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A survey of power supply and lighting patterns in North Central Nigeria—The energy saving potentials through efficient lighting systems

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ABSTRACT

While power crises persist in Africa with many heads of governments placing priority on power generation, the need for energy conservation through efficient lighting can be a short-term solution. This paper compiles the power supply and consumption pattern from lighting of six cities and towns in North Central Nigeria. A total of 1637 residential households were surveyed. Each compound had 2 to 4 houses. Most of the households surveyed had a combination of modern and local buildings such as huts. The work revealed that the predominant form of electricity consumption is in lighting. Electricity supply is found to last for an average of 5 days a week and 9.8 h a day. The major electric lighting source is the 60 W and 100 W incandescent bulbs, but a significant population uses both incandescent and energy efficient lamps (e.g. compact fluorescent lamps, CFLs) for their lighting needs. In the absence of public power supply, kerosene and low power generators are used as alternative sources for lighting. The number of kerosene lamps in a residential compound was found to be 3 or more. About 70 per cent of power generated in Nigeria can be saved if efficient lighting sources such as CFLs and solid state lighting are urgently adapted. Also, an estimated 796.4 billion naira (US$4.98 billion) will be saved annually from fuel to power electric generators if they are replaced by solar- based lighting.

1. Introduction

Global residential energy demand is about 23 per cent and Africa has the largest share of residential energy end use with 54 per cent [1]. Similarly, the residential sector account for the largest share of energy use in Nigeria (65 per cent) [2]. This large energy consumption has triggered research interest in the residential sector with the aim of findings ways to effectively utilize residential utilities for potential energy savings. Some of these research have been carried in Thailand [3], Australia [4], United State of America [5], England [6] and Nigeria [7–9]. In all these studies, it was realized that besides heating, lighting is one of the major sources of energy consumed in the residential sector. Also, apart from counties were the use of incandescent lamps has been banned, incandescent lamps are still a major source of household lighting especially in developing countries.

Though, electric lighting represents the most efficient form of artificial lighting source, in Nigeria like most sub-Saharan African countries, electric lighting is hampered by inadequate electricity generation and supply. Over 51.5 per cent of the over 160 million people in Nigeria lack access to electricity [10,11]. Nigeria's electricity demand is in the range of 20,000 MW to 25,000 MW [12]. However, the current nominal electricity generation capacity is less than 6000 MW [13] with the actual electricity generated fluctuating between 2950 MW to below 4000 MW [14]. This enormous shortfall in electricity production is further exacerbated by high losses due to inefficient distribution system [15], hence the frequent power outages experienced by consumers. Beside infrastructure deficits, the spate of gas pipe line vandalism by militants has worsened the power situation in Nigeria [16]. Frequent power outages affects everyone: students cannot read at their desired times because of the fear for power failure; households and business owners are forced to look for alternative power supply to meet their lighting needs, hence the prevalence of small generators popularly called "I better pass my neighbour" in Nigeria's small to medium income households. For high income households, diesel generators are used for lighting and other domestic appli-

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ances such as air conditioners, refrigerators, electric iron, etc. Beside huge income loss, generators are a source of stress (or fatigue) and health hazard as a result of the noise generated and the greenhouse gas emissions [17]. It has been reported that Nigeria spends an estimated sum of 796.4 billion naira, (US$4.28 billion equivalent) annually on fuel to power electric generators [18]. This huge expenditure on small power generators has a toll on the gross domestic product (GDP) growth of a nation whose per capita income is among the poorest globally [19]. Nigeria's KWh per capita electric power consumption of 148.9 KWh is the lowest among her peers such as Bangladesh (254.6 KWh), Brazil (2438.0 KWh), Indonesia (679.7 KWh) and South Africa (4315.1 KWh) [20].

As noted earlier in this work, electricity consumption in Nigeria has been reported to be dominated by the residential sector [18,21], of which lighting is a major contributor. Unfortunately, inefficient lighting sources such as the incandescent bulbs are generally common and are the most widely used in households [7]. Every household is adorned with incandescent bulbs. These lamps waste 95 per cent of their input energy as heat and barely convert 5 per cent of the energy to light. Besides the use of inefficient electric lighting bulbs, efficient utilization of available power by the end users is also lacking; it is not uncommon for electric lamps to be left on (glowing) when their light are not needed, e.g. during day light hours in homes, offices and commercial centers. With a population of more than 10 million people having access to electricity in Nigeria, there is a potential of saving large amount of electricity generated for other productive uses if efficient lighting technologies are adopted [22,23].

The Nigerian government's efforts towards solving the energy crises in the country has always been in the direction of building more power plants and the unbundling of agencies (National Electric Power Authority, NEPA in 2005 and the Power Holding Corporation of Nigeria, PHCN in 2013) [24] responsible for power generation, transmission and distribution. Despite this efforts and the huge amount of money invested into the power sector, electricity generation has remained below 4000 MW on the average. If the solution to electric power problem in the short term is not diversified to include electricity end users efficiency such as utilization of efficient lighting technologies, the quest for adequate and stable power supply would continue to elude the nation. Apart from the fact that efficient utilization of electricity means more power available to other productive and extended uses, it is also capable of substantially reducing materials waste and greenhouse gas emissions. The main objective of this work is to determine the energy consumption pattern of households in Nigeria and the energy saving potential associated with adapting new lighting technologies. Therefore, this paper presents the result of a survey carried out in North Central Nigeria on household electric lighting energy consumption. The contribution of this work comes about as the result of Nigeria's first attempt to evaluate energy savings opportunities from lighting by community households. In addition, this work would provide a framework for government to develop sustainable policies and programs on the efficient electricity utilization in the country, particularly in the area of efficient lighting systems. It will also inspire lighting retrofit scientist in developing countries to step-up efforts towards finding more efficient and cost effective lighting sources.

2. Methodology

The choice of residential building for this survey is because as stated in the introduction, residential energy consumption constitute about 65 per cent of the energy use in Nigeria [25]. Moreover, Lighting from households is one of the largest energy used in the residential sector. A large proportion of energy is wasted through the use of inefficient lighting sources and human behaviour. The 2006 national population and housing census report of the National Population Commission (NPC) is the latest document on population and housing in Nigeria. Therefore, this report was adapted for use in this work to decide on the number of residential households to conduct the survey. Other socio-economic information were obtained from the National Bureau of Statistics (NBS) report of 2010.

The study was conducted in two states in North central Nigeria and the map showing the surveyed areas is presented in Fig. 1. The choice of North Central Nigeria, and in particular, Benue and Nasarawa states is because to our knowledge this work has never been carried out in these places. In North Central Nigeria, there are reports on residential energy survey in Kaduna state [8], Plateau states [26] and Niger state [27,28]. States in Nigeria are divided into local Government areas (LGAs) and LGAs into council wards; six local government areas in Benue state and one in Nasarawa state were considered based on the 2006 housing census. These places make up the study strata were each local government area is a stratum and each ward is adopted as a sub-stratum consisting of households. A total of 1637 households were selected across wards, representing 10 per cent of the population (in the selected research areas) enumerated, based on the 2006 national population and housing census. The survey method includes the use of household questionnaires, interview with key informants (especially heads of households now known as respondent or their representatives), physical observations of different kinds of lighting fixtures and review of existing documents from relevant agencies.

2.1. Questionnaire

Questionnaires were administered orally to randomly selected households in the various wards that make up the local governments by enumerators who filled out the questionnaires during the interview. This questionnaire guided oral interview approach was employed because some of the households were illiterates. A sample of the questionnaire developed for this work is presented in Appendix A.The enumerators carried with them samples of electric light bulbs to the respondents. In households where access was granted the enumerators conducted energy audit by counting the bulbs by themselves and determined their numbers, types and properties. However, very few households allowed access to their homes especially bed rooms. Therefore, data obtained from this audit were only used for complementary purposes.

The questionnaire was divided into three sections; sections A, B and C. Section A involves some basic information regarding the household such as name, number of buildings in the house and house type. Section B duels exclusively on electric lighting generated from the grid system. Section C duelled primarily on lighting from alternative sources such as rechargeable lamps, kerosene lamps and generators among others. In both section B and C, questions include; sources of electricity for the home, characteristics of the various sources, duration of usage and activities in which the supplied electricity was used in the home. The data collected were subjected to simple statistical analysis using statistical package for social science (SPSS). It was used to implement selected descriptive statistics on the study data. The statistics include the mean, frequency and percentages and the results were presented in tables and charts.

Table 1 compares the lumen output of CFLs, LEDs and incandescent lamps. Using the information in Table 1 and Table 2, the total energy consumption by each lighting source was estimated using the modified top-down approach reported by Gifford et al., [5]:

$$E_i = P_r t x n N \quad (1)$$

where,

E_i = Average energy consumption for a given lamp type