An Assessment of Energy Performance Index of the Nigerian Universities’ Senate Building

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Abstract. Apparently, Nigeria is struggling with the developmental issues of the incessant power outage and lack of energy services. The primary sources of energy for office building are from national grid and gasoline generators. However, the former is not reliable and the latter is unsustainable; hence, the need to explore energy efficiency strategies to cut down the energy demand for cooling office building in Nigeria is unavoidable. The article aimed to assess the energy efficiency or performance index of the Nigerian Universities’ senate buildings in the north-eastern region (dry sub-humid climate). The research employed a case study approach, construction of baseline model with the Revit architecture software and applied DesignBuilder building analysis software to evaluate the energy performance of the senate building as built. The research findings showed that energy efficiency indexes for both universities’ senate buildings (57% and 63%) which were relatively below the recommended standard checklist. Also, the simulation results further showed that both case studies require 141.4wh/m² and 127.3wh/m² heating/cooling per annum compared to the stipulated LEED (Leadership in Energy and Environmental Design) standard of 15wh/m². Therefore, research implication is that it is essential for the architects and engineers to incorporate more proactive energy efficiency strategies in the design of office buildings in Nigeria.
1. Introduction

University Senate Building is a structure built to serve the central administrative function in university campuses, design to accommodate offices, exhibition hall, senate chamber, governing council chamber and other necessary facilities. The university senate is the agency for the articulation and representation of the views of the faculty [1]. Some buildings are said to consume more energy than others; office buildings consume a great deal of energy. Sadrzadehrafiei, Sopian, Mat, Lim, Hashim & Zaharim [2] asserted that great deal of energy is consumed by office buildings in Nigeria. Therefore, reduction in the quantity of energy consumed is inevitable; reduction of energy consumption in buildings can be achieved by simple methods and techniques using an appropriate energy-efficient system such as passive cooling system [3]. On the other hand, if the existing institutional structures in Nigerian universities were designed with least focus on energy efficiency in the past, built environment professionals especially practicing architects, engineers and students can still change the direction of the practice to a more efficient way of energy conservation. However, despite the numerous benefits of passive cooling strategies practicing Architects still linger between theory and practical application. Thus, the article aimed to assess the energy efficiency or performance index of the Nigerian Universities’ senate buildings in the north-eastern region (dry sub-humid climate).

2. Literature Review

2.1 Sources of energy supply in relation to energy efficiency in Nigeria

The energy crisis, which has engulfed Nigeria for almost two decades, has been enormous. Ref [4] explained the quantity of electricity generated, transmitted and distributed in Nigeria as summarized in Figure 2.1.

![Figure 1 The structure of Nigerian National Electricity Grid](image)

The megawatts are certainly too low, to be dependent upon, it is in this regard that this research proposes energy efficient model for office building.
The triangle for low energy building design is shown in Figure 2. Energy savings in Nigeria will lead to personal income saving; reducing the building of more power stations allowing the funds to be spent on other sectors of the economy; improve access to energy; and decrease load shedding.

Buildings contribute more than one third of total global greenhouse gas emissions and consume more than 50% of energy in Nigeria; therefore, Architects should explore and apply the existing research findings that optimize passive cooling.

2.2 Contemporary Methods of Passive Cooling

Recent review papers [6] which collated individual studies from a broader spectrum of climatic regions agree that cooling strategies for buildings should be designed at three levels such as solar and heat control, heat modulation and heat dissipation using naturally driven phenomena.

2.2.1 Solar and heat protection techniques

The most effective method to save energy and cool the building is to keep the heat from building up in the first place [6]. Solar and heat can be avoided through two techniques namely: microclimate of an urban area can be modified by appropriate landscaping techniques, with the use of vegetation and water surfaces; and shading. Among all other solar passive cooling techniques, solar shading is the most relevant to thermal cooling of buildings especially in a developing country owing to their cost effectiveness and easy to implement [7].
2.2.2 Modulation of heat gains

Heat modulation is associated with high thermal mass materials, like brick and concrete, in building structures that act as a storage for heat during daytime and cold at night. Modulation of heat gains is subdivided into two such as: Insulation whose effect is to reduce heat gain and heat loss [10] and thermal mass which stipulates that the time lag needs to be very long to delay the penetration of heat until the evening. However, insulation is typically a better option [6] because thermal mass requires very heavyweight construction.

2.2.3 Heat dissipation technique (Remove internal heat)

Effective dissipation of the excess heat depends on two main pre-conditions: (a) The availability of a proper environmental heat sink with sufficient temperature difference for the transfer of heat and (b) the efficient thermal coupling between the building and the sink [6].

3. Research Methodology

3.1 Environment and Material Settings for the Experiment

The research employed a case study approach, construction of baseline model with the Revit architecture software and applied DesignBuilder building analysis software to evaluate the energy performance of the senate building as built and the interpretation and presentation of results in various tables and charts.

| General Information on Case Studies |
|-------------------------------------|
| **Location** | Case A                   | Case B                   |
| Latitude & Longitude | 10°18’57” N; 9°50’39”E | 9°13’48” N; 12°27’36”E |
| Activity Period | 5 days a week from 08:00am to 05:00pm | 5 days a week from 08:00am to 05:00pm |
| Occupants’ Activities | Mostly paper based | Mostly paper based |
| Wall composition | sandcrete blocks (225mm); internal and external rendering (12.5mm); finished with medium | Ivory emulsion sandcrete blocks (225mm); internal and external rendering (12.5mm) |
DesignBuilder is building analysis software that allows user to easily design and work in 3D; it offers a wide range of analysis options from acoustics to energy efficiency tools. The simulation runs on average hot season day (5th April) also, it is important to note that the general parameters for the simulation are summarized in Table 1.

### 4. Results

#### 4.1 Monthly heating/cooling loads

Heating Cooling loads of air conditioning system working with 95% efficiency and 14m² per person at a state of office activity (55W) is considered for the calculations. The spaces observed are described in the following subsections

| Senate buildings |
|------------------|

Table 2 Monthly heating/cooling loads for cases A and B

| MONTH | HEA A (kWh) | COOL. A (kWh) | HEA B (kWh) | COOL. B (kWh) |
|-------|-------------|---------------|-------------|---------------|
| Jan   | 0           | 468.384       | 0           | 2299.477      |
| Feb   | 0           | 7131.288      | 0           | 17730.912     |
| Mar   | 0           | 26365.46      | 0           | 46806.129     |
| Apr   | 0           | 58443.12      | 0           | 84051.719     |
| May   | 0           | 63080.76      | 0           | 89620.016     |
| Jun   | 0           | 54036         | 0           | 77672.07      |
| Jul   | 0           | 39352.02      | 0           | 58138.551     |
| Aug   | 0           | 21149.49      | 0           | 45894.27      |
| Sep   | 0           | 23829.49      | 0           | 43102.422     |
| Oct   | 0           | 31048.23      | 0           | 59567.117     |
| Nov   | 0           | 1381.722      | 0           | 11145.439     |
| Dec   | 0           | 128.565       | 0           | 1291.624      |
| Total | 326414.64   |               |             | 537319.746    |

The thermal comfort zone is chosen as 18-28°C for the temperature band that the calculation would take place according to the standards [8-9] Standard 55-2000R) applied to the Yozgat weather data, 2002. However, due to geographical location and climatic condition of dry sub-humid zone, the total annual energy required for heating is very small (which can be negligible) and it’s only required for few hours in the two coldest months of the year which are January and...
December. For both cases A and B, the coldest months are January with 468.384kwh and 2299.477kwh respectively; and December with 128.565kwh and 1291.624kwh respectively, while the hottest month is May with 63080.76kwh and 89620.016kwh respectively, see table 2.

The possible reasons for case B requiring a lot of energy for cooling may be connected to the fact that the senate building does not have enough shading devices, the landscapes are limited to the backyard of the building neglecting walkways, paving to receive and reflect excessive solar radiation and due to the presence of the hard landscapes from the eastern side of the building. Conversely, case A building is compacted and receives cross ventilation. It comprises of four square blocks of offices connected by an octagonal atrium, as such the orientation of the building as a whole is relatively good because the longer side faces north and south, these may account for the reasons why case A requires lesser energy for cooling throughout the year.

II. Council Chambers

| MONTH | HEA B (kWh) | COOL. B (kWh) | HEA A (kWh) | COOL. A (kWh) |
|-------|-------------|---------------|-------------|---------------|
| Jan   | 0           | 32.36         | 0           | 0             |
| Feb   | 0           | 300.896       | 0           | 125.403       |
| Mar   | 0           | 912.891       | 0           | 486.853       |
| Apr   | 0           | 1655.246      | 0           | 1019.876      |
| May   | 0           | 1789.111      | 0           | 1111.967      |
| Jun   | 0           | 1538.775      | 0           | 947.619       |
| Jul   | 0           | 1206.649      | 0           | 729.012       |
| Aug   | 0           | 947.293       | 0           | 420.783       |
| Sep   | 0           | 892.097       | 0           | 430.406       |
| Oct   | 0           | 1224.386      | 0           | 574.358       |
| Nov   | 0           | 134.921       | 0           | 3.082         |
| Dec   | 0           | 15.405        | 0           | 0             |

Case B’s council chamber requires more energy for cooling, see figure 6, then case A. This is because case B’s apertures for council chamber face the east and does not have cross ventilation and shading devices. Case B’s council chamber faces south and has balconies as shading devices as well as deciduous trees from the south elevation.
III. VC’s Offices

Table 4 Monthly heating/cooling loads

| MONTH | HEA B (kWh) | COOL. B (kWh) | HEA A (kWh) | COOL. A (kWh) |
|-------|-------------|---------------|-------------|---------------|
| Jan   | 0           | 34.683        | 0           | 0             |
| Feb   | 0           | 282.702       | 0           | 67.624        |
| Mar   | 0           | 819.425       | 0           | 282.359       |
| Apr   | 0           | 1509.973      | 0           | 663.783       |
| May   | 0           | 1622.735      | 0           | 715.997       |
| Jun   | 0           | 1393.821      | 0           | 610.17        |
| Jul   | 0           | 1065.179      | 0           | 409.508       |
| Aug   | 0           | 834.885       | 0           | 165.472       |
| Sep   | 0           | 797.043       | 0           | 208.454       |
| Oct   | 0           | 1097.303      | 0           | 299.573       |
| Nov   | 0           | 140.605       | 0           | 0             |
| Dec   | 0           | 12.866        | 0           | 0             |
|       | 9611.22     | 3422.94       |

Case B’s VC’s office has more energy load followed by case A, see figure 4.6. This is because case A has better depth to span ratio and orientation.

4.1.1 input and output data for the case studies

The data input and output obtained for case A are summarized in figure 8

Figure 8 input and output for case A (source: field work)

The data input and output obtained for case B are summarized in figure 9

Figure 7 Monthly energy load for VC’s office of case A and B

for the VC’s offices of cases A and B
5. Conclusion

From the results presented above, it is observed that case A is more sustainable than case B. This may be connected to the fact that majority of the offices in case A are ensured with cross ventilation and vegetation.

1- Case A requires 127.3kwh/m² annual energy
2- In case B, as high as 141.4kwh/m² of heating/cooling required per annum;
3- These results are far away from the British American standards of 15kwh/m² or even the standards for Ireland of 120kwh/m² for energy efficient office buildings.

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