Energy Performance of Selected Administrative Buildings in Tertiary Education Institutions in Niger State, Nigeria

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The adverse effect of huge energy consumption of buildings on the global climate had made buildings object of research globally. Monitoring energy use had been the practise in most developed nations towards energy efficiency. However, developing nations including Nigeria are lagging behind in this noble objective which was visible in the absence of local energy benchmarks. Moreover, tertiary institutions globally had been admonished to ensure energy efficiency of their buildings as part of their corporate responsibilities. Meanwhile studies have revealed lack of empirical studies on energy use, most especially buildings in tertiary institutions in Nigeria where bulk metering is the usual practice thereby; making energy consumption of individual building remains unknown. Based on this premise, this study had assessed the operational energy performance of three administrative office buildings in Federal University, Polytechnic and College of Education in Niger state, Nigeria. The study was exploratory in nature via case study approach in the absence of energy bills by simple energy audit exercise and data was analysed using descriptive statistics. The findings revealed that none of the buildings had been audited before or took advantages of renewable energy but shared commonalities in terms of building parameters and sources of energy. Furthermore, energy end-uses disaggregation shown that cooling loads accounted for more than 45% of annual energy use, which was in accordance with global reports on similar buildings. Also, the derived Energy Use Index of 181.34 KWh/m\textsuperscript{2}/yr was above the global best practices of 128 KWh/m\textsuperscript{2}/yr and 130 KWh/m\textsuperscript{2}/yr according to South Africa Building Regulation SANS 10400-XA and Chartered Institution of Building and Service Engineers benchmark respectively. These results implied that the buildings are not energy efficient. Therefore, the need for effective monitoring of energy consumption by sub-metering and auditing of buildings in tertiary institutions and orientation should be given proper attention.

Keywords: Administrative buildings, Energy consumption, Energy efficiency, Energy end-uses, Global climate, Sub-metering, Tertiary institutions.

Introduction
Energy use in building sector and its related activities had been found to be significant to the global energy consumption (Rai, 2004). Studies have revealed that buildings consumed between 30-45% of the global energy supply (Huovila \textit{et al.}, 2007; Asimakopoulus \textit{et al.}, 2012) and this has makes buildings central to global energy use (Rowe \textit{et al.}, 2008). In this light, buildings have become object of research; this is not unconnected to the impact of their huge energy demand on the environment which is visible in the menace of climate change which has become a threat to human survival. However, most developed nations have gone to the extent of establishing benchmarks and standards for various building categories and components towards energy reduction of built environment. Meanwhile, inadequate empirical studies on building energy use had resulted into paucity of energy data and absence of energy benchmarks in Nigeria (Muafzu, 2011).
Moreover, Tertiary institutions are indispensable organisations globally because of the critical services being rendered to the nations. The cores of their services are to create and disseminate knowledge via effective teaching and learning processes (Pereira & Da Silva, 2003); these noble services are performed within the building facilities on campuses (Building Research Energy Conservation Support Unit [BRECSU], 1997). However, colleges and universities had been classified has as high energy consuming organisations owing to possession of large stock of buildings that sometimes runs to hundreds (European Commission Joint Research Centre [ECJRC], 2012) and subsequently are expected to report their energy use and improve their efficiency as part of their cooperate responsibilities (Maimunah & Shehu, 2010). United Kingdom was a notable example where energy benchmarks and assessment methodologies existed for different space types in tertiary institution buildings. However, the major shortcoming of the assessment methods was the adoption of cumulative spaces categories which do not give room for individual building assessment (BRECSU, 1997).

In the same vein, Adekunle et al. (2008) had equally stressed the need for monitoring and controlling of energy consumption in Nigerian universities owing to limited supply in order to achieve the aim of teaching, research and community development. The peculiarity of tertiary institutions in Nigeria where bulk metering is the usual practices made determining the energy consumption of individual building a major challenge coupled with limited effort geared towards establishing the actual end-use distribution for various building categories in Nigeria (Imaah, 2004b; Fadamiro & Ogunsemi, 2004). Based on this premise, this study investigated the energy consumption pattern and performance of administrative office buildings in selected Federal tertiary institutions in Niger state, Nigeria. Administrative building was of interest being a typical office building in design and operation within academic setting moreover, office buildings had been found to be high energy consuming buildings globally (Ravetz, 2008).

**Literature Review**

**Overview of energy use in built environment**

Energy is an indispensable factor and a major determinant of the socio-economic growth and life quality all over the globe (American Society of Heating, Refrigerating and Air-Conditioning Engineers [ASHRAE], 1990; Kousksou et al., 2014). The continuous increase in energy use by buildings sector globally has been a major source of concern. Statistically, between 2005 and 2011 the observed average annual growth of energy use in buildings was 3.15%. While in 2011, the global energy consumption rate was 8.92 Gigaton of oil equivalent/year (Gtoe/year). This has been predicted to increase to 14 Gtoe/year by 2020. This growing trend has been predicted to continue especially nations with emerging economies like Africa, South America, South-east Asia and Middle East (Energy Information Administration [IEA], 2008).

Meanwhile, brief overview of building energy demand of few developed nations shown that, in United States of America building sector consumes about 40% of energy supply and responsible for nearly 40% of greenhouse gas emissions. While in China, above 25% of entire energy use is consumed by the building sector, projection has shown that the figure will increase to 35% by year 2020. Furthermore, UK estimation stood between 40-50% of all the energy use and over 100million tons of CO₂ emission per annum (Pout et al., 2002; Perez-Lombard et al., 2008; Bouchlaghem, 2012). Equally, in India building sector accounted for 35% of the of the total energy consumption (Manu et al., 2016). Also Nigeria building sector consumed about 40% of electricity supply (Akinbami & Lawal, 2009), while energy scenario has shown that there was a gross inadequacy coupled with the epileptic nature of the supply (Aderemi, et al., 2009; Noah et al., 2012) only about 40% of the population
have access to electricity supply (United Nations Development Programme [UNDP], 2011).

Estimation and Performance assessment of building energy consumption

Over the years, different methods had been developed to estimate consumption and performance of building energy use. It had developed from simple survey approaches like monitoring, metering, simple walkthrough/detailed energy audits to more complex engineering methods (Cole, 1998; Krarti, 2012). Building energy audit is the first step in energy analysis of buildings. Audit reveals type, cost, what, where and how energy is used towards identifying saving opportunities. However, auditing buildings which is not metered individually is a herculean task. In this light, calculation methods using mathematical models/formulas are equally an acceptable alternative means which had been used in several studies in the absence of energy bills (Batagarwa, Hamza, & Dudek, 2011; Rosenberg, 2014; Mua’zu, 2015). Moreover, the calculation method had an added advantage of ability to disaggregate energy into end-uses like Heating, ventilation and air-conditioning (HVAC), lighting, equipment and building services as encapsulated in extant literature. Building services in this respect refers to any other energy consuming appliances apart from air-conditioning for example lift, pumping machines that ensure optimal functioning of the buildings.

Meanwhile, according to Poel et al. (2007) energy consumption indicators are necessary for a successful evaluation of energy performance of buildings. The globally acceptable performance indicators are Energy Use Index or Intensity (EUI), Energy Cost Index (ECI) and Carbon Emission Index (CEI) but the widely used among them was Energy Use Index or intensity [EUI] (Chung et al., 2006). This approach had been explored in different part of the world for office and other building types (Deng & Burnett, 2000; Perez-Lombard et al., 2008; Saidur & Masjuki, 2008). These indicators are expressed mathematically as follows: EUI is the summation of total energy use per unit floor area of condition space per annum. Hence;

\[
\text{EUI (KWh/m}^2/\text{a}) = \frac{\text{Total annual energy consumption}}{\text{Total floor area of building}}
\]

CEI (KgCO\(_2\)/KWh/a) = \[
\frac{\text{Total annual energy consumption} \times \text{Carbon Intensity by energy source}}{\text{Total annual energy cost}}
\]

ECI (NGN/m\(^2\)/a) = \[
\frac{\text{Total annual energy cost}}{\text{Total floor area of building}}
\]

Review of relevant studies

This study reviewed related researches on energy use in office buildings. The reviews covered office buildings in and out of academic domain because administrative buildings of tertiary institutions are typical office buildings with similar operational regimen like any other office buildings. To start with, Mambo and Mustapha (2016) had earlier exposed the open-ended nature of how much energy is consumed by an average building in Nigeria. Also, Mua’zu (2012) investigated energy consumption of selected office buildings in Abuja to understand their status and energy performance. The derived performance was between 13KWh/m\(^2\)/a to 134KWh/m\(^2\)/a, this result was attributed to prevalent suppressed energy supply. Also, Batagarawa (2013) investigated the likelihood of incorporating phase change material (PCM) on building envelope to save energy and improve indoor comfort. The end-use results shown that cooling, equipment and lighting loads was 40%, 48%, and 12% of the annual energy consumption respectively. Furthermore, Mua’zu (2015) derived a typical performance baseline for 22 office buildings in Abuja. The findings shown that 59%, 43%, 15% and 4% for cooling, equipment, lighting and services respectively and the EUI ranged between 90 KWh/m\(^2\)/a -134 KWh/m\(^2\)/a. In like manner, Salihu et al. (2016) examined the demand, supply and consumption of energy in office buildings in Kaduna metropolis. The study revealed that cooling, equipment and lighting loads
accounted for 51%, 35% and 14% of energy
demanded. It was obvious that all these
studies were out of academic environments.

Notwithstanding, quite a handful of studies
had explored energy use of few individual
buildings in tertiary institutions. Such
studies included Colin and Christopher
(2013) that investigated the effect of users
on the energy demand of five academic
buildings at the University of Sheffield, UK.
In the same vein, Mehreen and Sandhya
(2014) looked at the energy consumption
and occupancy of a multi-purpose academic
building of Heriot-Watt (HW) University,
Edinburgh, Scotland to understand the
relationship between electrical energy and
users’ activities. Also, Adokor (2014)
studied the window opening behaviour in
university office buildings as related to
ventilation and energy use, while Orola and
Adunola (2015) investigated impacts of
fenestration on energy use in three office
buildings in Obafemi Awolowo University,
Nigeria. In like manner, Odunfa et al.
(2015) explored the effect of building
orientations on energy demand of three
office buildings in University of Ibadan,
Nigeria. Adekunle et al. (2008) conducted
survey on energy consumption and demand
in university of Lagos, Nigeria. The study
examined the various form of energy
demand and the cumulative peak
consumption by end-uses where cooling
load accounted for the highest consumption.
Based on this analysis, it was obvious that
no study had attempted to explore energy
consumption pattern and performance of
main administrative office buildings in
tertiary education institutions. This scenario
thus created the gap to be filled by this
study.

Methodology
Absence of energy bills informed the
exploratory nature of this study through case
study approach. However, quite a number of
studies of similar characteristics have
explored case study for scientific researches
(Francis, 2001; Ogbonna, 2008; Batagarawa,
2013; Mu’azu, 2015). Furthermore, purposive sampling was
adopted to select case study buildings, and
data was collected by conducting simple
walkthrough energy audit with the use of
survey form (observation checklists)
adapted from earlier similar studies
(Mua’zu, 2012; Batagarawa, 2013; Mu’azu,
2015) in three administrative office
buildings of Federal University, Polytechnic
and College of Education in Niger state,
Nigeria. (Plate I). However, energy
consumption estimation was done using
mathematical model adopted from similar
studies (Batagarawa et al., 2011; Batagarawa,
2013; Rosenberg, 2014; Mua’zu, 2015). The detail of the
mathematical model is express as follows:

\[ Q_a = \text{energy rating} \times \text{quantity} \times \text{duration of use (hours)} \]  
\[ Q_A = Q_{a_1} + Q_{a_2} + Q_{a_3} + Q_{an} \] 
\[ Q_V = Q_{v_1} + Q_{v_2} + Q_{v_3} + Q_{vn} \] 
\[ Q_C = Q_{c_1} + Q_{c_2} + Q_{c_3} + Q_{cn} \] 
\[ Q_L = Q_{l_1} + Q_{l_2} + Q_{l3} + Q_{ln} \] 
\[ Q_T = Q_A + Q_V + Q_C + Q_L \] 
\[ Q_S = Q_p + Q_G \]

Where \(Q_a\) is the quantity of energy
consumed by appliance; obtained from
manufacturers label/maintenance manual
Where \(Q_A\) = total energy consumed by
appliance \(Q_{a_1}, Q_{a_2}, \ldots Q_{an}\) = different appliances
The same equation (2) is applied for
Ventilation (\(Q_V\)), air conditioning (\(Q_C\)) and
lighting(\(Q_L\)). Hence,
\[ Q_V = Q_{v_1} + Q_{v_2} + Q_{v_3} + Q_{vn} \] 
\[ Q_C = Q_{c_1} + Q_{c_2} + Q_{c_3} + Q_{cn} \] 
\[ Q_L = Q_{l_1} + Q_{l_2} + Q_{l3} + Q_{ln} \] 
So total energy consumption (\(Q_T\)),
\[ Q_T = Q_A + Q_V + Q_C + Q_L \] 
Also, total energy supply (\(Q_S\)),
\[ Q_S = Q_p + Q_G \] 
Where \(Q_p\), energy from primary source, and
\(Q_G\) energy from generator.
Furthermore, based on the responses from
the users of office appliances certain
assumptions were used for calculating the
annual energy consumption. These
assumptions were in line with energy audit
conducted by Energy Commission of
Nigeria (ECN) in conjunction with Japan
international cooperation Agency (JICA) in
2017 on selected public office buildings in
Abuja. These assumptions included:
i. Appliances such as electric kettles,
printers, and photocopy machines are
assumed to be actively used for 2 hours
daily while other appliances like computers, air-conditioners, fans, lighting and refrigerators are used for averagely 8 hours daily.

ii. Number of operational days in a year was taken to be number of official working day in Nigeria which is 247 days. The annual energy was further disaggregated into end-uses; Ventilation and Air-conditioning (VAC) in the absence of no heating load, lighting, equipment and building services. Meanwhile, the buildings were coded with alphabet CSB1 – CSB3 meaning case study building one to three in the course of data presentation, analysis and interpretation of results. The data was analysed using descriptive statistics that included tables, percentages, and pie charts.

Results and Discussion
The results of walk-through audit exercise and most importantly building parameters that impact significantly on energy consumption are presented in Table 1. The study revealed that all buildings were similar in terms of operating hours (8am - 4pm) on a daily basis which is in accordance with the official working hours in Nigeria. Also, they shared commonalities in terms of architectural design variables (orientation, plan layout and construction materials). The building orientation with respect to geographical north determines energy balance of buildings in tropical climate like Nigeria. All the buildings are improperly oriented with the longest side where most windows are located in east-west direction. This encourages direct solar penetration into the buildings, thus more energy will be needed to ensure indoor comfort. The buildings also had common sources of energy supply (national grid and diesel generators), but none of the buildings has been audited before or took advantages of renewable sources of energy.

The outcomes of estimation of the annual energy consumption revealed that (primary and generator) by the buildings CSB1, CSB2 and CSB3 were 761,862.34KWh, 617,264.76KWh and 587,565.75KWh respectively while the results of disaggregation into end-uses are presented in the Table 2.

With reference to Table 2, the CSB 1 outcomes revealed that VAC, lighting, equipment and building services accounted for 358,189.37KWh, 79,294.20KWh, 330,358.42KWh and 20.35KWh of the annual energy use while 254,983.72KWh, 60,416.03KWh, 301,846.16KWh and 18.85KWh respectively were the annual
energy use for VAC, lighting, equipment and building services for CSB 2. Also, CSB 3 end-uses disaggregation was 287,151.13KWh, 51,279.16KWh, 247,113.17KWh and 22.29KWh for VAC, lighting, equipment and building service respectively. Consequently, the percentages of energy end-uses by these buildings were presented in Figure 1 to 3.

Table 1: Audit report on building parameters

<table>
<thead>
<tr>
<th>Case study building</th>
<th>Previous audit/clean energy</th>
<th>Energy source</th>
<th>Operating hours</th>
<th>Orientation Plan layout</th>
<th>Opaque wall</th>
<th>Glazing</th>
<th>Roof covering materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSB 1</td>
<td>None</td>
<td>National grid/generator</td>
<td>8am-4pm</td>
<td>N/E</td>
<td>225mm hollow sandcrete block</td>
<td>6mm single pane clear glass</td>
<td>0.55mm lemon green longspan aluminiu m sheet</td>
</tr>
<tr>
<td>CSB 2</td>
<td>None</td>
<td>National grid/generator</td>
<td>8am-4pm</td>
<td>N/E</td>
<td>225mm hollow sandcrete block</td>
<td>6mm single pane reflectiv e glass</td>
<td>0.55mm colourles s longspan aluminiu m sheet</td>
</tr>
<tr>
<td>CSB 3</td>
<td>None</td>
<td>National grid/generator</td>
<td>8am-4pm</td>
<td>N/E</td>
<td>225mm hollow sandcrete block</td>
<td>6mm single pane clear glass</td>
<td>0.55mm red longspan aluminiu m sheet</td>
</tr>
</tbody>
</table>

Table 2: Disaggregation of annual energy consumption into end-uses

<table>
<thead>
<tr>
<th>Case study building</th>
<th>Annual energy consumption (KWh)</th>
<th>VAC (KWh)</th>
<th>Lighting (KWh)</th>
<th>Equipment (KWh)</th>
<th>Building services (KWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSB 1</td>
<td>767,862.34</td>
<td>358,189.37</td>
<td>79,294.20</td>
<td>330,358.42</td>
<td>20.35</td>
</tr>
<tr>
<td>CSB 2</td>
<td>617,264.76</td>
<td>254,983.72</td>
<td>60,416.03</td>
<td>301,846.16</td>
<td>18.85</td>
</tr>
<tr>
<td>CSB 3</td>
<td>587,565.75</td>
<td>287,151.13</td>
<td>51,279.16</td>
<td>247,113.17</td>
<td>22.29</td>
</tr>
</tbody>
</table>

Cumulative % 

- 45.6% 
- 9.6% 
- 44.4% 
- 0.003%
Figure 1: Disaggregation of energy end-use by percentage for CSB 1
Source: Author (2018)

Figure 2: Disaggregation of energy end-use by percentage for CSB 2
Source: Author (2018)
Energy end-uses by percentage for CSB 1 were 46.6%, 10.3%, 43% and 0.003% for VAC, lighting, equipment and building services respectively (Figures 1). While 41.3%, 9.8%, 48.9% and 0.003% accounted for VAC, Lighting, equipment and building services respectively for CSB 2 (Figure 2). Also, CSB 3 results shown that VAC consumed 48.9%, lighting 8.7%, equipment 42.1% and building services accounted for 0.004% of the annual energy consumption (Figure 3). However, the cumulative percentage average of energy consumed by these buildings revealed that VAC, Lighting, Equipment and building services consumed 45.6%, 9.6%, 44.4% and 0.003% of the annual energy consumption. Generally, the results indicated that VAC (cooling load) contributed to more than 45% of energy use in this category of office buildings. This result equally re-affirms the dominance of cooling loads as submitted by earlier studies on office buildings in Nigeria (Batagarawa, 2013; Mua’zu, 2015; Salihu et al., 2016). Even though, the office buildings examined was not within academic environment.

Meanwhile, the supply of electricity to these buildings varied on a daily basis but averagely the daily supply of energy from the primary source ranging between minimum of four (4) hours and maximum of eight (8) hours of the daily working hours. Based on this premise, Electricity from primary source was estimated to be averagely accounted for about 62.7% while back-up generator was responsible 37.3% of annual energy supply. This result was in contrary to report by Batagarawa, Hamza and Dudek (2011) that back-up was up to 75% in office buildings in Nigeria. This result implied that location of buildings is a significant factor on primary energy supply in Nigeria; tertiary education institutions are by this result seems to be given preferential treatment in terms of energy supply from the national grid in Nigeria.

Furthermore, the performance evaluation shown that EUI, CEI and ECI values for the CSB1 was 164.74 Kwh/m²/a, 417,409.9 KgCO₂/KWh/a and 8,204.43 NGN/m²/a. In the same vein, the values of EUI, CEI and ECI for CSB2 stood at 174.28 KWh/m²/a, 335,545.12 KgCO₂/KWh/a and 8,679.85 NGN/m²/a while that of CSB3 amounted to 204.99 KWh/m²/a, 312,820.00 KgCO₂/KWh/a and 9,977.98 NGN/m²/a respectively (Table 3). These results implied.
that the higher the annual energy consumption, the more the values of EUI, CEI and ECI for all the buildings. This is not out of place because EUI, CEI and ECI are factors of annual energy consumption and energy sources. Also, despite annual energy consumption percentage of 63% to 37% for primary and alternative sources their annual cost implications are almost the same in all cases.

Furthermore, in the absence of local benchmarks in Nigeria for direct comparative analysis of these results. The study attempted to compare the performances of these buildings to some global benchmarks. Although, this comparison may be deficient, because of the differences in climatic conditions as well as construction materials and technology. But at least it has been able to place the performance value in global contexts. The aggregated performance benchmarks derived for the case study buildings according to Table 3 for EUI, CEI and ECI were 181.34 KWh/m²/a, 355,258.34 KgCO₂/KWh/a and 8,954.09 NGN/m²/a respectively.

This study adopted EUI for the comparative analysis, being the most widely used indicator globally for energy comparative study and the architectural background of the author and also the unit of measurement being buildings was responsible for the choice. The derived EUI of 181.34 KWh/m²/a was above the best and good practise benchmarks of 130KWh/m²/a and 128 KWh/m²/a as stipulated by South Africa Building Regulation SANS 10400-XA and Chartered Institution of Building and Service Engineers (CIBSE) respectively. Likewise, EUI was also above 134KWh/m²/a benchmark of earlier reports on similar office buildings conducted in Nigeria (Batagarawa, 2013; Mu‘azu, 2015). Notwithstanding, these results are pointer to energy performance scenario of office buildings of this category in Niger State, Nigeria. These results implied that the buildings are not energy efficient. Excess CO₂, a significant component of greenhouse gases and major contributor to ozone layer depletion and the dreaded climate change will be emitted into the environment. Thus, these buildings can be concluded to be environmentally unfriendly.

Conclusions and recommendations
The bulk metering practice has made understanding of energy consumed by individual building in tertiary institutions buildings in Niger State, Nigeria unknown. However, findings have shown that these buildings are poorly oriented in relation to geographical north but shared commonalities in terms of some building parameters that included operating hours, energy sources and building envelope materials. Also evident was that, none of the buildings had been audited before; the cumulative effect of this type of attitude may be responsible for lack of building energy data and benchmarks in Nigeria as submitted by earlier studies. Notwithstanding, these buildings enjoyed more electricity supply from national grid compared to office buildings outside academic environment probably owing to the peculiarity of tertiary institutions where energy is required for effective teaching and learning.

Furthermore, disaggregated end-use re-affirmed the dominance of cooling loads while the derived EUI was above global benchmarks and similar studies conducted in Nigeria. This implied that these buildings are not energy efficient. Consequently, it is recommended that proper orientation of building should be ensured because of its significance on the overall energy balance of buildings. Also, regular energy audit should be encouraged as well as adoption of renewable energy sources to reduce carbon emission from these buildings.
Table 3: Energy performance of case study buildings

<table>
<thead>
<tr>
<th>Case study buildings</th>
<th>EUI (KWh/m² a)</th>
<th>CEI (KgCO₂/KWh/a)</th>
<th>ECI (NGN/m² a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSB 1</td>
<td>164.74</td>
<td>417,409.9</td>
<td>8,204.43</td>
</tr>
<tr>
<td>CSB 2</td>
<td>174.28</td>
<td>335,545.12</td>
<td>8,679.85</td>
</tr>
<tr>
<td>CSB 3</td>
<td>204.99</td>
<td>312,820.00</td>
<td>9,977.98</td>
</tr>
<tr>
<td>Performance benchmark</td>
<td>181.34</td>
<td>355,258.34</td>
<td>8,954.09</td>
</tr>
</tbody>
</table>

References


