Building Energy Audit in Nigeria: Some Guides for Energy Efficiency Building Regulations

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Abstract. Buildings account for a large proportion of total energy use in the world and that has surpassed all the other sector of the economy of most countries. There is a great need to gather better data on building energy performance and to be able to compare performance across locations and building typologies so that best practices can be more rapidly evolved. The question of how much energy the average Nigerian building consume is still an open ended one. This paper presents a synthesis of energy supplied and utilized in 105 buildings based on building energy audit, physical examination, onsite measurements and discussions with relevant stakeholders, conducted in three cities from different climatic belts of Nigeria. The aim was to draw a basic energy consumption profile of residential, commercial and institutional buildings. This survey found the preponderance of the use of energy inefficient products, inadequate utilization of daylighting, complete absence of building energy management systems, extremely low adoption of renewable energy systems and orienting building without due consideration to bioclimatic factors. This paper recommends policy changes that can be used to realise a large and feasible energy saving in new as well as existing buildings in Nigeria.

Keywords: Building energy audit · Nigeria building code
Building energy consumption

1 Introduction

The precarious energy situation in Nigeria is not just that of shortage of power but also that of gross end-use inefficiency and wastage. It was estimated by International Energy Agency that this wastage is as high as 40% of the power generated [1].

The main concern here is that, the current Nigeria standards [2] for new conventional construction result in buildings that are not energy efficient [3] and therefore use significant amounts of energy to cool the buildings, which results in increased greenhouse gas emissions nationwide. There is the need therefore, to evolve a new

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standard that set the minimum level that will take into account energy influential factors in the life cycle of buildings [4].

One of the benefit of energy efficiency standard for buildings is that it will help to stretch the availability of non-renewable energy resources to meet current demands while also providing the time to develop renewable energy sources. Other benefit is that it will reduce water and air pollution thereby improving health conditions of the people.

The objective of this paper is to provide information about energy consuming factors in the selected buildings, develop an energy profile of various building types in some selected towns and to make recommendation on the inputs for energy efficiency in the propose amendment of the National Building Code to incorporate energy efficiency.

2 Energy Audit of Buildings in Nigeria

Energy audit is the first step in increasing the energy efficiency of buildings [5]. It is often said; if you cannot measure it, you cannot manage/control it. There are very few energy efficiency studies in Nigeria. Community Research and Development Centre conducted an energy efficiency survey to elicit information that will guide the development of energy efficiency policy in Nigeria [6]. This study conducted in 3 cities of Benin, Abuja and Lagos is an opinion survey rather than energy audit. Olayinka and Oladele [7] conducted energy audit of food processing industry and Distillation and Bottling Company in Ota, Nigeria. The study observed that electric motors were the major consumer of electrical energy, accounting for 40–47% of total electric energy. In the study by Oyedepo *et al.* [8], energy audit was conducted at Covenant University, Ota to assess the pattern of electricity consumption in order to improve energy consumption efficiency in the University. The paper by Babangida *et al.* [9] presents a complete energy auditing for a student hostel in Ahmadu Bello University, Zaria to ascertain the effectiveness of energy management in the building. Other energy audit of educational buildings can be found in [10, 11]. Previous researches are made mostly on educational buildings. The aim has always been to develop energy efficiency strategy for a particular building. This energy audit involves visiting building facilities for a walkthrough survey, undertaking measurement of the orientation and building extents, material, size and orientation of openings, collection of electricity bills and interacting with building owners to know the duration of use of appliances, to determine the fuel type and the pattern of fuel use.

3 Materials and Methods

This work used the ASHRAE Level 1 and 2 energy audit method [12]. This entails brief selection interviews with building operating staff or occupants to have an overview of the facility's utility bills and additional data, and an abbreviated walk-through of the building. The audit was carried out in the March and April of 2016. These months are the hottest and driest months of the year with highest cooling demand as shown in the temperature and CDD chart of Fig. 2. The audit focused on the identification of the potential for energy efficiency improvements, understanding the overall building configuration, and defining the type and nature of energy systems. Specifically, during the course of this work, data were collected from two major sources which included; the use of Energy audit forms and interviews. The forms consist of tables with the variables of interest alongside spaces for respondent's answers as well as enumerators' measurements and observations. The enumerators carried out measurements to determine orientation of the buildings, size of façade and other building element of interest. The audit forms were subjected to thorough review and testing before being administered to willing respondents. 105 pieces of detailed audit forms were distributed to three towns in the Northwest representing the Semi-desert climate, Southwest rain forest region and Northcentral savanna climatic zones of Nigeria with slightly differing climate characteristics (see Figs. 1 and 2). Delineation of Nigeria's climate for architectural design purpose is still a work-in-progress.

The buildings selected were in the same area of each city so as to eliminate the factor of climate. The buildings were either of residential, commercial and institutional functions.

The enumerators ask questions from owners and/or occupants. The respondents were asked these questions to extract information on energy use in their respective buildings. The Interviews took care of questions that cannot be obtained from physical measurement and observation. For example, asking about for the actual duration of use of each appliance in the building. Other information such as year and nature of refurbishment or conversion were also obtained.

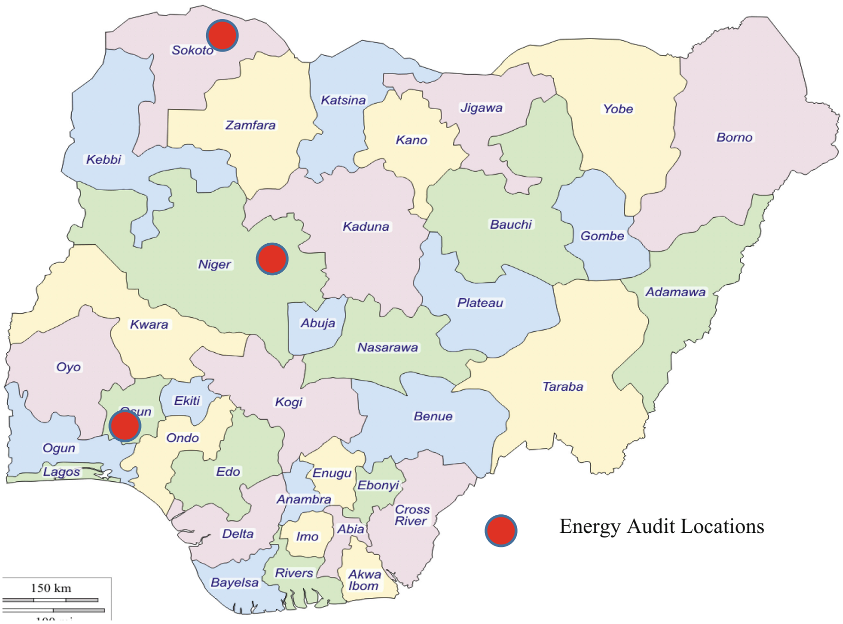

Fig. 1. Map of Nigeria showing building of audit location. Source: (http://www.d-maps.com)

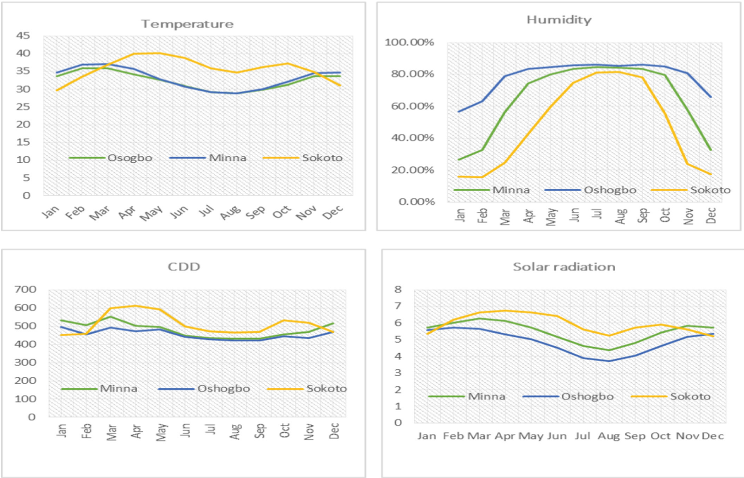

Fig. 2. Comparing the climate variables of the audited cities

Spreadsheets were developed and used to calculate and analyse the data gathered from the energy audit. The spreadsheet results of the survey were then used to develop the energy consumption pattern. The profile shows variations across building types as well as across the region. Charts and graphs were used where appropriate to provide pictorial information.

4 Results

4.1 Sources of Electricity

In all the buildings audited, sources of electricity were mainly from the national grid which is inadequate and epileptic in all the cities considered. The supply of electricity to households, commercial and institutional buildings averaged about 8 h per day across the zones. The supply from the grid was often augmented by private generators. The generators used petrol or diesel to produce power. Very few buildings have storage batteries and inverters used to store power whenever is available from the grid for use during the periods of outages. None of the building surveyed uses any form of renewable energy although about 30% of Nigeria's electricity comes from hydropower stations.

4.2 Energy Supply Profile

About 45 residential buildings were audited in the three ecological zones of the South-West, North-Central and the North-West. This number is a mixture of different types of residential accommodation such as low income, medium income and high income. The profile of energy consumption obtained from electricity bill and estimated fuel consumption from generators in Kwh/m^2/year is shown in Fig. 3 below.

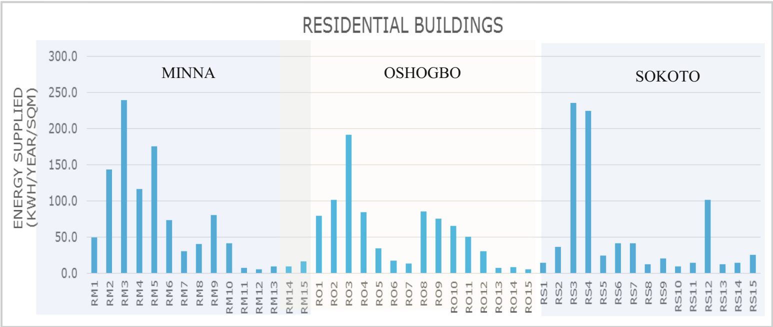

Fig. 3. Energy consumption profile of residential buildings

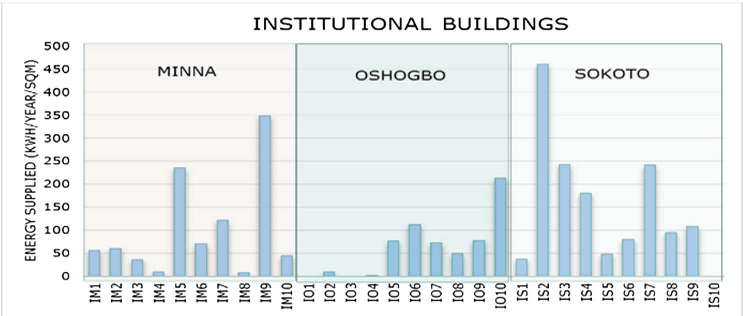

Fig. 4. Energy consumption profile of institutional buildings

A total of 30 commercial buildings were considered, 10 from each zone. The consumption pattern was similar to that of residential and institutional buildings.

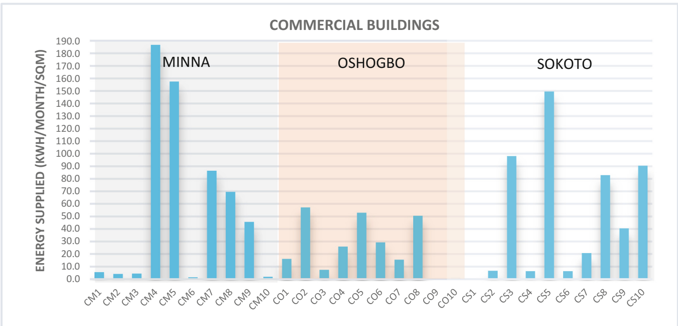

Fig. 5. Energy consumption profile of commercial buildings

4.3 Energy Use by Sector

In order to analyse the energy use pattern for the buildings, energy consuming equipment were categorized based on their functions as in Table 1. The number of such equipment, their power ratings and hour of use per day was used to compute energy use in kWh/m^2/a.

Table 1. Equipment categories

Category	Appliances
Ventilation & cooling	Air conditioners Fans
Hot water & cooking	Water heater Boiling rings/kettles Oven/microwave Cooker
Appliances	Fridge/freezer Washing machine Dish washer Television/computer VCR/DVD players Iron/vacuum cleaner Photocopiers Printer/scanner Water dispenser Stabilizers decoder etc.
Lighting	Energy bulbs Conventional bulbs

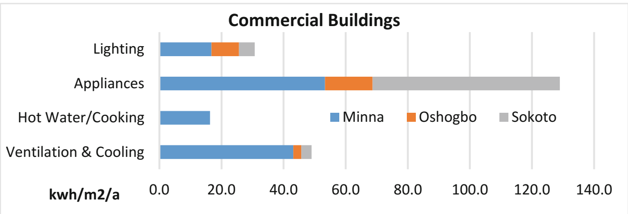

Fig. 6. Energy use pattern of commercial buildings

From Fig. 6, energy consumption of appliances dominates. It also appears that lighting contribution increases as one progresses southward of the country. Sokoto (North West) 10% is least followed by Minna (North Central) and the highest contribution from lighting (33%) comes from Oshogbo (South-West). Cooling energy consumption per floor area of Minna is higher (33%) because the type of commercial buildings surveyed comprise mainly of those with prestige air conditioning such as banks, telecom companies and big restaurants (explain the reason for 13% for hot water and cooking in Minna). In Sokoto and Oshogbo, the buildings comprise mainly of small scale retail shops where cooling is mainly achieved by natural ventilation and the use of fans.

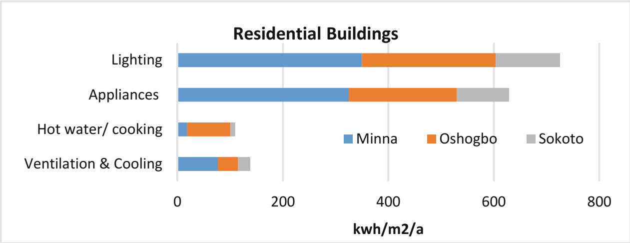

Fig. 7. Energy use pattern of residential buildings

From Fig. 7 lighting dominates the consumptions in residential buildings because of the duration of use. In commercial and institutional buildings, lighting is smaller because activities in those buildings occur mostly in the day time while occupancy for residential buildings occur throughout the day.

From Fig. 8 below, appliances energy consumptions dominate in Institutional buildings followed by ventilation and cooling. Lighting was smaller because period of use of most institutional buildings was during the day when little or no daylight will be required. Ventilation and cooling energy consumption was significant because appreciable number of these buildings air-conditioning and all the buildings uses fans. Expectedly hot water/cooking was the least energy consumer for most of the buildings in this category.

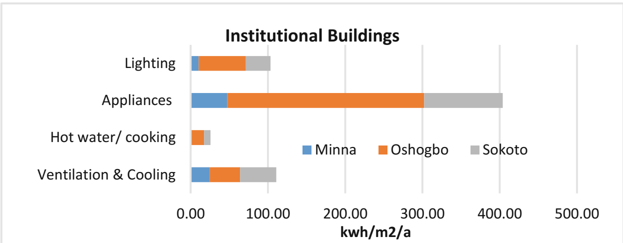

Fig. 8. Energy use pattern of Institutional buildings

4.4 Orientation of Building Major Façade

The orientation of the building's major façade was considered. Selecting the most optimal building orientation is one of the critical energy efficient design decisions that could have impact on building envelope energy performance, as it can be used to minimize the direct sun radiation into the buildings through windows, building openings as well as external opaque walls. It will be most affected for full glazed building. Buildings that are long should be oriented in the north to south direction. This allows the avoidance of direct solar gain in to a greater path of the building. It also helps to reduce areas subject to frequent energy fluctuations due to the rising and setting of the sun. Solar heat gains from the east may be a least nuisance since it often occurs in the morning after the cooler night compare to the gains from the west which usually occurs after an already warm day (Fig. 9).

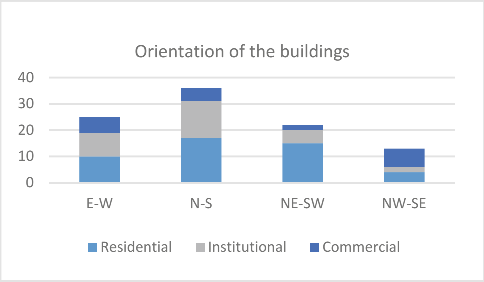

Fig. 9. Orientation of Institutional buildings

Nine (9) out of the 30 institutional buildings surveyed have the orientation of their long axis facing East-West, and 14 out of the 30 buildings have their orientations in the North -South direction. The remaining buildings surveyed have their orientations in the North East-South West or North West-South West direction.

Similarly, except for 5 building with their long axis in the North -South direction, the orientation of the remaining 25 buildings ranges from East-West, Northeast-Southwest and Northwest-Southeast. Overall, most of the buildings long axis were not oriented to offer protection to the façade against solar radiation.

4.5 Building Fabrics: Window, Roofs and Floor

The wall fabrics of all the building surveyed were made up of (from external to internal) paint, plaster, hollow concrete block (6 or 9 inches thick), plaster and paint resulting in very similar u-values, varies only according to the expertise of the builder. The roofs materials range from galvanized roofing sheets, alloyed zinc roof sheets or aluminum sheets and concrete slabs.

Window sizes are very similar; however, openings may differ from using sliding windows (allowing 50% opening) to louvres (allowing over 80% opening). This is significant because appropriate selection for windows orientation, optimal size of the glass and applying natural ventilation system, can reduce the negative effect of solar radiation in increasing indoor air temperature.

It was observed in the survey that majority of the rooms in the building types surveyed had very poor ventilation, most of them being single sided ventilation. Most buildings adopt the sliding window types which offers only 50% of the window area for natural ventilation. Also, the glazing of most of the windows, even of those in the major building façade were of single glazing and they had poor sealing quality. This could increase energy consumptions of air-conditioning system.

The lack of appropriate natural ventilation and presence of fairly good sealing quality of windows, could increase the use of energy in these commercial buildings.

5 Discussion of Results

Consumption level differs remarkably from house to house. From the chart in figure, it may be concluded that Nigerian residential buildings are generally energy efficient since more than half of the building falls below the 50 $kWh/m^2/a$ and none of the buildings exceeded 750 $kWh/m^2/a$ This assumption can be erroneous because the case with Nigeria is that of suppress demand. At the time of this survey, maximum number of hours of electricity supplied from the grid to consumers ranges from 8 to 12 h per day. The consumption for those that augment grid supply with private generation was higher than those that rely exclusively on the national grid.

The same can be said for commercial and institutional buildings as shown in Figs. 4 and 5. Institutional buildings comprise school, hospitals, libraries and government offices. 30 buildings were analysed. The results show that consumption ranges from zero to 450 $kWh/m^2/a$. The zero consumption comes from some public schools that do have electricity at all and the highest consumers augment their electricity supply from the grid with private generators.

6 Conclusion and Recommendations

This report is a basic building energy audit of some 105 buildings in three cities of Nigeria from three different climatic zones earlier identified in the report. The report studied energy supply and use pattern, orientation of major building façade, types of wall, roof and window fabrics and their influence on energy consumption.

From the observations, physical measurements, and interview with occupants and owners of buildings surveyed, the following conclusions were reached: It was obvious that buildings are being constructed without deliberate recourse to energy efficiency issues. Orientation of majority of the building does not seek to harness bioclimatic factors of the building site.

Nigeria's electricity is still predominantly sourced from gas thermal stations and from petrol or diesel generators. Renewable energy uptake has remained remarkably low in spite of the huge potentials. A policy encouraging the increase use of renewable energy to power buildings will improve the environment, stretch the existing energy capacity, introduce stability in supply of power and provide gainful employment.

Although the buildings vary in size and outlook, they are about the same in terms of the fabric layers. Across the region, there was no clearly discernible difference in the features of the buildings to suggest that the differences in climate of the three cities has any influence on the design of the building fabric, window, floor or roofing. A policy encouraging climate specific design and construction could be helpful.

Appliances energy consumption in almost all the building types audited across the three zones was high. A policy encouraging the use of energy efficient appliances, switch offs of appliance when not in use and discouraging the use of second hand electronics will have tremendous impact.

Although energy consumption of cooling and ventilation appears comparatively low, it is a component with perhaps greater future implication. There is likely to be an upsurge in the use of air-conditioning and refrigeration equipment as is the pattern in other tropical countries. A policy laying emphasis on passive cooling, use of solar air-conditioning, energy efficiency labelling and reduction in the importation of old fridges and air-conditioners will be in the right direction. Discouraging the use of sliding windows that leaves only 50% of the widow size for natural ventilation should be implemented. Households should be encouraged to plant trees on the eastern and western sides of their building to provide solar shading against morning and evening sun heat as the sun rises and fall in the horizon respectively.

There are significant opportunities for energy savings in the area of energy management systems and renewable energy as none of the buildings surveyed used EMS or has usable renewable energy system install.

Federal government should review the existing building code to incorporate enforceable energy and resource efficiency provision. This is necessary to ensure that energy efficiency is introduced right from the design stage and also in the event of any refurbishment work.

Dissemination of best practice in energy and resource efficiency should be supported by constructing demonstration buildings such low or zero energy buildings and passive house so that people can see that building energy efficiency is a verifiable reality and not just some impractical concepts.

Energy and resource efficiency should be targeted in all major refurbishment across all building typologies. Government should lead the way in ensuring that public buildings during construction, refurbishment and operation are energy efficiency compliant.

Energy efficiency should be made attractive and visible in the market place such that building owners would see it as a viable alternative to conventional built forms. These could be achieved through labelling, certification of building and appliances as well as subsidies and tax rebate.

The huge advantage in traditional architecture in thermal mass, use of local material, courtyard and shaded veranda system could be harnessed and improved upon to evolve a new built form that is durable, functional and beautiful. The potentials that lie in mud bricks, stone and straw bale may also need to be combined with modern technology so as to produce a new generation of homes that require no mechanical air-conditioning during hot days and nights.

References

1. U.S. Energy Information Administration: International Energy Statistic: Total Electricity Net Consumption (2012)
2. Ministry of Environment, Government of Finland: National Building Code. NBD 2013 (2013)
3. Nduka, D.O.: Stakeholders Perception of Factors Determining the Adoptability of Green Building Practices in Construction Projects in Nigeria, vol. 5, no. 2, pp. 188–197 (2015)
4. Dahiru, D., Abdulazeez, A.D., Abubakar, M.: An Evaluation of the Adequacy of the National Building Code for Achieving a Sustainable Built Environment in Nigeria, vol. 4, no. March 2010, pp. 857–865 (2012)
5. Etiosa, U.: The concept of energy efficiency. In: The Report of a National Dialogue to Promote Renewable Energy and Energy Efficiency in Nigeria, p. 16 (2008)
6. Etiosa, U., Agho, M., Edevbaro, A., Godfrey, O.O., Uyigue, O.P., Okungbowa, O.G.: Energy Efficiency Survey in Nigeria: A Guide for Developing Policy and Legislation. Benin, Nigeria (2009)
7. Olayinka, S., Oladele, A.T.: Energy Audit of Manufacturing and Processing Industries in Nigeria : A Case Study of Food Processing Industry and Distillation & Bottling Company, vol. 1, no. 3, pp. 36–44 (2013)
8. Oyedepo, S.O., et al.: A study on energy demand and consumption in. In: International Conference on African Development Issues (CU-ICADI) 2015 (2015)
9. Babangida, M., Abubakar, M., Abba, L.B., Abubakar, K.A.: Energy auditing and management. J. Multidiscip. Eng. Sci. Technol. **2**(7), 1807–1813 (2015)
10. Itabor, N.A., Damisah, L.E., Olatunji, J.O., Eyakwanor, T.O., Akingba, O.O., Orerome, R. O.: Energy efficiency in buildings: case of post graduate hostels at the University of Benin, Nigeria. Phys. Sci. Res. Int. **3**(November), 51–58 (2015)
11. Maina, M.B., Shuwa, M.: Electricity use characteristics of tertiary institutions in Nigeria: a case study of Ramat Polytechnic Maiduguri, Borno State. Int. J. Eng. Res. Technol. **4**(12), 596–601 (2015)
12. Deru, M.P., Jim, K.P.E., ASHRAE: Procedures for Commercial Building Energy Audits. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (2011)