Household energy consumption within a low-income neighbourhood in Akure, Nigeria

S D Olanrewaju* and O B Adegun

1 Department of Architecture, Federal University of Technology, Akure, Nigeria.
*Corresponding Author: olanrewajso@futa.edu.ng, oyindami@yahoo.com

Abstract. Globally, energy consumption represents a major contributor to climate change and global environmental problems. Identifying the potential factors explaining the variability in household energy consumption in buildings aids the development of appropriate energy conservation policies. The analysis of energy in residential sectors captures energy consumed by households to maintain operational functions of their daily lives. This study examines the household energy consumption in a low-income neighbourhood in Akure. Based on the results from a survey of 80 households, this study presents the energy consumption pattern of households in the study area. The study finds that energy is dominated by fossil fuel sources. Predominant proportion of energy consumed is used for cooking. The study concludes by outlining some practical implications for policy and practice.

1. Introduction

Globally, the building sector consume about 40% of the total energy consumption and accounts for 33% of CO₂ emissions [1]. Building energy demand is constantly increasing due to population growth, high rate of urbanization, technological advancement and lifestyle changes [2]. Energy efficiency is a key strategy effective to minimize energy production cost, utilization of natural resources as well as climate change mitigation [3]. The residential sector is the largest source of energy demand especially in developing economies [4]. For example, residential sector is the second and third largest energy user in China and Malaysia respectively [5, 6]. In Nigeria, about 65% of the annual energy consumption is used by the residential sector [7]. Therefore, residential sector is an important target for improving energy efficiency.

Building energy analysis consists of operational and embodied energy. While embodied energy deals with energy used in the course of building construction, operational energy is the amount of energy required to maintain the operational functions during the lifecycle of a building. The evaluation of energy performance of existing buildings serves as basis for design and non-design strategies for retrofitting or behavioural change to achieve energy-efficient buildings [9]. The potential interventions for energy-efficiency through embodied energy might be quite challenging for the residential sector in Nigeria since the existing housing stock is majorly self-built. In addition, households are made up of individuals with different socio-demographic characteristics, wherein compliance to energy regulation might be difficult [10]. Therefore,
understanding operational energy consumption patterns is imperative and seem a better approach for the development of strategies and policies for energy conservation and energy efficiency.

Studies from the developed countries have explored energy consumption pattern in residential sector [11-13]. Previous studies have also explored the characteristics and factors influencing energy consumption in developing countries such as China [14] and Malaysia [15]. Some studies examined energy consumption for cooking and grid electricity in Nigeria [16-19]. However, there is paucity of research on residential energy consumption that captures operational energy in low-income residential urban setting. Hence this study, seeks to fill this gap by exploring household operational energy consumption pattern in Akure. To explore the existing knowledge base in available literature, the next section presents a review that provides overview on operational energy consumption, residential energy sources and conservation. The subsequent sections discuss the methodological approach for data collection and findings of this study.

2. Literature Review

Residential energy consumption analysis is based on available energy sources utilized by households [20] and the sources can be categorized into that which is renewable and non-renewable. Nigeria is endowed with abundant renewable energy sources such as solar, wind and hydropower. For example, for solar energy there is an average solar radiation of 5.25 kWh/m2/day which, if harnessed, might meet the entire national household energy demand [21]. Despite the abundance of renewable energy sources, Nigerian energy supply is mostly dependent on non-renewable energy sources such as natural gas, petroleum products, and coal. High rate of dependency on fossil fuels can be linked to electricity supply distribution problems. The installation of renewable energy requires technical expertise which is not yet widespread and high installation cost which most homes cannot afford also constitutes an hinderance [22].

Residential energy consumption varies significantly across different geographical region due to climatic variations across cities and household formations. In Nigeria, energy consumed within households is predominately from electricity, LPG, diesel, kerosene. The major end-use activities for residential energy are lighting, cooking and household appliances. Household cooking takes up to 91% of the energy consumed in households [23]. A survey conducted in urban SouthWest Nigeria in 2012 found that the main fuel used for cooking is kerosene (about 90% of the households) while electricity and LPG are used minimally [24]. A more recent survey in Bauchi city (NorthEast Nigeria) revealed something different. Kerosene still was mostly used (41%), followed by wood (35 %), LPG (24 %) and charcoal (20 %) [25]. In Malaysia, LPG and petroleum products are the dominant household energy sources, which accounted for the largest share (27%), followed by wood (25%), electricity and natural gas with a share of 18% and 3%, respectively [15]. In Chinese households, space heating, cooking, and water heating dominate energy-consuming end uses, with 45% of total energy needs from coming district heating supplies [14].

Household energy usage is influenced by individual and household situational factors that affect energy-related practices [26]. Several studies have established the influence of socio-economic status e.g. income [20], home ownership [27], household size [28], dwelling type/size and number of appliances [29] on the variability of energy usage in households. In addition, psychological factors such as occupants’ attitude, behavioural control and awareness are also important predictors of energy consumption [27]. For example, primary influencing factors of energy consumption in China include household income and size, presence of children, home ownership, living area, and households' awareness [20]. Corroborating this, single occupant Irish apartment consume less electricity than apartment with two or more occupants. It has also been confirmed that occupant’s indoor temperature preference, amount of time spend indoor and attitudes are relevant behavioural variables [31].
Dwelling characteristics have been considered as an interactive factor influencing the energy-related practices of households. In a survey of American households, it was revealed that dwelling size and number of household appliances mediates the effects of household socio-economic characteristics on energy consumption [12]. Apart from dwelling size, the type of dwelling also have significant impact on energy consumption especially for space conditioning [32]. For instance, [33] observed that households living in detached buildings consume more electricity than those in semi-detached buildings, and these households consume more than those in terrace and apartment buildings. The use of air-conditioners and high-energy consuming appliances in newer apartments contribute to high consumption of electricity [34]. The use of TV in US households have significant effect on domestic electricity use [35].

The influence of some situational factors in Nigeria is evident in the literature accessed. For instance, [17] investigated energy use and emission pattern in south western Nigeria, the study revealed that post-paid low-income earners utilized more energy than prepaid high-income earners. Energy consumption was found to vary across density, as densely populated area consumes more energy than sparsely populated areas [19]. In a survey of energy use in public housing, [36] revealed high energy use intensity based on non-renewable energy sources. The price of petroleum-derived energy sources also affects energy consumption pattern for cooking. According to [16] low-income households switched from kerosene to fuel wood and other inefficient energy sources due to increase in price of fossil fuels. Apart from cost increase, availability of energy sources, increase in household size, dwelling ownership status, seasonal variation, education level and house location influence household cooking energy choice [25].

3. Research methodology

The purpose of this study is to examine energy source and consumption pattern in households within the inner-city area of Akure, Ondo State in the southwestern region of Nigeria. Akure is a medium-sized city with population of around 484,798 people in 2006, which is projected to have grown beyond 588,000 at present [37]. The core area of Akure, which consist of low-income informal housing, was selected as the study area. About one-third of household heads in the area earned less than 10,000 naira (US$30) monthly [38]. A quantitative research approach was adopted, and a survey was conducted. Following the review of literature, a questionnaire (as research instrument) structured into two parts was developed. The first part included questions about demographics such as gender, age, income, educational status, tenure type, household size. The second part consisted of questions about operational energy sources, the pattern of energy used, frequency of usage and amount incurred on energy.

The research population consists of all residential buildings within the study area - the Old Stadium road/Oke Igan neighbourhood in Akure. Satellite image helped to identify all buildings in the area and a sample of 100 households spread across the entire neighbourhood was taken. The questionnaire was administered to every fifth house, where an adult available and willing to respond was engaged with the questionnaire. The research assistants completed the questionnaire by interviewing each respondent. Total of 80 questionnaires administered to the respondents were successfully completed. The data was analyzed using descriptive statistical tool. Based on the data collected, energy consumption of a typical household in the study area was calculated using the following basic equations for primary energy content for electricity and direct fuel consumption [39-41].

\[ OE = PEOGE + PEODFC \]  
\[ PEOGE = GE \times 3.6 \times PEF \]  
\[ PEODFC = DFC \times LHV \]
Table 1: Description of symbols

| Symbol | Description                                      | Value | Unit    |
|--------|--------------------------------------------------|-------|---------|
| OE     | operational energy                              |       | MJ      |
| PEOGE  | primary energy content of grid electricity       |       | MJ      |
| PEoDFC | primary energy content of direct fuel consumption|       | kWh     |
| GE     | grid electricity consumption based on electricity bill and unit price of electricity |       | MJ/kWh  |
|        | Conversion factor                               | 3.6   | MJ/kWh  |
| DFC    | Fuel consumption                                |       | Litres  |
| LHV    | Lower heating value of fuel                     |       | MJ/Kg   |
|        | DPK                                             | 43.1  | MJ/Kg   |
|        | PMS                                             | 44.0  |        |
|        | LPG                                             | 45.3  |        |

4. Findings and Discussion

This section presents findings from the survey. It deals with sources of energy, what activities energy is used for and how much energy is consumed by households in the study area. As shown in table 2, majority of the respondents are males (51.3%). A total of 31.3% are between 18-24 years, 23.8% are between 25-34 years, 20% are between 35-44 years while 15% are between 45-54 years. In terms of academic qualifications, 66.3% had secondary education, 21.3% had tertiary education, 10% had primary school education while 2.4% had no form of education. Furthermore, 42.5% earn below #21,000 monthly, 48.7% earn between #22,000 - 60,000 monthly, 7.5% earn between #61,000 - 120,000 monthly while 1.3% earn above #120,000. These indicate diversity in household composition within the area. As initially stated, the results confirm that the study area is dominated by low-income earners.

Table 2: Household characteristics

| Variables          | Frequency (N=80) | Percentage (%) |
|--------------------|------------------|----------------|
| Gender             |                  |                |
| Male               | 41               | 51.3           |
| Female             | 39               | 48.7           |
| Age                |                  |                |
| 18-24              | 25               | 31.3           |
| 25-34              | 19               | 23.8           |
| 35-44              | 16               | 20             |
| 45-54              | 12               | 15             |
| Above 55           | 8                | 10             |
| Level of Education |                  |                |
| None               | 2                | 2.4            |
| Primary            | 8                | 10             |
| Secondary          | 53               | 66.3           |
| Tertiary           | 17               | 21.3           |

| Monthly Income     | Frequency (N=80) | Percentage (%) |
|--------------------|------------------|----------------|
| Below #21,000      | 34               | 42.5           |
| 22,000-60,000      | 39               | 48.7           |
| 61,000-120,000     | 16               | 7.5            |
| Above 120,000      | 1                | 1.3            |

| Employment status  | Frequency (N=80) | Percentage (%) |
|--------------------|------------------|----------------|
| Self employed      | 48               | 60             |
As shown in table 3, the dominant energy sources are grid electricity, PMS, DPK, LPG. Among the 80 households surveyed, 93.3% use grid electricity, 58.75% use DPK, 67.6% use PMS, and 95% use LPG. This indicates overlapping use of different types of energy as most households use more than a source of energy for an activity e.g. cooking, lighting. The findings align with findings of earlier studies, which posit that LPG, petroleum products, electricity are the predominant energy sources in similar developing economy [14, 24]. Multiple energy use patterns in urban households were identified in Bauchi [25].

| Energy source | Usage | Usage ratio |
|---------------|-------|-------------|
| Electricity   | Electrical appliances (television, fan, light, hot plate, etc.) water pump | 93.3% |
| DPK           | Cooking | 58.75% |
| PMS           | Generator | 67.6% |
| LPG           | Cooking | 95% |

The end-use activities for residential energy were cooking, lighting, household electrical appliances and water pumping. In an average household, gas cooker and kerosene stove are the major cooking devices, electric cooker, kettle as well as boiling rings are also available for daily cooking and domestic hot water. Despite the shortage of electricity supply, residents still acquire a quite number of home appliances such as refrigerators, lamps, televisions, computer washing machines. Nearly, 75% of household surveyed have electric fans for space cooling. This supports earlier findings that emphasized the transition from traditional energy sources to modern sources in developing countries [42]. This indicates that the respondents acquire different appliances to improve their quality of life.
Information about mode of electricity billing and associated monthly expenditure were sought. As shown in table 4, 37.5% of the respondents use prepaid meter, 60% use postpaid meter while 2.5% do not have either of the two. It is evident that post-paid billing system is more prominent in the study area. The findings further revealed that most householders using prepaid meter reported consciousness of the conservative measures for available limited supply. The average expenditure on grid electricity is ₦3000. Considering the electricity tariff of BEDC as of 2019 (#29 per KWh), the average electricity consumption was estimated to be 1236kWh annually per household and the energy content of electricity was estimated to 16,019MJ using equation 1. With an average household size of 4, the energy consumption per capita is 309kWh, this is higher than the per capita estimation of 156kwh in 2012.

Table 5: Weekly direct fuel consumption

|         | Frequency | Percentage |
|---------|-----------|------------|
| **DPK** |           |            |
| None    | 33        | 41.3       |
| 1-5litres | 16      | 20         |
| 6-10litres | 16    | 20         |
| 11-20litres | 12   | 15         |
| 21-30litres | 2    | 2.5        |
| Above 30 liters | 1  | 1.3        |
| **PMS** |           |            |
| None    | 26        | 32.4       |
| 1-5litres | 5       | 6.3        |
| 6-10litres | 15    | 18.8       |
| 11-20litres | 12   | 15         |
| 21-30litres | 12   | 15         |
| Above 30 litres | 10  | 12.5       |
| **LPG 6kg** |         |            |
| None    | 4         | 5          |
| Weekly  | 11        | 13.75      |
| Every two weeks | 11   | 13.75      |
| Every three weeks | 12  | 15         |
| Every four weeks | 42  | 52.5       |

The direct fuel consumption was estimated based on the average liquid fuel consumption for each type of fuel. As shown in table 5, average DPK and PMS used per week are 7litres and 15litres respectively. This amounts to 336litres of DPK and 720litres of PMS annually. On the average, the residents use 6kg LPG cylinder monthly. This amount to 72kg annually. Using equation 2, the primary energy content for DPK, PMS and LPG was estimated. The estimated energy contents are 14,482MJ, 31,680MJ and 3,262MJ for DPK, PMS and LPG respectively. Therefore, the annual operational energy is 65,443MJ. This indicates that the energy mix in the study area is fossil fuel driven basically due the use of fossil fuel powered generators as a result of the shortage of electricity supply. Based on the household characteristics obtained, the lower low-income earners use more of DPK for cooking than LPG which is less efficient and have the potential of increasing the greenhouse emission in the area. This finding aligns with previous studies [20, 16, 36] that identified DPK as the most used fuel for cooking. This suggests that the prices of energy source affects choice of energy for cooking. Only one respondent derive energy through solar energy. This confirms that the study area is largely dependent on non-renewable energy sources.
5. Conclusions

This paper presents the operational energy consumption pattern in an Akure inner-city neighbourhood based on data obtained from 80 households. The sources of energy are important aspects of physical development and economic growth. Overall, we find that the major sources of energy are non-renewable which are dominated by fossil fuel resources. The average estimated household energy consumption was 65,443MJ. The postpaid metering system is the mostly available electricity billing system.

Our results are important for policy implications. The diversification of energy basket for the residential sector is important. Hence, the installation of appropriate infrastructure to enhance energy provision using the abundant renewable energy resources present in the country is more than urgent. In addition, initiatives to drive energy efficiency such as use of incandescent light bulbs, energy performance labeling of electrical appliances should be enhanced. In addition, the full implementation of prepaid metering system is necessary as it is in consonance with global best practices. Promotion of energy-efficiency among households through relevant information, awareness and rewards are necessary.

References

[1] Baek C, Park S, Suzuki M and Lee S 2013 Life cycle carbon dioxide assessment tool for buildings in the schematic design phase. Energy Build 61 275-287.
[2] Pérez-Lombard L, Ortiz J and Pout C 2008 A review on buildings energy consumption information. Energy Build 40(3) 394-398.
[3] Oyedepo S 2014 Towards achieving energy for sustainable development in Nigeria. Renewable and Sust Energy Reviews 34 255-272.
[4] Nejat P, Jomehzadeh F, Taheri M, Gohari M and Majid M 2015 A global review of energy consumption, CO2 emissions and policy in the residential sector Renewable and Sust Energy Reviews 43 843–862.
[5] Yuan X, Wang X and Zuo J 2013 Renewable energy in buildings in China—a review. Renewable and Sust Energy Reviews 24 1–8
[6] Malaysia Energy Commission 2014 National Energy Balance. Putrajaya.
[7] Oyedepo S, Adekeye T, Leramo R, Kilanko O, Balolola P, Balogun A, and Akhibi V 2016 Assessment of energy saving potentials in covenant university, Nigeria, Energy Eng 113(3) 7–26.
[8] Giordano R, Giovanardi M, Guglielmo G and Micono C 2017 Embodied energy and operational energy evaluation in tall buildings according to different typologies of façade. Energy Procedia 134 224–233.
[9] Olarewaju S, Adetunj O and Ogundope T 2019 Achieving Energy Efficient Building through Energy Performance Analysis of Building Envelope in Student Housing. Journal of Physics: Conference Series, doi:10.1088/1742-6596/1378/4/042023.
[10] Hori S, Kondo K, Nogata D and Ben H, 2013 The Determinants of Household Energy-saving behavior: Survey and Comparison in Five Major Asian Cities. Energy Policy 52 354–362.
[11] Fertel C, Bahn O, Vaillancourt K and Waaub J 2013 Canadian energy and climate policies: a SWOT analysis in search of federal/provincial coherence. Energy Policy 63 1139–50.
[12] Karatasou S and Santamouris M 2019 Socio-economic status and residential energy consumption: A latent variable approach. Energy Build 198 100–105.
[13] Heinonen J and Junnila S 2014 Residential energy consumption patterns and the overall housing energy requirements of urban and rural households in Finland. Energy Build 76 295–303.
[14] Zheng X, Wei C, Qin P, Guo J, Yu Y, Song F and Chen Z 2014 Characteristics of residential energy consumption in China: Findings from a household survey. Energy Policy 75 126–135
[15] Azlina A, Siti E, Abdullah E, Kamaludi M and Radam M, 2015 Energy conservation of residential sector in Malaysia. Journal of Business and Social Development 3(2) 51-62.
[16] Adelekan I, and Jerome A, 2006 Dynamic of household energy consumption in a traditional African city, Ibadan. Environmentalist 26 99–110.
[17] Abimbola O, Amori A, Omotosho O, Igbode I, Omoyeni D and Ajayi-Banji A 2015 Investigation of energy use pattern and emission discharge in Nigeria: a case study of South-west zone. International Journal of Engineering and Technology Innovation 5(1) 56-65.

[18] Ubani O, Umeh L and Ugwu L 2013 Analysis of the electricity consumption in the south - east geopolitical region of Nigeria. Journal of Energy Technologies and Policy 3(1) 2224-3232.

[19] Akinola A, Oginni O, Rominiyi O and Eiche J, 2017 Comparative study of residential household energy consumption in Ekiti state-Nigeria. British Journal of Applied Science & Tech 21(2) 1-10

[20] Zhang J, 2010 Operational energy consumption and GHG emissions in residential sector in urban China: An empirical study in Jinan. Unpublished Master’s thesis, Massachusetts Institute of Technology.

[21] Abam F, Nwankwojike B, Ohunakin O and Ojomu S, 2014. Energy resource structure and on-going sustainable development policy in Nigeria: A review. Int Journal of Energy and Env Engr 5(2-3)102.

[22] Ogunleye I and Awogbemi O 2011 Constraints on the use of solar photovoltaic as a sustainable power source in Nigeria, American Journal of Scientific and Industrial Research 3(1) 2224-3232.

[23] Oyedepo O 2012 Energy and sustainable development in Nigeria: the way forward. Energy Sustain Soc 215.

[24] Ajayi P 2018 Urban household energy demand in southwest Nigeria. African Development Review 30(4) 410-422.

[25] Bisu D, Kuhe A and Iortyer H, 2016. Urban household cooking energy choice: an example of Bauchi metropolis, Nigeria. Energy, Sustainability and Society 6(1) 15-27.

[26] Frederiks E, Steen K and Hobman E 2015 The socio demographic and psychological predictors of residential energy consumption: a comprehensive review. Energies, 8, 573-609.

[27] Rehdanz K, 2007 Determinants of residential space heating expenditures in Germany. Energy Econ. 29 167–182.

[28] Bedir M, Hasselaar E and Itard L 2013 Determinants of electricity consumption in Dutch dwellings. Energy Build 58 194–207.

[29] Kavousian A, Rajagopal R and Fischer M 2013 Determinants of residential electricity consumption: using smart meter data to examine the effect of climate, building characteristics, appliance stock, and occupants’ behavior Energy 55 184–94.

[30] Leahy E and Lyons S 2010 Energy use and appliance ownership in Ireland. Energy Policy 38(8) 4265–79.

[31] Nair G, Gustavsson L and Mahapatra K, 2010 Factors influencing energy efficiency investments in existing Swedish residential buildings. Energy Policy 38, 2956–2963.

[32] Kaza N 2010 Understanding the spectrum of residential energy consumption: A quantile regression approach. Energy Policy 38 6574- 6585.

[33] Chong H, 2012 Building vintage and electricity use: old homes use less electricity in hot weather. European Economic Review 56(5) 906-930.

[34] Carlson D, Mathews H and Bergés M 2013 One size does not fit all: averaged data on household electricity is inadequate for residential energy policy and decisions. Energy Build 64 132-144

[35] Sanquist T, Orr H, Shui B and Bittner A 2012 Lifestyle factors in U.S. residential electricity consumption Energy Policy 42 354-64.

[36] Ezema I, Olotuah A and Fagbenle O, 2016 Evaluation of energy use in public housing in Lagos, Nigeria prospects for renewable energy sources. Int Journal of Renewable Energy Dev 5 15-24

[37] National Population Commission, 2006. Federal Republic of Nigeria Official Gazette Abuja.

[38] Ayoola H, Fakere A and Oluosoga O, 2019. Place Attachment in Poor Residential Neighbourhoods of Akure Nigeria. Covenant Journal of Research in the Built Environment 7(2) 20-36.

[39] GREET 2010 The greenhouse gases, regulated emissions and energy use in transportation model, GREET1.8d.1. http://greet.es.anl.gov/ accessed 08/05/2020.

[40] Hofstrand D 2008 Energy measurements and conversions, file C6-86, University Extension, Iowa State University, www.extension.isate.edu/agdm.
[41] IINAS 2015 Development of the primary energy factor of electricity generation in the EU-28 from 2010-2013, International Institute for Sustainability Analysis and Strategy, Darmstadt, Germany.

[42] Alam M, Sathaye J and Barnes D 1998 Urban Household Energy Use in India: Efficiency and Policy Implications. *Energy Policy* **26**(11) 885-89.