
Dec	0	392789.969	392789.969
TOTAL	**0**	**4783198**	**4783198**
PER M^2	**0**	**164.134**	**164.134**
Floor Area:	**29141.971 m2**		

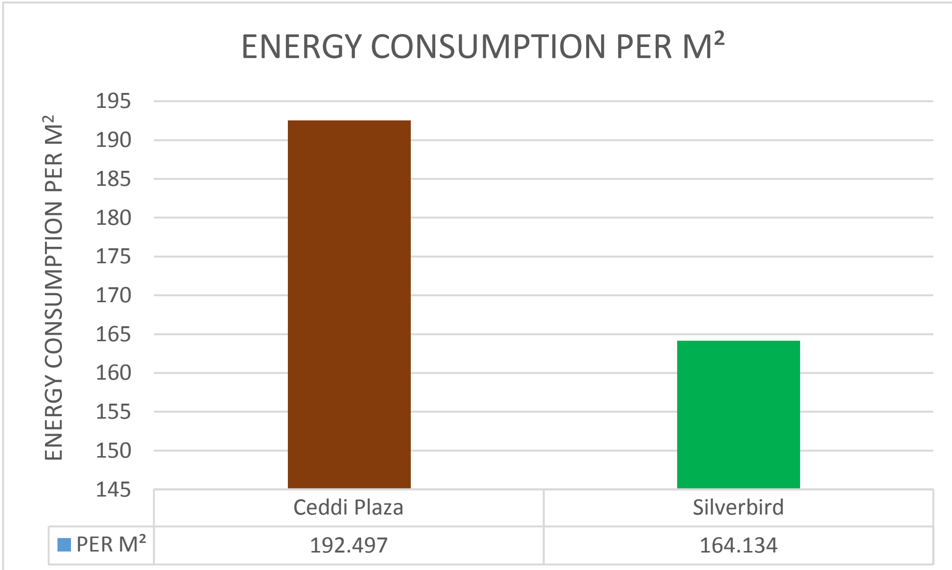


Figure 4: **Energy consumption per M^2 of case study 1 and 2**

Annual Energy Consumption Validation

In order to validate the results obtained from the Ecotect analysis software, an energy consumption survey was conducted for the case study 2 building and a random sample of a shop within the central business district of Abuja, as shown in table 6, figure 4 and table 7.

Table 6: **Annual Energy Consumption Validation Table**

ENERGY CONSUMPTION TABLE OF SILVERBIRD ENTERTAINMENT CENTRE ABUJA				
Appliances	Power (kw)	Quantity	Hours of Operation	Annual Energy Consumption (kwh)
Mechanical Machines				
Central Plant Air Conditioning System	0.53 kw per ton (350 tons) 1ton=3.5kw 649.25kw	1	18	4,265,572.5= **146.37 per m²**
Escalator	7.5 H.P=5.592KW	10	14	285,751
Elevator (Panoramic)	2943w=2.943kw	2	14	30,077.46
Elevator (Hoist)	3924w=3.924kw	1	7	10,025.82
Pro Cinema 1080p 3LCD Projector	528W=0.528kw	12	16	37,002.24
Lighting				
Compact Fluorescent	18w=0.018kw	150	18	17,739
Incandescent Lamp	15w=0.015kw	800	18	78,840

Incandescent Lamp	20w=0.020kw	400	18	52,560
Halogen Lamp	300w=0.300kw	10	12	13,140
Kitchen Equipment				
Coffee Maker	1000w=1kw	2	2	1,460
Dish Washer	1500W=1.5kw	5	2	5,475
Micro wave oven	1500kw=1.5kw	7	2	7,665
Toaster oven	1000w=1kw	7	2	5,110
Freezer	1000w=1kw	12	24	105,120
Refrigerator	800w=0.8kw	30	24	210,240
Electronics				
Desktop pc	75w=0.075kw	90	14	34,492
Television	150w=0.150kw	20	14	15,330
Stereo System	33w=0.033kw	5	10	602.25
TOTAL				**5,176,202.27**
TOTAL FLOOR AREA	**29,141.971 m²**			
PER M²				**177.620**
Note: For Elevator Power=work/time: Work=Force*Distance: Force=mass*acceleration Power=mass*acceleration*distance/time. 1 horse power (h.p) =0.7457kw				

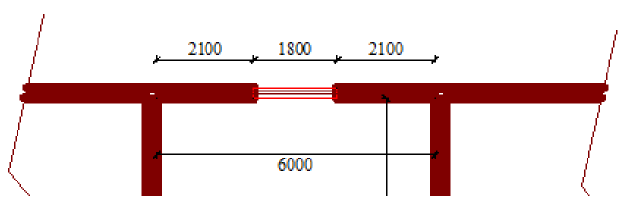


Figure 5: **A Sample Shop**

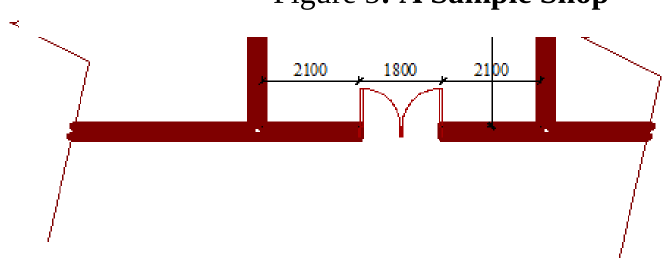


Table 7: **Annual energy consumption of the sample shop**

ENERGY CONSUMPTION OF A SHOP WITHIN THE CENTRAL BUSINESS DISTRICT, ABUJA				
Appliances	Power (kw)	Quantity	Hours of Operation	Annual Energy Consumption (kwh)
Split A.C	1500W=1.5KW	2	8	7,488 **=231.11 per M²**
Television	150w=0.150kw	1	8	374.2
Incandescent Bulbs	40w=0.040kw	6	8	599.04
Fridge	1000w=1kw	1	8	2,496
TOTAL				**10,957.24**
TOTAL FLOOR AREA		32.4 m²		
PER M²				**338.186**

SIMULATION RESULT OF THE PROPOSED SHOPPING MALL

In conducting the analysis, a few assumptions related to the building zones were made. The building was divided into zones, Table 8 shows various essential assumptions about each zone that were considered for calculating the energy consumption of the building. After considering all assumptions and conducting the analysis of energy consumption, a calculation was done to determine the amount of cooling energy required to keep the temperature of the building between 18°C and 22°C. The energy consumption was determined based on the case study building component as a design baseline. Finally, a set of higher-performance building component materials was recommended for the purpose of reducing the energy consumption of the building, as shown in table 9 which has led to a decrease in the annual energy consumption of the proposed shopping mall. Table 10 and 11 shows the Monthly Heating / Cooling Load Comparison with Case Study 1 and 2 showing percentage drop from the case study building components, the sustainable building components and the use of light colour paint. Figure 6 below shows a schematic air flow into the atria of the mall and figure 7 shows how stack effect is control to achieve an effective passive ventilation.

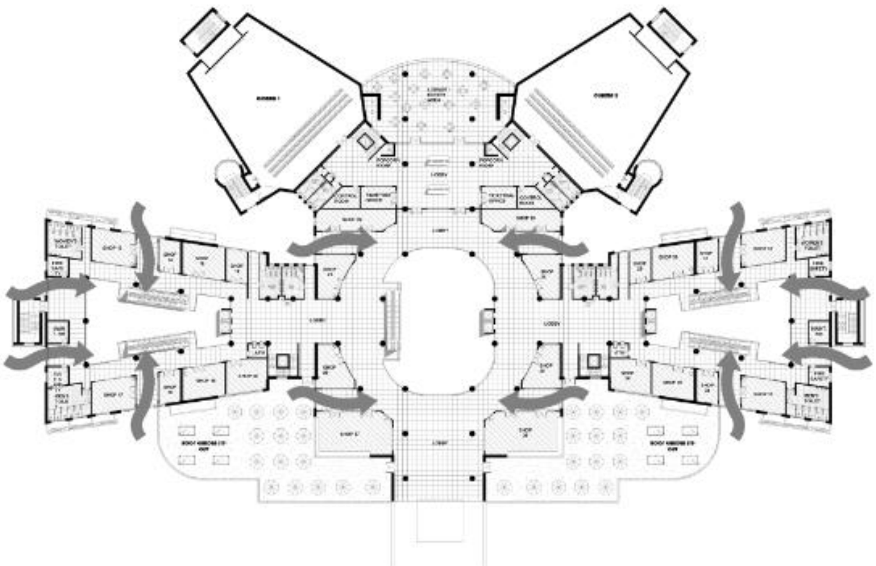


Figure 6: **Air flow schematic diagram**

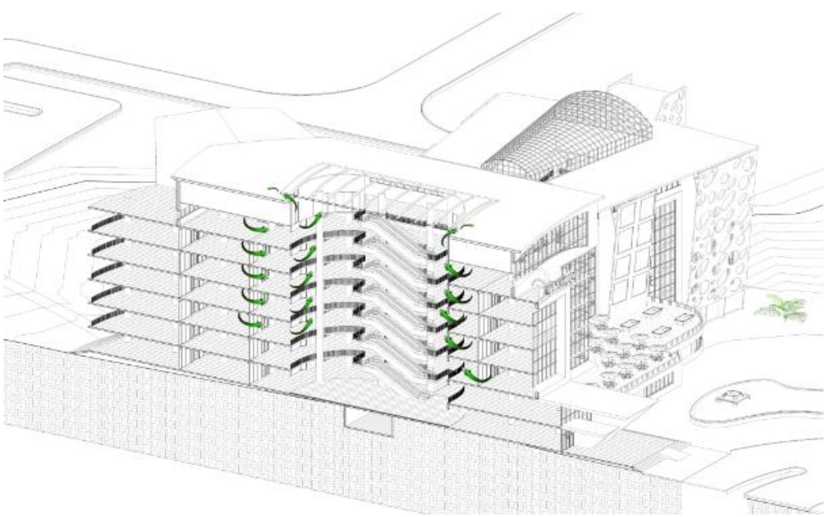


Figure 7: **Stack effect control Mechanism**

Table 8: Basic Assumption of the zones in the Analysis of Energy Consumption

BASIC ASSUMPTION OF THE ZONES IN THE ANALYSIS OF ENERGY CONSUMPTION							
					THERMOSTAT RANGE		
FUNCTIONAL SPACE	LIGHTING LEVEL	NUMBER OF PEOPLE	ACTIVITY	TYPE OF SYSTEM	LOWER BAND	UPPER BAND	HOURS OF OPERATION
Shopping Area	900lux	5	Walking slow 115w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Hyper-market	900lux	70	Walking slow 115w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Cinema Hall	50lux	100	Resting 45w	Full Air Conditioning	18°C	22°C	8:00AM-1:00AM
Basement	400lux	20	Walking 80w	Natural Ventilation	18°C	22°C	8:00AM-11:00PM
Stair case	50lux	15	Walking slow 115w	Natural Ventilation	18°C	22°C	8:00AM-11:00PM
Toilet	50lux	8	Resting 45w	Natural Ventilation	18°C	22°C	8:00AM-11:00PM
Control Room	50lux	3	Walking slow 115w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Circulation Area	900lux	150	Walking slow 115w	Natural Ventilation	18°C	22°C	8:00AM-11:00PM
Office	400lux	3	Reading 55w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Amusement / Games and Bowling Section	600lux	20	Exercise 1100w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Pantry / Food Court	300lux	35	Resting 45w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM
Event Hall	300lux	150	Resting 45w	Full Air Conditioning	18°C	22°C	8:00AM-11:00PM

Table 9: Sustainable Building Components used in the Proposed Design

SUSTAINABLE BUILDING COMPONENTS			
STRUCTURAL MEMBER	MATERIAL	DESCRIPTION	U-VALUE
WALL	MASONRY BRICK WALL	16" BRICK CAVITY WALL WITH INSULATION	0.25w/m²k
FLOOR	SOLID CONCRETE FLOOR SLAP	SOLID CONCRETE FLOOR SLAB FINISHED WITH THERMOPLASTIC TILES INSULATION	0.18w/m²k
ROOF	ALLUMINIUM CORRUGATED ROOF	ALLUMINIUM CORRUGATED ROOF FINISHED WITH 12" FIBERGLASS INSULATION	0.027w/m²k
WINDOW	GLASS	DOUBLE GLAZED WINDOW WITH ALLUMINIUM FRAME	0.70w/m²k
DOOR	WOODEN DOOR	1" THICK WOODEN DOOR WITH TIMBER FRAME	0.64w/m²k

Source: (Combustion Research Corporation, 2016),(kingspan insulation, 2016), (Department of the Environment Building 2005, Regulation technical guidance document, 2005)

Table 10: Monthly Heating / Cooling Load Comparison with Case Study 1

MONTHLY HEATING/COOLING LOADS				
	CASE STUDY 1 (CEDDI PLAZA)	CASE STUDY BUILDING COMPONENTS	SUSTAINABLE BUILDING COMPONENTS	USING LIGHT COLOUR WALL AND ROOF BUILDING COMPONENTS
	TOTAL ENERGY DEMAND	TOTAL ENERGY DEMAND	TOTAL ENERGY DEMAND	TOTAL ENERGY DEMAND
MONTH	(kWh)	(kWh)	(kWh)	(kWh)
Jan	127574.258	489220.781	443570.062	442675.781
Feb	136152.703	489179.094	441121.312	440078.031
Mar	161372.297	571725.438	513389.031	512065.5
Apr	139615.234	519544.781	470174.594	468849.062
May	129342.023	504907.375	460350.188	459021.5
Jun	108567.242	455721.156	419599.312	418238.906
Jul	102736.891	452152.219	416726.688	415438.062
Aug	102626.547	453040	418774.719	417373.125
Sep	95019.32	427273.219	395715.844	394420.094
Oct	117258.016	476273.719	435832.094	434590.938
Nov	112941.531	450742.281	409987.906	409165.875

Dec	117468.766	468114.781	425587.594	424755.469
TOTAL	**1450674.875**	**5757894.5**	**5250829.5**	**5236671.5**
PER M²	**192.497**	**140.085**	**127.749**	**127.404**
Floor Area:	**7536.083 m2**	**41102.750 m2**		
% Energy Reduction		27%	9%	0.30%
TOTAL ENERGY DROP	36.30%			

Table 11: Monthly Heating / Cooling Load Comparison with Case Study 2

MONTHLY TOTAL ENERGY DEMAND				
	CASE STUDY 2 (SILVERBIRD)	CASE STUDY BUILDING COMPONENTS	SUSTAINABLE BUILDING COMPONENTS	USING LIGHT COLOUR WALL AND ROOF
	TOTAL ENERGY DEMAND	TOTAL ENERGY DEMAND	TOTAL ENERGY DEMAND	TOTAL ENERGY DEMAND
MONTH	(kWh)	(kWh)	(kWh)	(kWh)
Jan	426001.219	489220.781	443570.062	442675.781
Feb	452451.656	489179.094	441121.312	440078.031
Mar	536288.188	571725.438	513389.031	512065.5
Apr	461655.531	519544.781	470174.594	468849.062
May	425635.656	504907.375	460350.188	459021.5
Jun	352604	455721.156	419599.312	418238.906
Jul	334173.188	452152.219	416726.688	415438.062
Aug	330767.219	453040	418774.719	417373.125
Sep	306816.469	427273.219	395715.844	394420.094
Oct	385199.375	476273.719	435832.094	434590.938
Nov	378815.531	450742.281	409987.906	409165.875
Dec	392789.969	468114.781	425587.594	424755.469
TOTAL	**4783198**	**5757894.5**	**5250829.5**	**5236671.5**
PER M²	**164.134**	**140.085**	**127.749**	**127.404**
Floor Area:	**29141.971 m2**	**41102.750 m2**		
% Energy Reduction		15%	9%	0.30%
TOTAL % DROP	**24.3%**			

CONCLUSION

The main purpose of this paper is geared to develop theoretical solutions as well as design solutions through passive design approach in order to reduce the annual operational energy demand in shopping mall design within the hot-humid climate of Nigeria. The paper also suggested some sustainable solutions that have been proven to be effective in reducing the energy consumption of the building. After the essential data required for the simulation had been gathered and after importing the data to the energy analysis software, the building was simulated using Ecotech analysis software, and the annual energy consumption of the building was estimated. The annual amount of energy used for case study 1 and 2 buildings was determined to be **1,450,674.875kwh** and **4,783,198kwh** respectively, and the energy consumption per square meter is **192.497kwh** and **164.134kwh** respectively. The results of the study indicated that the use of alternative sustainable building materials, such as 16" brick cavity wall with insulation, solid concrete floor slab finished with thermoplastic tiles insulation, aluminium corrugated roof finished with 12" fiber glass insulation, double glazed window with aluminium frame, 1" thick wooden door with timber frame in the components of the walls, floor, roof, windows and doors, respectively, was more energy efficient than the case study building component as shown in table 9 above. Thus, they have a significant, role in reducing the building's operational energy requirements. Furthermore, at the end of the research the proposed shopping mall was design, modelled and simulated and the results indicate a decrease in the annual operational energy demand by 36.3% and 24.3% with respects to case studies 1 and 2 as shown in table 10&11. Finally, building simulation and investigating the performance of the building virtually in the pre-construction stage will help architects and other consultants to apply suitable passive design principles that will suit a particular local climate and reduces the building annual operational energy.

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