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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/m²/yr was above the global best practices of 128 KWh/m²/yr and 130 KWh/m²/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 *et al.*, 2007; Asimakopoulus *et al.*, 2012) and this has makes buildings central to global energy use (Rowe *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 (Mua'zu, 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 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;

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

$$CEI (KgCO_2/KWh/a) = \frac{\text{Total annual energy consumption} \times \text{Carbon Intensity by energy source}}$$

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

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/m²/a to 134KWh/m²/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/m²/a -134 KWh/m²/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, Adorkor (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; Mua'zu, 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:
 $Q_a = \text{energy rating} \times \text{quantity} \times \text{duration of use (hours)} \dots \text{equation (1)}$

Where Q_a is the quantity of energy consumed by appliance; obtained from manufacturers label/maintenance manual
 $Q_A = Q_{a1} + Q_{a2} + Q_{a3} + Q_{an} \dots \text{equation (2)}$

Where Q_A = total energy consumed by appliance
 $Q_{a1}, Q_{a2}, \dots, Q_{an}$ = different appliances
 The same equation (2) is applied for Ventilation (QV), air conditioning (QC) and lighting (QL). Hence,
 $Q_V = Q_{v1} + Q_{v2} + Q_{v3} + \dots + Q_{vn} \dots \text{equation (3)}$
 $Q_C = Q_{c1} + Q_{c2} + Q_{c3} + \dots + Q_{cn} \dots \text{equation (4)}$
 $Q_L = Q_{l1} + Q_{l2} + Q_{l3} + \dots + Q_{ln} \dots \text{equation (5)}$

So total energy consumption (QT),
 $Q_T = Q_A + Q_V + Q_C + Q_L \dots \text{equation (6)}$
 Also, total energy supply (QS),
 $Q_S = Q_P + Q_G \dots \text{equation (7)}$

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 247days. 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.

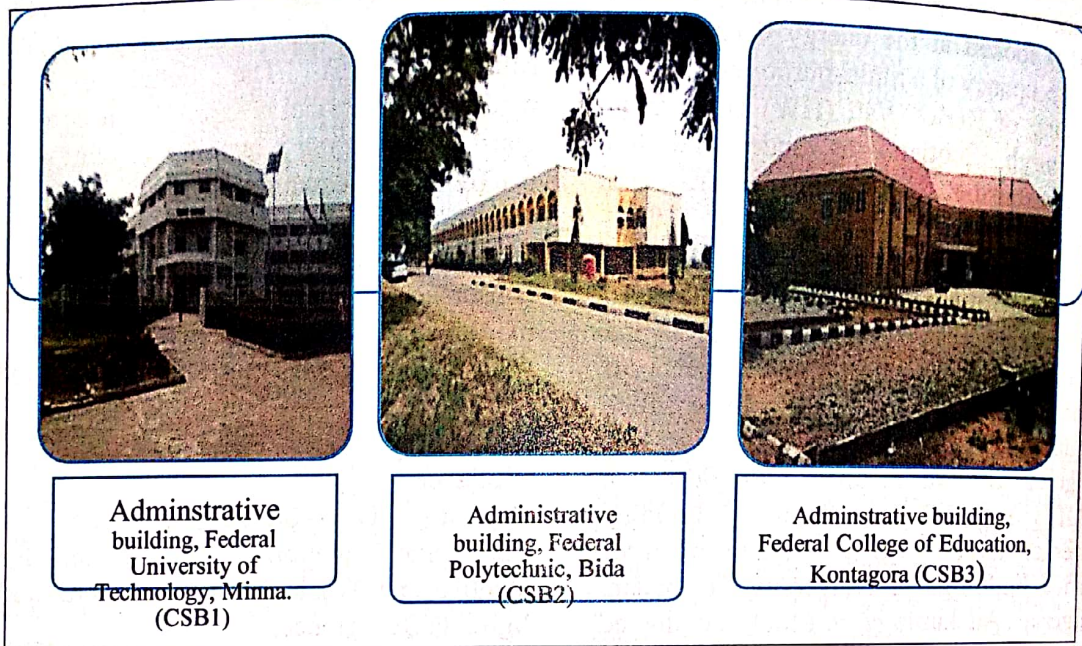


Plate I: Selected administrative office buildings Source: Author's fieldwork (2018)

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

| Case study building | Previous audit/clean energy | Energy source | Operating hours | Orientation | Plan layout | Opaque wall | Glazing | Roof covering materials |
|---------------------|-----------------------------|-------------------------|-----------------|-------------|--------------------------|------------------------------|----------------------------------|---|
| CSB 1 | None | National grid/generator | 8am-4pm | N/E | Narrow/courtyard concept | 225mm hollow sandcrete block | 6mm single pane clear glass | 0.55mm lemon green longspan aluminium sheet |
| CSB 2 | None | National grid/generator | 8am-4pm | N/E | Narrow/courtyard concept | 225mm hollow sandcrete block | 6mm single pane reflective glass | 0.55mm colourless longspan aluminium sheet |
| CSB 3 | None | National grid/generator | 8am-4pm | N/E | Narrow/courtyard concept | 225mm hollow sandcrete block | 6mm single pane clear glass | 0.55mm red longspan aluminium sheet |

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

| Case study building | Annual energy consumption (KWh) | VAC (KWh) | Lighting (KWh) | Equipment (KWh) | Building services (KWh) |
|---------------------|---------------------------------|------------|----------------|-----------------|-------------------------|
| CSB 1 | 767,862.34 | 358,189.37 | 79,294.20 | 330,358.42 | 20.35 |
| CSB 2 | 617,264.76 | 254,983.72 | 60,416.03 | 301,846.16 | 18.85 |
| CSB 3 | 587,565.75 | 287,151.13 | 51,279.16 | 247,113.17 | 22.29 |
| Cumulative % | | 45.6% | 9.6% | 44.4% | 0.003% |

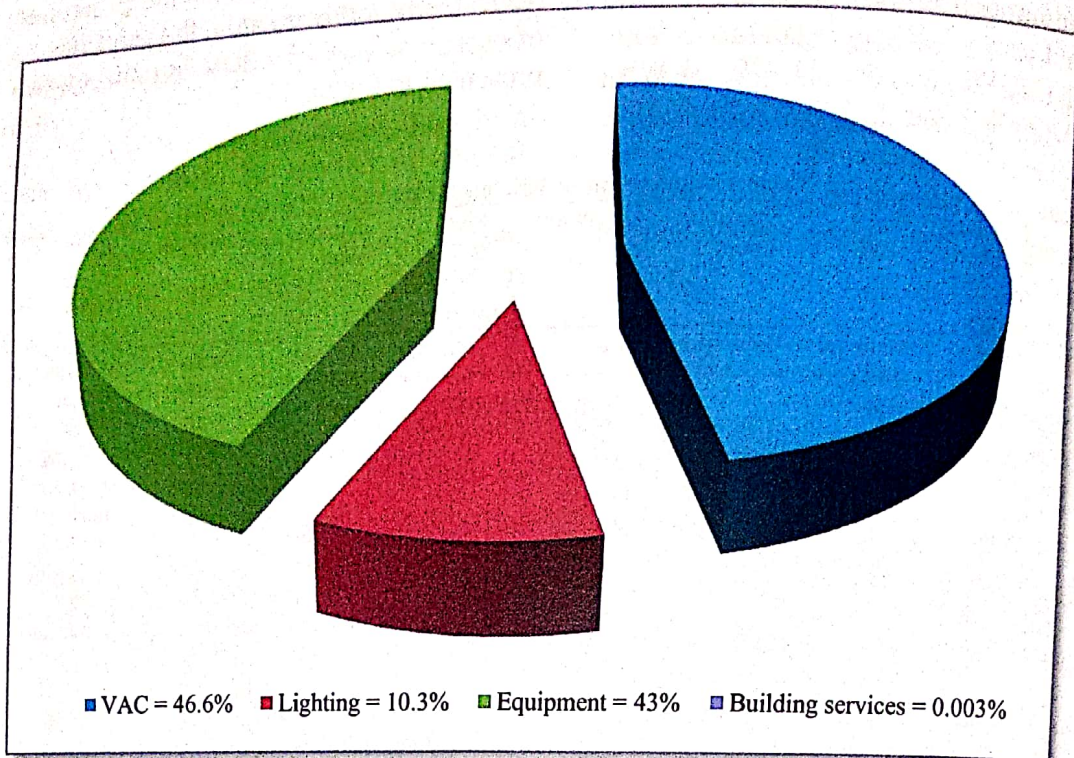


Figure 1: Disaggregation of energy end-use by percentage for CSB 1
Source: Author (2018)

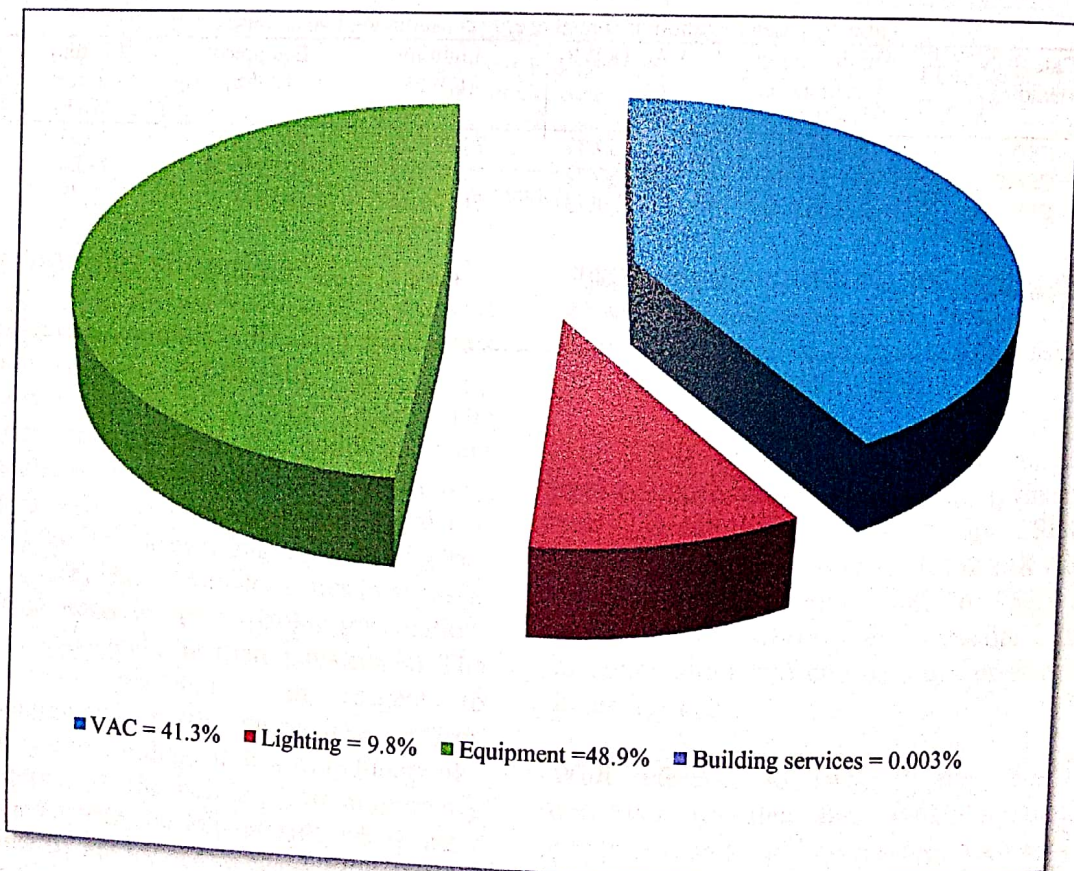


Figure 2: Disaggregation of energy end-use by percentage for CSB 2
Source: Author (2018)

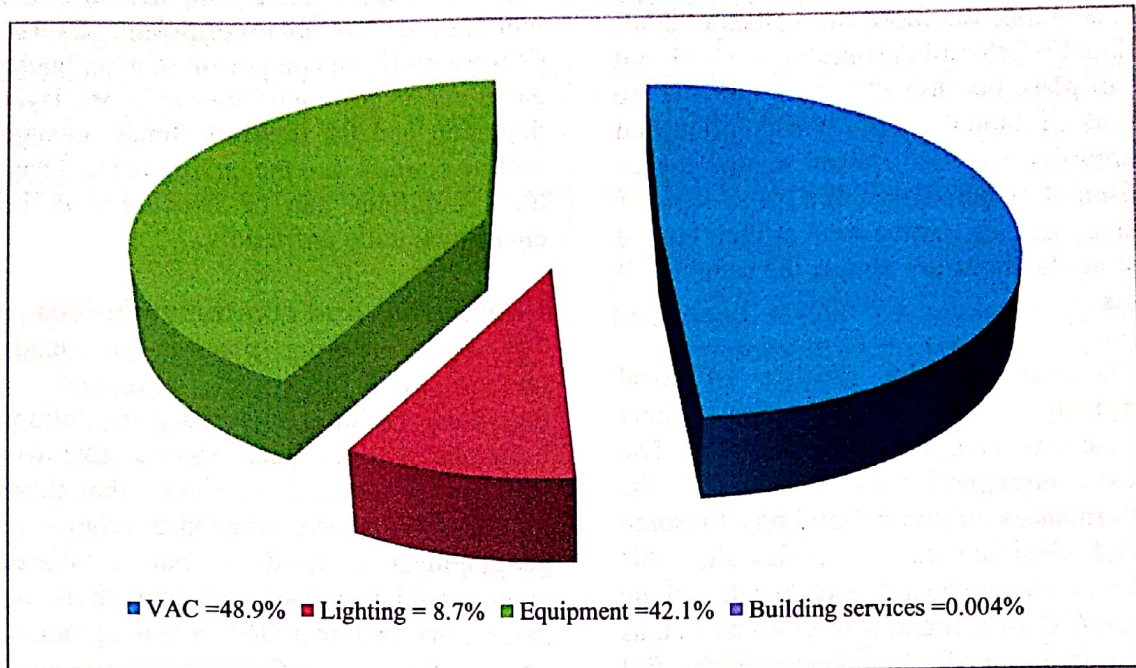


Figure 3: Disaggregation of energy end-use by percentage for CSB 3
 Source: Author (2018)

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; Mua'zu, 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 reaffirmed 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

| Case study buildings | EUI (KWh/m ² /a) | Performance indicators CEI (KgCO ₂ /KWh/a) | ECI (NGN/m ² /a) |
|-----------------------|--------------------------------|--|--------------------------------|
| CSB 1 | 164.74 | 417,409.9 | 8,204.43 |
| CSB 2 | 174.28 | 335,545.12 | 8,679.85 |
| CSB 3 | 204.99 | 312,820.00 | 9,977.98 |
| Performance benchmark | 181.34 | 355,258.34 | 8,954.09 |

References

- Adekunle, O. A., Olatunde, D., Sunday A. O., Akinwale, B. A & Allen, O.A. (2008). A survey on the energy consumption and demand in a tertiary institution, *Maejo International Journal of Science and Technology*, 2(02), 331-344.
- Akinbami, J.F. K & Lawal, A. (2009). Opportunities and challenges to electrical energy conservation and CO₂ emissions reduction in Nigeria's building sector. *Paper presented at the 5th Urban Research Symposium: Cities and climate change*. Retrieved from <http://siteresources.worldbank.org/INT/URBANDEVELOPMENT/Resources/336387-1256566800920/6505269-1268260567624/Akinbami.pdf>.
- Aderemi, A.O., Ilori, M.O., Aderemi, H.O., & Akinbami, J.F.K. (2009). Assessment of Electrical energy use efficiency in Nigeria food industry, *African Journal of Food Science*, 3(8), 206-216.
- Adorkor, B. (2014). Occupant Window opening Behaviour: the relative importance temperature and carbon dioxide in university office building, unpublished PhD thesis, Department of Construction and Structural engineering, the University of Sheffield. Retrieved from <https://core.ac.uk/download/pdf/30267736.pdf>, [accessed 11th February 2018].
- Asimakopoulos, D.A., Santamouris, M., Farrou, I., Laskari, M., Saliari, M., Zanis, G., Giannakidis, G., Tigas, K., Kapsomenakis, J., Douvis, C., Zerefos, S.C., Antonakaki, T., & Giannakopoulos, C. (2012). Modelling the energy demand projection of the building sector in Greece in the 21st century. *Energy and Building* (49) 488–498. doi:10.1016/j.enbuild.2012.02.043.
- ASHARE (1990). ASHARE Position Statements, *ASHARE Journal*, 32, 52.
- Batagarawa, A. (2013). Assessing the Thermal Performance of Phase Change Materials in Composite Hot Humid/Hot Dry Climate: An Examination of Office Buildings in Abuja Nigeria, Unpublished PhD Thesis, School of Architecture, Planning and Landscape, Newcastle University, UK. Retrieved from <https://theses.ncl.ac.uk/dspace/bitstream/10443/2146/1/Batagarawa,%20A.%2013.pdf>
- Batagarawa, A., Hamza, N. & Dudek, S. J. (2011) Disaggregating primary Electricity consumption for Office Buildings in Nigeria. *Proceedings of Building Simulation, 12th Conference of International Building Performance Simulation Association, Sydney, 14-16 November*. Sydney, 1033-1040. Retrieved from http://www.ibpsa.org/proceedings/BS2011/P_1379.pdf
- Bouchlaghem, D. (2012). Architectural Engineering and Design Management sustainability themed issue, *Architectural Engineering and Design Management*, 8(1), 3-5. Retrieved from <https://www.tandfonline.com/loi/taem20>.
- Building Research Energy Conservation Support Unit [BRECSU] (1997). ECG 54: Energy Efficiency in Further and Higher Education: Cost-Effective Low Energy Buildings. London. Retrieved from <https://www.thenbs.com/PublicationIndex/documents?Pub=BRECSU>.
- Chung, W., Hui, Y., & Lam, Y. (2006). Benchmarking the energy efficiency of commercial buildings. *Applied Energy*, 83(1), 1-14, doi:10.1016/j.apenergy.2004.11.003. Retrieved from <http://www.sciencedirect.com>

- Cole, R. J. (1998). Emerging trends in building environmental assessment methods. *Building Research & Information*, 26(1), 3-16.
- Colin, G.W & Christopher, R. J. (2013). User Perceptions of Energy Consumption in University buildings: University of Sheffield Case Study. *Journal of Sustainability Education*, 5, 2151-7452. Retrieved from <http://www.susted.org/>.
- Deng, S.M., & Burnett, J. (2000). A study of energy performance of hotel buildings in Hong Kong. *Energy and Buildings*, 31(1) 7-12, doi:10.1016/j.enbuild.2009.07.028.
- Energy Information Administration (EIA), International Energy Outlook (2008). USA: EIA Publications. Retrieved from [http://www.eia.doe.gov/oiaf/ieo/pdf/0484\(2008\).pdf](http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2008).pdf)
- European Commission Joint Research Centre (ECJRC). (2012). Retrieved from http://re.jrc.ec.europa.eu/energyefficiency/html/standby_initiative_data_centers.htm.
- Francis, M. (2001). A case study method for landscape architecture. *Landscape Journal*, 20(1), 15-29, doi: 10.3368/lj.20.1.15.
- Fadamiro, J. A., & Ogunsemi, D. R. (2004). The Impact of Construction Activities on the Quality of the Environment. *The Journal of the Nigerian Institute of Architects*, 4(2), 417-431.
- Huovila, P., Ala-Juusela, M., Melchert, L, & Pouffary, S. (2007). Buildings and Climate Change Status, Challenges and Opportunities, *United Nations Environment Programme*, Paris, France. Retrieved from https://ec.europa.eu/environment/integration/research/newsalert/pdf/71nal_en.pdf
- Energy Information Administration (EIA), International Energy Outlook (2008). USA: EIA Publications. Retrieved from [http://www.eia.doe.gov/oiaf/ieo/pdf/0484\(2008\).pdf](http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2008).pdf)
- Imaah, N. O. (2004b). Sustainable construction: the dilemma of high-rise buildings in a developing country such as Nigeria. Retrieved from In-house Publishing: Retrieved from <http://www.irb.fraunhofer.de/CIBlibrarv/search-quick-result-list.jsp?A&idSuche=CIB+DC10316>
- Krarti, M. (2012). *Energy audit of building systems: an engineering approach*. Florida, USA: CRC press.
- Kousksou, T., Bruel, P., Jamil, A., El Rhafiki, T., & Zeraouli, Y. (2014). Energy Storage: Perspective and Challenges, *Solar Energy Matter*, Solar Cell 120, 59-80. Retrieved from DOI: 10.1016/j.solmat.2013.08.015.
- Maimunah, S., & Shehu, M. (2010). Monitoring Energy Performance in Higher Education Buildings for Sustainable Campus, *Malaysia Journal of Real Estate*, 5(1). Retrieved from <http://www.academia.edu/516618/>
- Mehreen, S. G., & Sandhya, P. (2014). Understanding the Energy Consumption and Occupancy of Multi-Purpose Academic Building. *Energy & Building* 87, 155-168.
- Mambo, A.D., & Mustapha, Z. (2016). Modelling the Energy Profile of Typical Building in Nigeria: A case study of Sokoto, Osogbo and Minna, *Proceeding of School of Environmental Technology International Conference (SETIC 2016)*, Federal University of Technology Minna, Nigeria, 10th -12th May 2016.
- Manu, S., Shukla Y., Rawal R., Thomas L.E, De Dear R. (2016). Field Studies of Thermal Comfort across Multiple Climate Zones for the Subcontinent: India Model for Adaptive Comfort (IMAC). *Building and Environment*; 98, 55-70, <https://doi.org/10.1016/j.buildenv.2015.12.019>.
- Mu'azu, A. I. (2011). Promoting Energy Use Regulation for a Sustainable Built Environment in Nigeria. Retrieved from <https://www.academia.edu/798614/>
- Mu'azu A. I. (2012). Scenario of Energy Consumption of Office Buildings in Abuja, Nigeria, *international journal of Science and Advanced technology*, 2 (9), 2221- 8386.
- Mu'azu A.I. (2015). Sustainable Design Strategy: Assessment of impact of Design Variables on Energy Consumption of Office Buildings in Abuja, Nigeria, Unpublished PhD Thesis, School of Architecture, University of Portsmouth, U.K. Retrieved from http://eprints.port.ac.uk/19227/1/FINAL_CORRECTED_THESIS.pdf.

- Noah, O.O., Obanor, A.I., & Audu, M.L. (2012). Energy Audit of a Brewery-A Case Study of Vitamalt Nig. Plc, Agbara, *Energy and Power Engineering*, 4, 137-143.
- Odunfa, K.M., Ojo, T.O., Odunfa, V.O., & Ohunakin, O.S. (2005). Energy Efficiency in Building: Case of Building at the University of Ibadan, Nigeria. *Journal of Building Construction and Planning Research*, (3) 18-26.
- Ogbonna, A. C. (2008). An integrated assessment of domestic energy demand and use for energy planning in sub Saharan Africa; the case of Jos, Nigeria, Unpublished PhD Thesis, School of the Built Environment, Heriot Watt University, UK.
- Olofsson, T., Meier, A., & Lamberts, R. (2004). Rating the energy performance of buildings. *The International Journal of Low Energy and Sustainable Buildings*, 3, 1-19, Retrieved from <https://www.researchgate.net/deref/http%3A%2F%2Fescholarship.org%2Fuc%2Fitem%2F52j7d39x>.
- Orola, B. A., & Odunola, O. A. (2015). Impact of Fenestration on Energy Use in office Buildings within Obafemi Awolowo University, South-west, Nigeria, *Proceeding of the OAU Faculty of Technology Conference* (2015). 226-232.
- Pereira, M. A. C. & Da Silva, M. T. (2003). A key question for higher education: Who are the customers, *31st Annual Conference of the Production and Operation management Society*, POM-2003, Atlanta, and GE .Retrieved from <https://pomsmeetings.org/ConfProceedings/001/Papers/SOM-19.3.pdf?>
- Perez-Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy Consumption information, *Energy and Buildings*, 40(3), 394-398.
- Poel, B., Van Cruchten, G., & Balaras, C. A. (2007). Energy Performance Assessment of Existing Dwellings. *Energy and Buildings*, 39(4), 393-403.
- Pout, C.H., MacKenzie, F., & Bettle, R. (2002). Carbon Dioxide Emissions from Non-domestic Buildings: 2000 and Beyond, BRE Energy Technology Centre, Watford. Retrieved from <https://www.brebookshop.com/details.jsp?id=140114>
- Rai, G.D. (2004). Non-Conventional Energy Sources. Delhi: Khanna Publishers. Retrieved from <http://www.amazon.in/Non-conventional-Energy-Sources-G-D-Rai/dp/8174090738>
- Ravetz, J. (2008). State of the Stock- What Do We Know About Existing Buildings and their Future Prospects? *Energy and Policy*, 36 (12), 4462-4470.
- Rosenberg, E. (2014). Calculation method for electricity end-use for residential lighting. *Energy*. Elsevier, 66(C), 295-304.
- Rowe, D., Day, J., Gard'ner, J., Judson, P. & McLennan, S.(2008). Heritage Buildings and Sustainability. Technical leaflet. Published by Heritage Council. Received from http://www.dpcd.vic.gov.au/data/...Sustainability_Heritage_tech_leaflet.pdf
- Saidur, R., & Masjuki, H. (2008). Energy and Associated Emission Analysis in Office Buildings. *International Journal of Mechanical and Materials Engineering*, 3(1), 90-96.
- Salihu, M. M., Ejeh, D., & Hassan, O.S. (2016). Walkthrough Energy Audit Exercise on Office Buildings of Kaduna Central Business District, Nigeria, *Proceeding of School of Environmental Technology International Conference (SETIC 2016)*, Federal University of Technology Minna, Nigeria, 10th -12th May 2016.
- United Nations Development Programme [UNDP] (2011). Promoting Energy Efficiency in Residential and Public Sectors in Nigeria. Retrieved from <https://erc.undp.org/evaluation/documents/download>