 

# A Comparative Analysis of Energy Performance Index (EPI) of Selected Office Buildings in Jos, Nigeria

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**Abstract**
Energy Performance Index (EPI) is a parameter used to appraise and examine office, residential and commercial building energy efficiency during design, construction, renovation and operations. Similar buildings in North America and Europe have EPI of less than 150 kWh/sq m/year. Energy-conscious building design has been shown to reduce EPI to 100 to 150 kWh/sq m/year in India. However, this research indicates an EPI of between 21 to 41 kWh/sq m/year here in Nigeria. This gives an average of 31 kWh/sq m/year for the three (3) buildings studied. This low EPI is not unconnected with the fact that these Buildings lack HVAC equipment and other energy consuming devices that are required standards in developed and some developing regions. On the positive side, this low EPI indicates that the Carbon Emission Footprint of these buildings studied are low.
**Keywords:** Energy Audit, Energy Performance Index, Energy Conservation, HVAC Equipment, Office Productivity.

## 1.0 INTRODUCTION

According to Marszal (2008), buildings globally account for 40% of the primary energy used and, 24% of the green-house gas emissions. In support of this, Crawley (2008) stated that in developed countries, buildings are the single largest user of electricity.

Also, energy is regarded as the prime mover of any economy, and the engine of growth around which all sectors of the economy revolve (Adeniran, 2004). However, Nigeria generates, on the average 4,000 megawatts of power as oppose to the calculated demand of 40,000 megawatts. This conundrum is made worse by an ever-increasing demand for power (Babatunde & Shaibu 2008). It therefore follows that in a cash-strapped developing economy such as Nigeria, the need to judiciously utilize and account for the meager energy that is being generated becomes paramount. Hence the need to establish an Energy Performance Index of buildings of selected government office buildings.

Nnaji (2012), stated that despite the challenge of low energy generation and distribution in Nigeria, government agencies are the most critical sources of the power generating company's illiquidity. Establishing the Energy Performance Index of government buildings will therefore be part of the solution to the energy crisis as this will serve as an incentive and a Test-Bed for energy policy formulation by government agencies. Research conducted by Doris, Cochran, & Vorum. (2009) & IEA (2011) show that due to the factor of scale, government policies formulation as energy conservation tool, are the most effective mean of tackling energy crisis. The recent Building Energy Efficiency Guideline (BEEG) proposed by Nigeria government also comes to mind here.

An exhaustive Energy Performance Index would, by analysis, provide resolutions as to the appropriate use of available technology and understanding of environmental conditions and inherent virtues in the existing building technology in Nigeria.

## 2.0 STATEMENT OF THE PROBLEM

Research activities so far executed on energy performance in Nigeria have largely been limited to industrial sectors, academic institutions or investigations into climatic influences as a function of thermal comfort measurement as indicated by users. The preferred method of assessment has mainly been simple audit that is commonly referred to as Walkthrough. In Unachukwu (2010) for instance, after data collection as to energy use where established, it proposed an Energy Management Unit for a University under study. While, in Akpama & Okoro (2010), data was obtained through inspection, survey and analysis of energy flows in the institution studied. Here, changes in user behaviour were highly recommended as an energy saving measure. However, Adekunle et al (2008) presented the results of a walk-through energy audit conducted in a university and recommends means of tackling the problem from the demand end by focusing on the areas of potential savings flagged by the energy audit. In Ogunsote & Ogunsote (2003), the emphasis was the analysis of different comfort parameters or indices with special reference to the climate in Nigeria. Ogbonna (2008), took it further in his research conducted in Jos, Nigeria. The research was based on domestic energy demand for different living spaces in different house types. Energy outflow levels were also calculated while thermal comfort ranges were established.

An exception is Mu'azu (2011), this research, conducted in Abuja-Nigeria, falls within the ambit of a comprehensive general audit and it carried out energy audit of government buildings in Abuja. Using SPSS based correlation analyses; it was able to garner information useful to the architects in understanding the relationship between their design decisions and energy use implications in the context of a developing country.

In this instance, energy analysis for the purpose of assessment of performance index was obtained from measured data as opposed to audited data. An E2 Wireless Electricity monitor was used to evaluate (See Fig 2 and 3). eQUEST 3-65 software was used for the purpose of simulation of energy consumption (See Fig 6). All of these have not been carried out for office buildings in Nigeria. These are the gaps in knowledge that this research intends to be focused on.

## 3.0 AIM OF THE STUDY

The aim of this study is to evaluate the Energy Performance Index (EPI) of some selected office buildings in Jos, Nigeria. This is to establish relative energy efficient in comparison to other regions of the world.

### 3.1 Building Energy Performance Index

According to the National Academy of Sciences (2010), "one very rarely encounters an explicitly stated definition of "energy efficiency." However, building energy efficiency can be defined as the provision of a constant level of energy service while using less energy (Goldstein & Eley, 2014).

Literature reveals that the terms Energy Efficient Indices or Energy Performance Index have been used interchangeably (See Bassi, 2015., Larsen & Ditlefsen, 2013). However, Energy Efficient Indices or Energy Performance Index are parameters used to appraise and examine office, residential and commercial building energy efficiency during design, construction, renovation, and operation of a building under research. These indices work by answering question such as: "How does the energy intensity of this building compare with its peers and by extension, how efficient is this building?" These questions are paramount in the context of a comprehensive energy management program that would be required in the pre and post construction evaluation in the context of energy performance analysis.

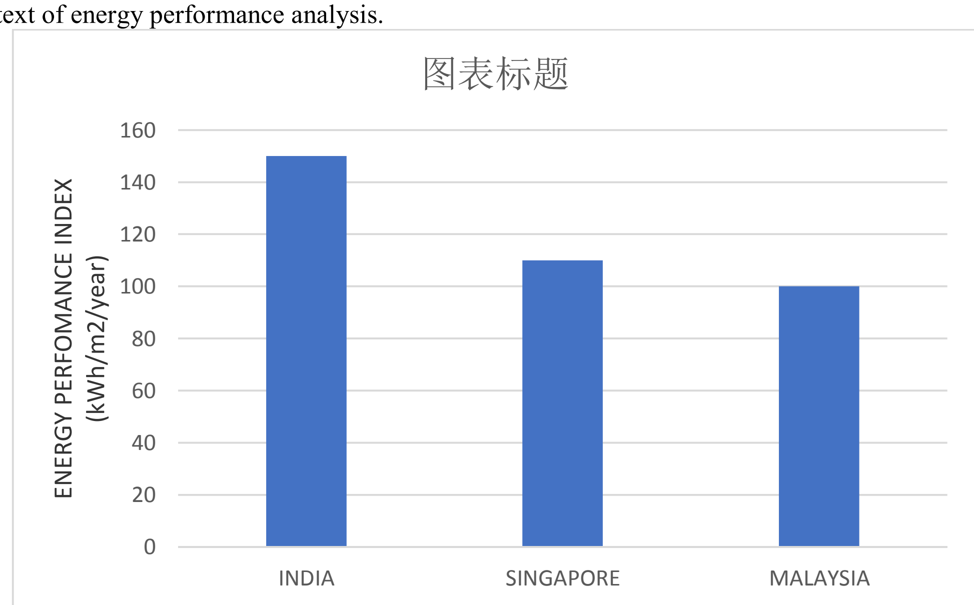


Fig 1: Average Energy Performance Index of Office Buildings in Some Third World Countries.

## 4.0 METHODOLOGY OF STUDY

The study was carried out in the month of April 2014 in Jos, Nigeria. The location had an altitude above sea – level of 1286 meters. The GPS location is given as Lat. (N) $9^0$ 58' 01.83 and Long. (E) $8^0$ 52' 21.63. All offices under study were selected randomly, east-facing and naturally ventilated (NV). The period of study was between 8.00hrs and 15.00hrs week days.

Measurements were taken at hourly intervals within working hours. (See Fig 7). Objective data obtained from Measurement Instruments were put through Bar Graphs and Tables. The instruments enumerated below were used to obtain objective data as tabulated in Table 1 Figure 7.

The evaluation of building energy performance would require the understanding of the interaction of an engineered system (Gross floor area in m2) with operation and maintenance (O&M) practices vis-à-vis occupant demands and behaviour (Total building energy consumption in kWh/year). In other words, post construction building energy management is efficient and contextual, when it is based on quantitative and objective measurements and predictions. These measurements are therefore a function of total building energy consumption (kWh/year) and Gross floor area (m2). The calculation is thus:

Calculation of Energy Performance Indices (EPI):

EPI = TBEC / GFA

where:

a) TBEC: Total building energy consumption (kWh/year)

b) GFA: Gross floor area (m2)

Using this method, Bassi (2015), opined that most buildings in North America and Europe have EPI of less than 150 kWh/sq m/year. Energy-conscious building design has been shown to reduce EPI to 100 to 150 kWh/sq m/year in India (Bassi, 2015). The research conducted by Larsen & Ditlefsen (2013) indicated that most office buildings in Malaysia and Singapore have Energy Efficient Index greater than 100 kWh/m2/year (See Fig 9).

**4.1 Wireless Electricity Monitor**

An E2 Wireless Electricity monitor was used to evaluate, in real time, electricity consumption of the building under research. This is attached by a CT Sensor to the live cable of the service panel. The CT Sensors relays the amount of current being drawn to the transmitter and ultimately to the monitor. The monitor records time, date, energy used and carbon emission as a result of energy consumption. It has a voltage range of 110v to 400v and a measuring current of 50mA to 200A (See Fig 2 and 3).

**4.2 Global Positioning System**

A Cobra GPS 100 global Positioning System receiver was used to obtained global location of building of interest. This device provided accurate positioning to within 3 meters, if held in any position open to the sky. It offers information as to current positioning, altitude above sea level, bearing and time of the day.

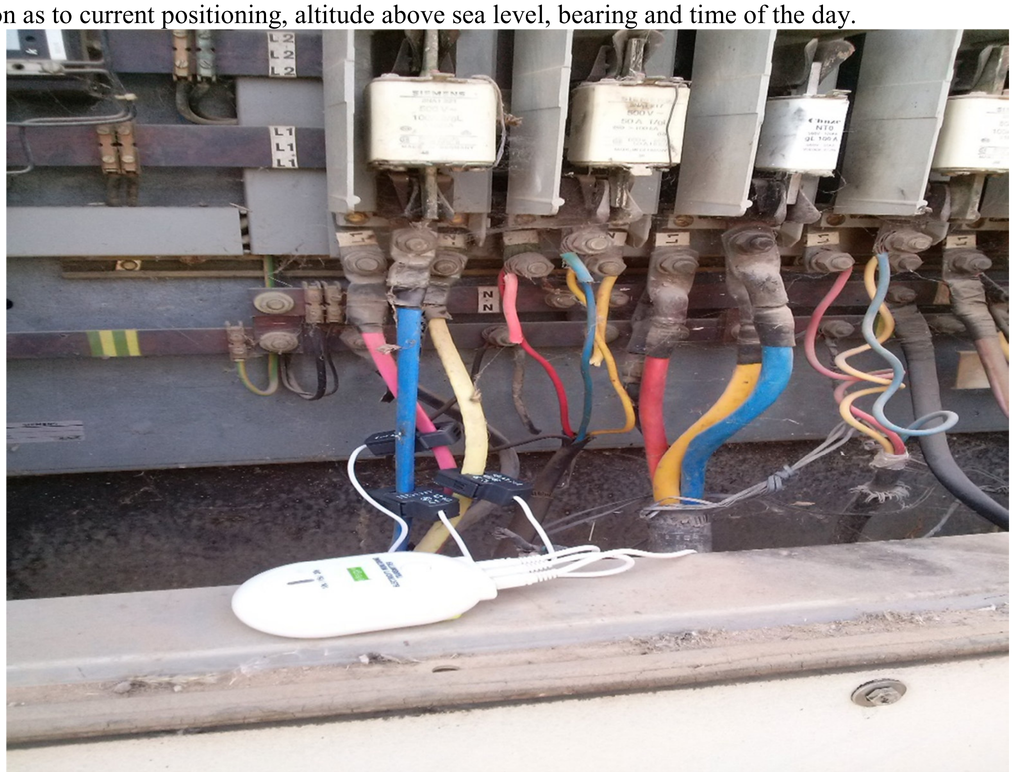

Fig 2: Wireless Energy Monitoring Device Installed at Point of Supply in Office Building.

 

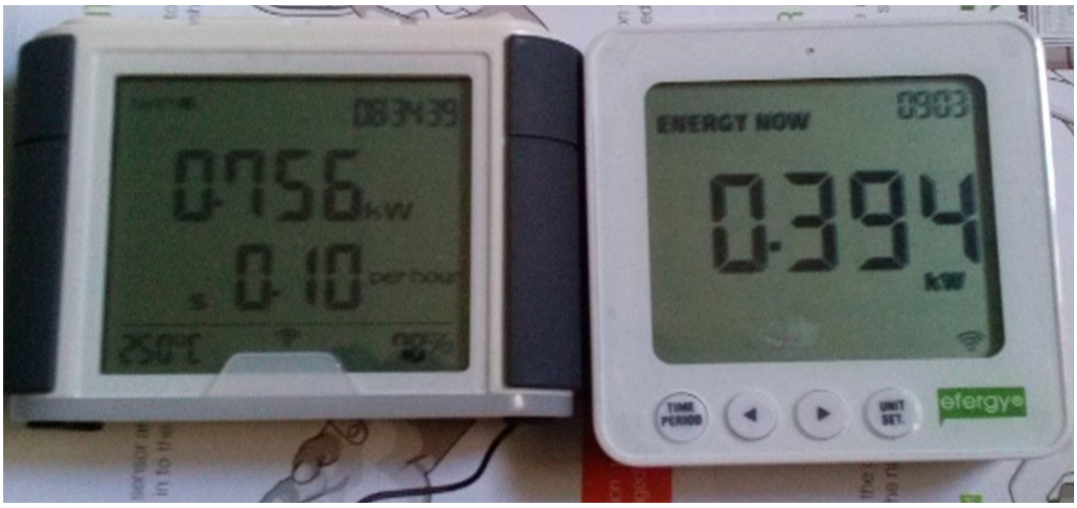

Fig 3: Wireless Energy Monitoring Devices Indicating Readings.

**4.3 The Buildings**

Out of the ten (10) buildings studied, three (3) were randomly selection for computerized energy use analysis (See Table 1 and 2). All the buildings studied had Ground Floor Slabs composed of 300mm Non-Reinforced Concrete Slab, while one (1) had Upper Floor slabs consisting of 150mm Reinforced Concrete Slab. 50% had floor is finished with Cement Sand Screed overlaid with Terrazzo (See Fig 4 and 5).

They all had 230mm Hollow Sandcrete Blocks finished with 13mm Cement/Sand Mortar rendered smooth with Emulsion Paint. They all had casement aluminum windows with 5mm thick glass infill and Wooden Flush Doors in Metal Frames. They all had Ceilings that are 13mm Cement/sand plaster to upper floor slab while Ceiling type for the ground floor buildings are 5mm Asbestos Ceiling Boards. The Roofs are made of long span Aluminum Roofing Sheets. Further building parameters required for simulation are enumerated in Table 1.


Fig 4: Typical Office building Studied. (Building ID: UJ ADMIN).

Fig 5: Typical Double-loaded Corridor in Building ID UJ ADMIN.

**5.0 FIELDWORK**
The field work consists of obtaining objective data for the purpose of analysis. Objective data was obtained from measurement instruments.

**5.1 Sample Area Characteristics**
Jos, plateau state characterized by rocky terrain (topography) giving rises to plateaux and plains, hills and valleys. It enjoys a unique climate (temperate climate) than must of the rest of Nigeria. Jos is located in Jos-North local government area of the state. It is at an altitude of 1,217m (3,993ft) above sea level. The wet season starts from April – October and the dry season starts from November- march. The mean annual rainfall here is about 320mm in the month of august with an average monthly temperature ranging from 21$^{O}$C-25 $^{O}$C. From mid-November to late January, night time temperatures drop as low as 11$^{O}$C. Daily solar radiation averages over 4300wh/m2 per annum annually. For most periods in the year, the sun sets in at relatively low altitudes at the West and conversely rises from the East.

Data acquisition for the purposes of Energy performance Index assessment was carried out in Jos, Nigeria. The studies were executed in four (4) different administrative buildings within Jos city, Nigeria. In all, four (4) survey sessions were conducted in this Naturally Ventilated (NV) building in the month of April 2014. In obtaining objective data using instruments earlier enumerated, there was the need to conduct the instrument data session for all offices in each randomly selected building simultaneously on same day. This is to ensure integrity and interoperability of data collected.

**5.2 Methods of Objective Data Analysis.**
For objective data from instruments, data presented were analyzed using simple bar graphs and percentages. This is to grant visual correlation to relationships between the variables under study. This enhances understanding of subsequent objectives inputs and inferences.

**5.3 Simulation Analysis**
The energy performance simulation tool used for this purpose is the eQUEST 3-65 (Fig 6). The simulation was

 

carried out using the Modeling Parameter in Table 1. Literature review reveals that Tampa, Florida has the closest weather attributes to Jos, Nigeria.

This simulation was for one-year period and it showed a primary area of energy consumption as Area Lighting, Task Lighting and Miscellaneous Equipment. Energy consumption readings were obtained in hourly bases from the start of a typical working day to its close (8hrs to 15hrs) (See Fig 9). It should also be noted that all the building studied had no central HVAC equipment (See Table 1).

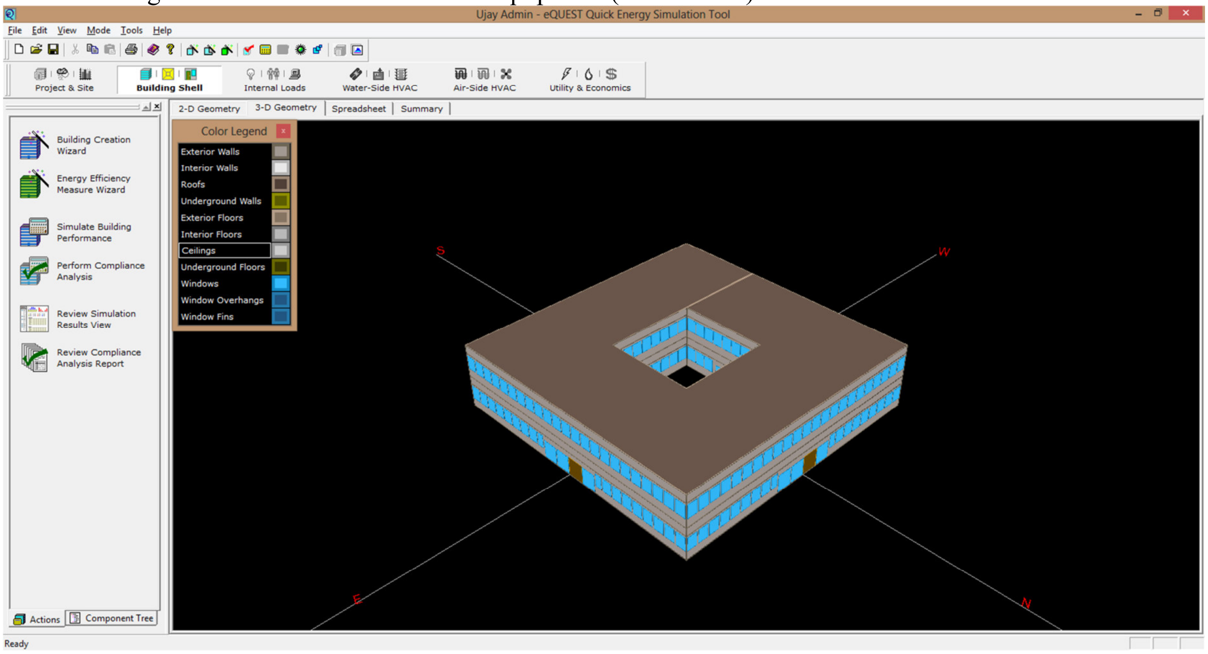


Fig 6: Sample of Computer Simulated Model.

**Table 1: Input and Output Data for Measured and Simulated Schemes.**

| MODELLING PARAMETER | BUILDING ID | | |
|---|---|---|---|
| | UJ/ADMIN | NIPSS/ADMIN | MIN/LSTP |
| **SHAPE OF BUILDING** | SQUARE/ATRIUM | RECTANGLE | RECTANGLE |
| **ENERGY ZONING PATTERN** | 1 PER FLOOR | 1 PER FLOOR | 1 PER FLOOR |
| **FLOOR HEIGHT** | 10FT | 10FT | 10FT |
| **NUMBER OF FLOORS** | 2 | 2 | 1 |
| **WEATHER FILE** | WEATHER DATA TAMPA FLORIDA | WEATHER DATA TAMPA FLORIDA | WEATHER DATA TAMPA FLORIDA |
| **HVAC EQUIPMENT** | NONE | NONE | NONE |
| **BUILDING AREA** | 1,524 $m^2$ | 648 $m^2$ | 273 $m^2$ |
| **USAGE DETAIL** | 8AM TO 3PM | 8AM TO 3PM | 8AM TO 3PM |
| **SEASON CYCLES** | 2 | 2 | 2 |
| **SEASON PERIOD** | 01/03 to 30/09 and 01/10 to 30/04 | 01/03 to 30/09 and 01/10 to 30/04 | 01/03 to 30/09 and 01/10 to 30/04 |
| **OCCUPANCY RATE (%)** | 90 | 70 | 50 |
| **DAYLIGHT CONTROL** | NONE | NONE | NONE |
| **ENERGY SIMULATED** | 5.78 kWh | 1.91 kWh | 0.98 kWh |
| **ENERGY MEASURED** | 4.07 kWh | 1.33 kWh | 1.11 kWh |
| **LEVEL OF ACCURACY** | 70.4% | 69.6% | 88% |
| **PERFORMANCE INDEX ($M^2$/kWh/Year)** | 32 | 41 | 21 |
| **CARBON EMISSION/HOUR** | 2.27 KgCo2 | 0.74 KgCo2 | 0.69 KgCo2 |
| **CARBON EMISSION/$M^2$** | 671.4 | 875.7 | 395.7 |

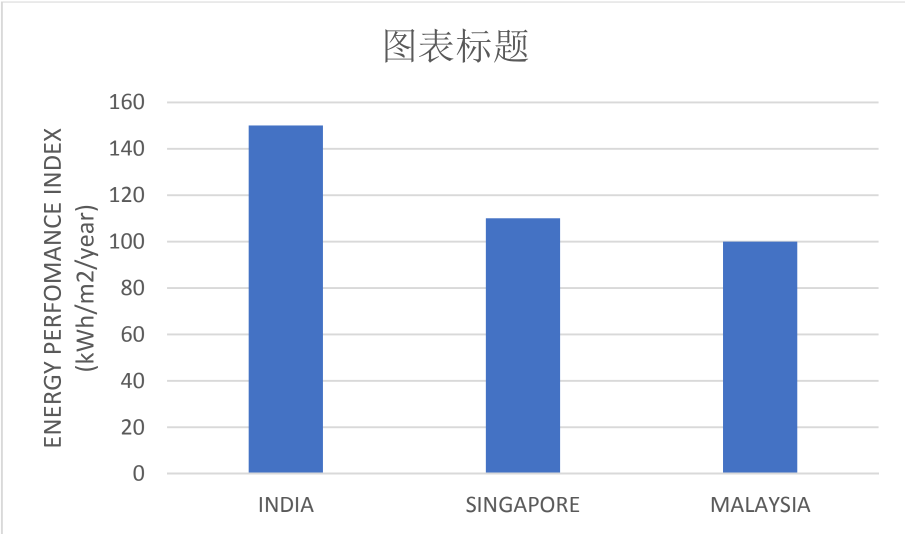


Fig 7: Average Energy Performance Index of Office Buildings in Some Third World Countries.

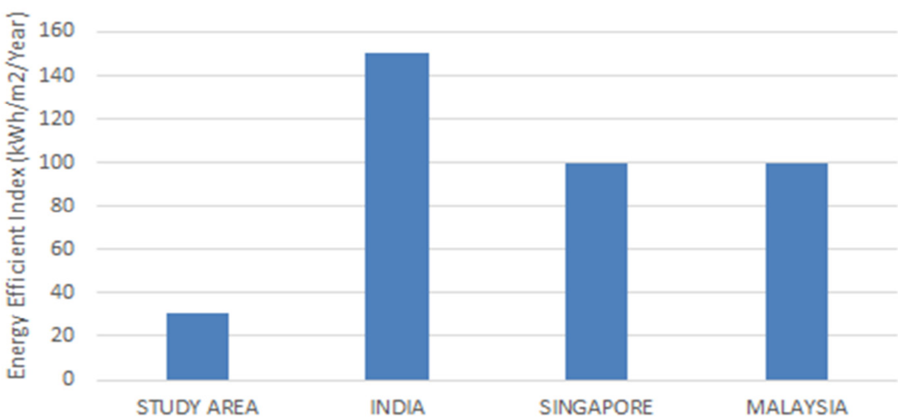


Fig. 8: Average Energy Performance Index of Office Buildings in Some Third World Countries Including Study Area.

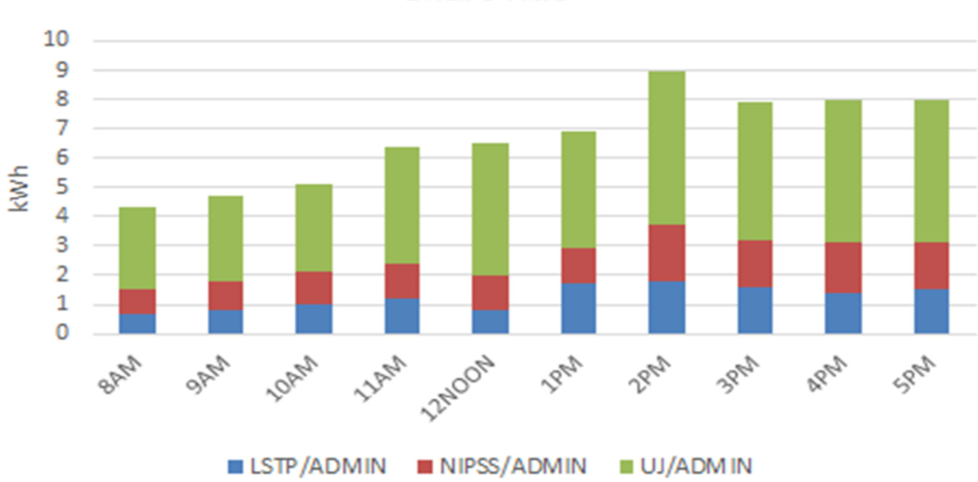


Fig 9: Combined Graph of Real Time Energy Use (Average Kwh Every Hour) For Buildings Measured.

**6.0 ANALYSIS OF FINDINGS**

Table 1 shows an EPI of between 21 to 41 kWh/sq m/year for the building studied here in Nigeria. This gives an average of 31 kWh/sq m/year for the three (3) buildings studied. Superficial observation of data obtained by simulation indicates that buildings with smaller floor area had better EPI results. Only two (2) of the buildings studied had same rectangle shape. The effect of this shape on EPI would be a subject of further study.

This general low EPI is not unconnected with the fact that these Building lack HVAC equipment and other energy consuming devices that are required standards in developed and some developing region. On the positive side, this low EPI indicates that the Carbon Emission Footprint of these buildings studied are low. For similar buildings in North America and Europe have EPI of less than 150 kWh/sq m/year (See Table 2).

**Table 2: Average Energy Performance Index (EPI) of Office Buildings in Some Third World Countries and Nigeria**.

| S/NO. | BUILDING/ REGIONS | PERFORMANCE INDEX (/kWh/ $M^2$YEAR) |
|---|---|---|
| 01 | UJ/ADMIN | 32 |
| 02 | NIPSS/ADMIN | 41 |
| 03 | MIN/LSTP | 21 |
| 04 | INDIA | 150 |
| 05 | SINGAPORE | 100 |
| 06 | MALAYSIA | 100 |

Source: Larsen and Ditlefsen (2013) and Author's field work.

## 7.0 CONCLUSION

Similar buildings in North America and Europe have EPI of less than 150 kWh/sq m/year (See Table 2). Energy-conscious building design has been shown to reduce EPI to 100 to 150 kWh/sq m/year in India (Bassi, 2015). According to research conduct by Larsen and Ditlefsen (2013), most office buildings in Malaysia and Singapore have Energy Efficient Index greater than 100 kWh/m2/year. However, Table1 shows an EPI of between 21 to 41 kWh/sq m/year for the building studied here in Nigeria. This gives an average of 31 kWh/sq m/year for the three (3) buildings studied. The absence of certain energy consuming equipment that are essentials in developed climes might be the reason. Examples are HVAC devices and other modern office paraphernalia. On the positive side, this low EPI indicates that the Carbon Emission Footprint of these buildings studied are low.

This research has been able to establish substantial implementable findings in the areas of Energy Performance Index using administrative buildings as Test-Bed. This should lead to significant understanding and energy savings in administrative buildings. The incentive for this savings to be transformed into energy conservation policy for downward implementation becomes high. Substantial implementation of these energy conservation policies would lead to cumulative saving for government and corporate bodies locally. Globally, the long-term benefit of this would be sustainable designs which will in-turn reduce environmental challenges such as global warming.

## 8.0 RECOMMENDATION

1) This research was conducted in the month of April 2014 in Jos, Nigeria. It coincides with the beginning of rainy season in the sub-Saharan region of which the research was conducted. There would also be the need for similar research to be conducted in other seasons and other location within developing countries, thereby exposing this research framework and associate tools to further use and thus granting validity to these tools. This would facilitate a complete and comprehensive picture of energy performance assessment for administrative buildings in sub-Saharan region of Africa.
2) The common challenge of using energy simulation softwares in developing regions is that the gamut of material type used in building construction in these regions are not adequately represented in these softwares. Also, most developing countries lack jurisdiction building codes which is also a required input in these softwares. This limits the ability of these tools to accurately predict thermal performance of buildings in sub-Saharan regions. Energy simulation tools with broader technical capability would be needed for future research.
3) Two (2) of the buildings studied had similar rectangle shape. Further studies may be required to establish the effect of building shapes and orientation on EPI.

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