ASSESSMENT OF OPERATIONAL ENERGY OF RESIDENTIAL BUILDINGS IN AKURE, NIGERIA

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ABSTRACT
Efficient use of energy in residential buildings is important in the energy and climate strategies that promise carbon reduction. Residential buildings largely contribute to the emission of Co_2 which has not only resulted in health hazards but a major traceable cause of climate change. The paper assessed the impact of operational energy consumption in residential buildings with a view to establishing energy savings and efficiency in residential buildings. The study is a survey research conducted in low, medium and high density area of Akure, the Ondo state capital with a selected sample size of 150. The data used was collected through structured questionnaires. The findings revealed that operational energy sources are grid electricity, liquefied gas, Kerosene and petrol. However, residents and building owners are enlightened on the importance of sustainable and accessible renewable energy options (solar and wind) which when adopted reduces reliance on alternative energy sources in the area.

Keywords: Climate change, energy efficiency, grid electricity, operational energy, residential building,

1. INTRODUCTION

Energy efficiency is one of the issues that have gain popularity in architecture in recent times, and this seeks to ensure that the level of energy consumed in the built environment is reduced to the lowest percentage possible. Energy efficiency in residential buildings plays an important role in the energy and climate strategies that assure carbon reductions (Paone and Bacher 2018). Studies have shown that buildings generate about 40% of the global energy consumption and contribute over 30% of the Co_2 emissions (Oyedepo, 2012). In the United States, buildings generate about 41% of energy consumption. In 2004, building consumption in the EU was 37% of final energy, bigger than industry (28%) and transport (32%) (Nguyen and Aiello 2013).

However, these discoveries have motivated significant research efforts all over the world to investigate the energy use of buildings during their life time to develop energy efficient building design and technologies (Azar and Al Amoodi, 2016). This has made building designers focus their efforts on improving the designs and materials of building to reduce the operational energy consumption of building especially in residential buildings (Waldron, Jones, Lannon, Bassett and Iorwerth 2013).

Operational energy is the energy used in a building's life cycle to meet necessary needs such as cooling, heating, and provide power for appliances. This accounts for about 33% of the total final energy demand globally and about 30% of CO_2 emitted globally in relation to energy use (Koezjakaov, Urge-Vorsatz, Crijns-Graus and Van den Broek, 2018). Building systems are made up of a series of components that are involved in thermal dissipation that are influenced by design and environmental conditions. A deliberate attempt to control heating and cooling loads can reduce green gas emission by reducing energy consumption (Vlinejad Shoubi *et al* 2014). Based on the discoveries made, several renewable and available energy sources have been suggested to meet the world's goal of energy efficiency for guaranteeing energy security and tackling climate problem caused by energy consumption (Wei and He 2017).

In Nigeria, grid electricity generated from Hydroelectricity distributed to buildings is the most available source of energy in residential buildings. However, access to this form of energy is not adequate with limited access per day has resulted to direct fossil fuel combustion in the residential units which have not only increased the operational energy intensity but also had the added disadvantage of increasing the carbon footprint of the residential units (Ezema *et al* 2016). It was discovered that the total energy consumed in Nigeria is generated from 78% petroleum (fossil fuel) which is the largest source of greenhouse gases emission (Oyedepo, 2012).

This study seeks to evaluate the operational energy consumption in residential buildings in low, medium and high density area of Akure with a view to establishing energy savings and efficiency in residential buildings. The goal is to determine whether energy is used efficiently in residential buildings in Akure, Nigeria.

2. LITERATURE REVIEW

Buildings can be regarded as one of the most essential infrastructures in any modern society (Guana, Walmselya and Chenb, 2015). The primary objective of any building is the provision of shelter, comfort, and safety for its occupants (Amasuomoa, Atandab and Baird, 2017) therefore, buildings use energy throughout their lifecycle right from construction, to activities within the building to meet human daily needs to demolition (Guana *et al* 2015). Buildings in general and residential buildings in particular account for a large proportion of both energy use and carbon emissions to the environment through building operation and procurement (Ezema et al, 2016). This has a significant influence on the total influence on the total natural resources consumption and emissions (Guana *et al* 2015). However, the adverse effect of climatic change and the increase in public environmental awareness in the building industry has resulted in the development of creative solutions to reduce the Green House Gas (Amasuomoa *et al* 2017). Wei and He (2017) report that the energy consumption from building fall between 20% and 40% in developed countries, which far exceeds the ratios of the energy consumed in the industrial and transportation sectors. Universally, energy consumption among buildings in the world became a challenge to study or investigate in the difficulty of reducing the consumption by creating sustainable structures and constructing more energy efficient buildings for decreasing (Alkhayyat and Pehlivan, 2017).

Carbon dioxide emissions from buildings are largely due to the high carbon content of energy consumed for building operations (Ezema *et al* 2016). One of other factors that have contributed to increase in the emission of carbon dioxide can be traced to rapid urbanization especially in developing countries where increased urban population with access to improved income has resulted in increased energy consumption (Ezema et al, 2016). Wei and He 2017, attested that from the year of 2000 to 2014, the total energy consumption of China (largest developing country in the world) has increased and keeps increasing dramatically. However, due to increase in the living standard of the people use of household appliances has increased and rapid urbanisation and boom in construction has increased the number of building completed per year (Wei and He 2017). With this in view, a combination of low-carbon energy and energy efficiency measures are necessary to reduce emissions from the housing sector (Ezema *et al*, 2016).

Wei and He (2017) identified two kinds of definition of building energy consumption. The first is the operating energy which is expended in maintaining indoor environment and performing building's equipment such as heating and cooling, air conditioning, lighting, household appliances, office equipment, hot water supply, cooking, elevator, ventilation, and other operating appliances. The other is referred embodied energy. The total life cycle energy of buildings includes both embodied energy (building materials from processes of production, on-site construction, and final demolition and disposal) and operating energy (buildings operational phase).

2.1 Operational Energy

Buildings play a vital role in global energy consumption and carbon dioxide emissions. Carbon dioxide emissions from buildings are due largely to the high carbon content of delivered energy for building operations (Ezema et al, 2016). Guana *et al* (2015) define operational energy as energy required for maintaining comfort conditions and day-to-day maintenance of the buildings. Prior to this time, it was known that operation energy represents by far the largest share in the life energy bill, ranging about 90 to 95% (Sartori and Hestnes, 2007).

Operating energy of any building is its primary energy because it runs through the life cycle of the building. In recent times, the awareness of environmental problems relating to energy and the daily trend of increase in energy demand has led building designers to the development of more energy efficient designs, building codes and systems which have become requirements and enforced (Sartori and Hestnes, 2007). Consequently, Alkhayyat and Pehlivan (2017) reported the case of most conventional buildings to be constructed under poor or without any energy plans plus inefficient technologies, where the factor of material selection played a significant influence on the building type comparing with the sustainable and energy efficient buildings

In Lagos one of the prominent cities in Nigeria, located in the south western region of Nigeria, the energy end uses identified in residential buildings were lighting, cooling, domestic hot water, cooking, household appliances and water pumping (Ezema et al, 2016). Energy consumed by all activities related to the usage of the buildings such as for heating, ventilation and air conditioning (HVAC), domestic hot water, lighting, and for running appliances (Guana *et al* 2015) is largely influenced by the using habits of the occupants and the efficiency of equipment in the buildings (Wei and He 2017) as well as the level of required comfort and climatic conditions of the building environment (Guana *et al* 2015). Also, growth in population, enhancement of building services, and comfort levels, time spent inside buildings have raised building energy consumption to the levels of transport and industry. Other important factors identified by Lombard, Ortiz and Pout (2007) are the size of the residential building, the economic levels of occupants and location as dwellings in developed countries use more energy than those in developing countries. Emergences of new appliances such as computers, air conditionals, etc. have continued to increase consumption and demand of dwellings.

According to the Federal Ministry for Economic Affairs and Energy (BMWi), 2015, a residential building has its energy-related potential determined significantly by the following factors: building stock, present building owner structures and tenant structure. Meanwhile, at the construction stage of buildings the operational energy consumption is usually hidden this makes it difficult to make a distinction between the policy efficiency of either operational energy conservation or embodied energy conservation by the statistical method of life-cycle building energy consumption (Wei and He 2017). Only the energy consumption of residential building sector ranked second after the industry sector (Wei and He 2017).

Guana et al (2015) examined eight residential buildings in Brisbane, Australia and identified electrical appliance and equipment generally used in kitchen, living area, laundry and bathroom etc. to estimate the operational energy for these studied houses. In the study, electrical appliance and equipment varied considerably between these studied houses and energy inputs from solar panels were excluded. Typically, it is noted that two houses (B and F) had swimming pool, two houses (B and H) have installed solar panel and four houses (B, C, G to H) used electric hot water system. It was found that energy used by general appliance varying from 45% to 75%, by lighting energy varying from 5% to 15%, by pool pumps varying from 20% to 35%, by air conditioner varying from 15% to 45% and by electric hot water system varying from 15% to 30% (Guana et al, 2015)

Direct fuel used includes kerosene also referred to as dual purpose kerosene (DPK), liquefied petroleum gas (LPG) and petrol or premium motor spirit (PMS). Grid electricity was the most preferred energy for operation of the buildings. Also, kerosene and liquefied petroleum gas (LPG) were the predominant cooking fuel. Given the low supply of electricity from the national grid, the residents resorted to the use of electricity generators which were powered by petrol or premium motor spirit (PMS). The use of diesel was also identified but the quantity was not significant and the diffusion was low. (Ezema et al, 2016).

2.2 Renewable Energy Options in Nigeria

National Renewable Energy and Energy Efficiency Policy (2015) states that Nigeria is blessed with abundant primary energy resources. These include non-renewable energy sources such as natural gas, crude oil, coal and tar sands; and renewable energy sources such as hydro, biomass, solar and wind. In recent times, a combination of thermal and hydro system has been adopted by the Power Authority in Nigeria to generate electricity which is distributed nationwide by a transmission network known as national grid (Oyedepo, 2012). According to Ezema et al (2016), the supply of electricity from the national grid has never been sufficient or not accessible to some households as only about 55.6% of the population has access to grid electricity. Therefore, most buildings depend on petrol and diesel generators to generate electricity. Over-dependence on subsidized oil and gas as primary energy sources has slowed down the development of renewable energy in Nigeria. However, diversification to achieve a wider energy supply mix will ensure greater energy security for the nation and the future of energy supply should not be tied to sources that may likely becomes too expensive and not sustainable (National Renewable Energy and Energy Efficiency Policy, 2015).

However, Ezema et al, (2016) is of the opinion that the use of renewable energy technology is gradually being established mostly in micro-level off-grid installations such as street lighting, water pumping, agriculture, refrigeration in rural medical centres, private residential buildings as well as in institutional buildings.

2.2.1 Solar Energy

According to Federal Ministry of Power, Works and Housing (Housing), 2016 solar energy is main renewable energy source in Nigeria. Solar energy is generated from Sun's radiation incident on the earth's surface and this varies in intensity with location, season, day of the month, time of day, instantaneous cloud cover and other environmental factors, (National Renewable Energy And Energy Efficiency Policy (NREEEP), 2015). In Nigeria, it has its highest irradiance in the north of Nigeria and lowest in the southern coastal region. The annual average of total solar radiation varies from about 12.6 MJ/m2-day in the coastal latitudes to about 25.2 MJ/m2-day in the far North. However, it remains the most abundant and freely available renewable energy source that can provide energy need of the world (Adebayo, 2014). Solar energy produces more energy per hour than what the earth uses in one year, and asides that it is free from pollutants, greenhouse gases and secure from geo-political constraints and conflicts (Oyedepo, 2012). Also, solar passive building is a technology that has been developed to use natural concepts to achieve comfort in buildings without us of artificial devises and can power low to medium applications (Nwofe, 2014). Generally, Solar energy is expected to play a significant role in the future global energy needs and most especially, in developing countries, (Oyedepo, 2012)

Unconsciously, solar thermal has been greatly utilised by rural dwellers over the years for drying and preserving agricultural products such as grains, cassava (tubers or marsh), yam flakes, meat, fish, fruits, kernels, drying of manure, hides and skins, etc. (Olayinka et, al 2013) (Olayinka et, al 2013) pointed out that several research institutes and tertiary institutions in Nigeria such as Sokoto Energy Research Centre (SERC), National Centre for Energy Research and Development (NCERD) have built several Solar energy devices. In addition to these, solar energy has also found wide usage in Nigeria viz: solar street lightings, solar refrigerators, solar cookers, solar-powered water pumps, etc; different applications exist in the form of solar thermal and solar PV.

However, the integration of solar architecture with energy efficient materials and devises into the architectural designs of buildings will lead to eco-friendly cities in Nigeria (Nwofe, 2014).

2.2.2 Wind Energy

Wind is a natural occurrence that involves the movement of air across the earth surface. The force generated during the movement can be harnessed as a source of energy. According to Community Research and Development Centre, (2009), the annual average wind speed ranges from 1.4 to 3.0 m/s near the coast to 4.0 to 5.12 m/s at the northern borders. Wind energy can be converted to rotary mechanical energy and electrical energy for a variety of uses. Wind energy can be used to turn the blades of windmills or wind turbines, which in turn could drive electrical generators to produce electricity. Large modern wind turbines operate together in “wind farms” to produce electricity for utilities, while small ones can meet localized and small energy needs. Wind energy has few ecological and social drawbacks (National Renewable Energy and Energy Efficiency Policy (NREEEP), 2015).

2.2.3 Bioenergy

Bioenergy is energy produced from renewable biological material, and such is derived from living (or recently living) organisms, that can be turned into fuel (also known as biofuel when it is made from biological material) which can be used for cooking, drying and heating Federal Ministry of Power, Works and Housing (Housing), 2016. Nigeria can potentially produce about 6.8 million m3 of biogas every day from animal waste only. Although biogas technology is not common in Nigeria

3. Materials and Methods

Survey research was adopted, with the use of questionnaires as a tool for data collection. The focus of the study is on operational energy demand in residential buildings in Akure metropolis. The research population include all residential buildings in Akure. According to Adeoye (2015), the population density of residential district in Akure is divided into 3 different areas, the high, medium and low. The high density area has a density of over 200 persons per hecter which are within the core area of the city. Such areas include the Arakele, Ayedun, Ijoka, Oja-Oba and Odo Ikoyi area in Akure. The medium density area has a population density of 100 to 200 persons per hectare. Such areas are Oke-Aro, Leo, Araromi and Champion area. While the low density area are the planned government residential area such as Ijapo housing estate, Algbaka estate etc, these areas have about 60 to 100 persons per hectare.

A total of 150 questionnaires were distributed across the three identified population density area in Akure and fifty questionnaires were randomly distributed in selected areas within each population density. The questionnaires were distributed equally among the low, high and medium income earners to elicit information about household socio-economic characteristics, basic energy use; such as lighting, cooling, and water pumping and washing. Also, sources of household operational energy which includes grid electricity consumption measured in Kwh and direct fuel (kerosene and petrol) consumption measured in litres and kilogram sand renewable energy sources were obtained. The data was analysed using descriptive statistics and in all, 108 questionnaires were retrieved and useful for analysis.

However, energy conversions and protocols used by previous researchers to determine operational energy consumption was adopted in conjunction with the results obtained to determine the operational energy consumption. Hence, find below the conversions:

1) OE = PEoGE + PEoDFC Unit of primary energy: Conversions of kWh to Mj
2) PEoGE = GE x 3.6 x PEF direct fuel consumption to primary energy.

Note:

- OE is operational energy (Mj)
- GE is grid electricity
- PE is primary energy
- PEoGE is primary energy content of grid electricity (Mj)
- PEoDGE is primary energy of direct fuel consumption (Mj)

4. DISCUSSIONS AND FINDINGS

The basic operational energy identified from the most frequent is lighting, cooking, cooling, hot water heating, water pumping and washing. Hoverer, majority identified that the major energy source used to carry out most of their basic operation is the main grid electricity although; most household has low access to electricity form the national grid at an average of 8 hours per day. An alternative to grid electricity identified was direct fuel combustion (liquefied petroleum Gas, petrol and kerosene). Kerosene and liquefied petroleum gas were used basically for cooking and domestic hot water heating, while the use of generators powered by petrol was used for others operations. The use of wood as fuel was identified but usage was not significant.

The median was used as the measure of central tendency to determine the average monthly expenditure of residents for grid electricity consumption; the result was estimated to be about ₦2,500 as shown in Table 1. The tariff for grid electricity of Benin Electricity Distribution Company (BEDC) the electricity company in charge of the study area was obtained from an electricity bill to be 14.83kWh. Therefore, the average monthly energy consumption per household was estimated to be 135kWh and 1620kWh annually. To determine the annual energy consumed by grid electricity, equation 2 above and a primary energy conversion factor for grid electricity was used which was estimated to be 15505MJ.

Also, the median was used as the measure of central tendency to determine the average monthly fuel consumption measured in litres as shown in Table 2. The result shows that an average of 2 litres of kerosene was used by the residents per week and 104 litres annually. Also, the result shows that an average of 10 litres of petrol was used by the residents per week and 520 litres annually. The quantity of Liquefied gas used was not captured in this survey. Based on the calculations, the Kerosene annual primary energy consumed was estimated to 3,664MJ, while that of petrol was estimated to be 18,320MJ.

As shown in figure 1, the annual primary energy profile for grid electricity, kerosene and petrol were estimated to be 15505MJ, 3,664MJ and 18,320MJ respectively. Therefore, the overall annual operational energy for a residential unit was estimated to be 37,489MJ.

5. CONCLUSION

The study has investigated occupant's operational energy consumed in residential buildings in low, medium and high density areas of Akure, the State capital of Ondo state, Nigeria. The result showed that operational energy sources were grid electricity, liquefied gas, Kerosene and petrol. However, the study is similar to the study carried out in public residential buildings in Lagos State, where the pattern of operational energy use was examined in relation to non-renewable and renewable energy (Ezema, Olotuah, and Fagbenle 2016). The study showed a direct dependence of occupants on non-renewable fuel combustion for electricity as a result inadequate supply from national grid which corresponds with our findings in this study.

However, this study identified the basic operational energy from the most frequent is lighting, cooking, cooling, hot water heating, water pumping and washing. Also, the major energy source used to carry out most of their basic operation is the main grid electricity although most households have low access to electricity form the national grid at an average of 8 hours per day. An alternative to grid electricity identified was direct fuel combustion (liquefied petroleum Gas, petrol and kerosene). Kerosene and liquefied petroleum gas were used basically for cooking and domestic hot water heating, while the use of generators powered by petrol was used for others operations.

Consequently, this has not just increased the level of operational energy intensity of residential buildings but has largely contributed to the emission of Co_2 into the atmosphere which has not only resulted to health hazards but emission of Co_2 is a major traceable cause of climate change (Oyedepo, 2012).

However, energy use and energy intensity regulations in building codes should be enforced in the erection of buildings (Ezema et al 2016). Residents and building owners should also be enlightened on the importance of renewable energy options (solar and wind) that are sustainable and accessible which can be adopted to reduce reliance on alternative energy sources. Also, energy efficient will go a long way to reduce operational energy intensity; building occupants should be educated on building energy efficiency practises that will go a long way to reduce energy consumption in the residential buildings.

Table 1: Monthly Grid Electricity Consumption

Category	Frequency	%
Below 2000 naira	23	21
2000 – 3000 naira	48	44
3001 – 4000 naira	08	7
4001 – 5000 naira	14	13
Above 5000 naira	14	13
Total	108	98

Source: Researcher's survey

Table 2: Direct fuel use in Households

Type Of Fuel	Users Frequency	%	Non-Users Frequency	%
Kerosene	65	60	43	40
Petrol	102	94	6	6

Source: Researcher's survey

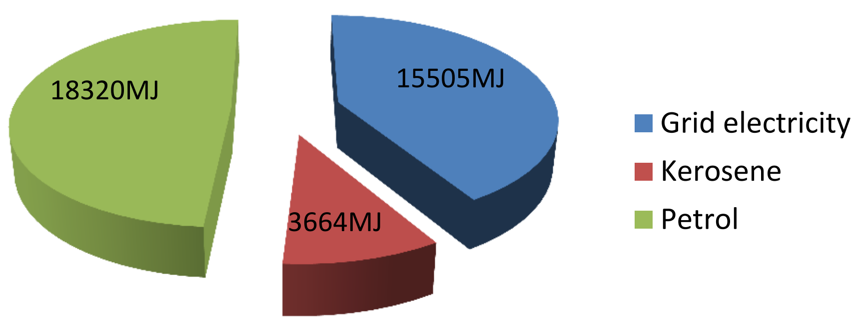

Figure 1: Annual primary energy profile measured in MJ per Housing unit

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