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TECHNICAL ARTICLE

The Evolution of Rural Household Electricity Demand in Grid-Connected Communities in Developing Countries: Result of a Survey

Salisu Isihak*, Uduak Akpan† and Sanusi Ohiare*

The expected electricity demand level of unelectrified communities is one of the variables that guide rural electrification planners and electricity distribution utilities in making the choice of extending electricity grid to such communities and in using appropriate sizes of distribution assets such as transformers. This study presents the result of a survey to determine the level of household electricity demand in two villages in South-West Nigeria. The electricity demand is determined using a bottom-up approach which traces the household electricity demand through the purpose of use, the type and number of electrical appliance, and the duration of use. The result shows that most respondents will use bulbs for up to 8 hours per day but those who own refrigerators will power it for over 16 hours per day. The level of electricity consumption in the households sampled range from 0.38–20.56 kWh/day. Policy implications are discussed.

Keywords: Household survey; bottom-up approach; electricity demand; rural areas; Nigeria

1. Introduction

In many developing countries especially those in sub-Saharan Africa (SSA), a large percentage of the population is poor and resides in rural areas where there is substantial lack of basic amenities and social infrastructures such as good transport network, water, modern energy services, etc. Of the modern energy services, access to electricity is the most crucial because electricity is the most versatile energy carrier. The International Energy Agency estimates that about 789 million people were without access to electricity in 2018 and most of them were in SSA (IEA *et al.* 2020). Nigeria contributes substantially to the number of people without access to electricity in SSA. The National Population Commission (of Nigeria) puts Nigeria's electricity access rate in 2018 at 56.5%, with rural and urban access rate being 37.1% and 81.7% respectively (National Population Commission, 2019). Access to electricity has been noted to be an important driver of the socio-economic transformation of rural areas in different facets of development such as health care, water supply, education, etc. (Kanagawa & Nakata, 2007, 2008; Sokona *et al.*, 2012). Consequently, investment in the provision of electricity services and ensuring the availability of electricity in rural communities has the potential to raise the productivity and profitability of rural micro-enterprises thereby providing rural dwellers additional disposable income that may be used to improve their standard of living (Akpan *et al.*, 2013).

Given the importance of electricity access to rural development and the lack of it in many rural areas, the Nigerian government through the Electric Power Sector Reform Act had established the Rural Electrification Agency and saddled it with the responsibility of developing a Rural Electrification Strategy and Plan to minimize the cost of achieving universal electricity access in Nigeria. Most communities are powered by extending the existing grid. However, electricity distribution utilities are often reluctant to make such investment because of the concern that the demand from such communities may be low thereby leading to underutilization of electricity, and by extension, monetary losses. The expected electricity demand level of unelectrified communities is one of the variables that guide rural electrification planners and electricity distribution utilities in making the choice of extending electricity grid to such communities and in using appropriate sizes of distribution assets such as transformers.

The level of electricity demand of a rural household in an unelectrified community may be estimated in two ways: (a) by examining the present end-use of energy in the household (whether for lighting, cooking, motive use, etc.) and making assumptions regarding the expected level of switch in energy source from the present energy

* Rural Electrification Agency, Rural Electrification Fund, NG

† Sustainability, Policy, and Innovative, Development Research (SPIDER) Solutions Nigeria, Uyo, Akwa Ibom State, NG

Corresponding author: Salisu Isihak (risalisu@gmail.com)

source to electricity, and adding the demand for electricity that will arise gradually due to the availability of electricity; and (b) by examining the level of electricity demand in other rural households which have access to electricity and assuming the electricity demand patterns will be similar for the households in the unelectrified community. Both methods have their pros and cons. However, the latter is more applicable in our situation because it provides insights on the evolution of the electricity demand in a rural community within a given period after electricity has been provided to such a rural community. This latter option may be achieved in two ways:

- first, one may obtain from the utility servicing the area the average meter reading of households. This approach will provide precise data on the electricity demand; however, it will not be feasible in households that are not properly metered whereby electricity bills are usually estimated or in households that connect to the grid informally. In addition, because the meter reading shows the total consumption of the households within a period, it shields the consumption pattern and the likelihood of households to own certain appliances or to imbibe demand-side management behaviors by switching off unused appliances;
- second, by conducting household survey on electricity use.

This second method overcomes the setback of the first method as it adopts a bottom-up approach to capture the propensity of households to use electricity as the source of energy for different end uses. The advantage of this approach is evident in the fact that it is often employed in energy-use accounting (Bhattacharyya & Timilsina, 2010) and it is integrated into computer programmes like RETScreen.

Given the increased commitment of government towards increasing access to electricity in rural areas and the amount of information that may be obtained through conducting household electricity demand and load assessment, this study intends to use the bottom-up approach to examine the level of electricity demand of households in two rural communities in Nigeria that have been connected to the grid within the last ten years. This will enable us to understand the evolution of rural household electricity demand within ten years of the community being connected to the grid. This study is important because it fills the data gap on rural household electricity demand in Nigeria and will be useful to rural electrification planners and policy makers especially in assessing the techno-economic viability or otherwise of decentralized electrification options.

Several studies have examined the household electricity consumption and/or it determinants by examining the underlying factors that contribute to electricity consumption such as the stock of appliances owned, socio-economic and lifestyle factors, climatic and cultural factors, etc. (Murthy *et al.*, 2001; Genjo *et al.*, 2005; Ghisi *et al.*, 2007; Zhou & Teng, 2013; Wijaya & Tezuka, 2013). Ghisi *et al.* (2007) surveyed 17,643 households in 12 states in different bioclimatic zones in Brazil to obtain the electricity consumption of all appliances owned by households. The study observed the largest end-use of electricity are for refrigerator and freezer together which accounted 38–49% of electricity consumption of the dwellings. Murthy *et al.* (2001) conducted a survey of 1,165 households in four districts of Karnataka State in India to examine the electricity consumption of the households and employed three approaches: the engineering approach, the appliance stock approach, and the appliance census approach. The engineering approach is akin to the bottom-up approach because it examines the end-use of electricity using the appliance, the wattage of each appliance and the duration of use of each appliance. Genjo *et al.* (2005) conducted a survey of 505 Japanese households to examine the relationship between possession of household appliances and electricity consumption and observed that increase in electricity consumption was due to increased number of appliances. Murata *et al.* (2008) surveyed households in 13 cities in China to examine end-use of electricity in the households and the ownership of different appliances as well as the potential of electricity savings in the future by improving the efficiency of appliances. Wijaya & Tezuka (2013) examined the electricity consumption characteristics of households in two cities in Indonesia and observed that appliance stock and socio-economic characteristics of households had a significant effect on electricity consumption.

Our study is similar to these studies because it uses household surveys to examine the households' ownership and use of electrical appliances. However, it is different from most of these studies: they examine the determinants of household electricity consumption using a regression model where actual data on electricity consumption level obtained from electricity bill is the dependent variable and the stock of electrical appliances, socio-economic variables, price of electricity, etc. are explanatory variables (Wijaya & Tezuka, 2013; Zhou & Teng, 2013).

The study is organized as follows: following this brief Introduction will be the Methodology. We will present and discuss the results in the third section and make our Conclusion and Policy recommendations in the fourth section.

2. Methodology

2.1. Study Area

The study was conducted in Oyo State, Nigeria. Oyo State is one of the 36 states in Nigeria located in the South-Western part of the country. The state lies between latitudes 7° 3′ and 9° 12′ North, and longitudes 2° 47′ and 4° 23′East, is bordered by Kwara State to the North, Ogun State to the South, Osun State to the East, and the Republic of Benin to the West. The state is made up of 33 local government areas[1] and has several urban areas including Ibadan, Oyo, Ogbomosho, etc. and also has several rural areas. The average household size in the state is 4.0 (NBS, 2009). Agriculture is the predominant economic activity in the rural areas and the climate of the state favors the

cultivation of Maize, Yam, Cassava, Millet, Rice, Plantain, Cocoa tree, Palm tree and Cashew. Other non-agricultural economic activities like broom making, tailoring, carpentry, etc. also thrive in the rural areas.

2.2. Survey design and data collection

To examine the electricity demand of households in rural areas, the study adopted a multistage sampling procedure. First, we select *Lagèlu* LGA purposively because it is one of the least developed LGAs in Oyo State. The LGA covers a land area of 342.34 sq. km. and has a population of 148,133 based on 2005 census (National Population Commission, Nigeria, 2006). Second, we set out to identify villages in *Lagèlu* LGA of Oyo State which met the following inclusion criteria: the village must be formally recognized in the official gazette of the state and must have an official village head; must be without some social institutions/infrastructure such as banks, hospital, well tarred roads (apart the connecting road that links several villages) etc; but will have primary schools, microenterprises, churches/mosque, and the grid (400V low voltage distribution line) must have been extended to the village not earlier than 2005. After identifying up to five villages that met the inclusion criteria, we selected two of them randomly, i.e. *Adeleye* and *Adewumi* villages. It is important to note that the number of villages that would have met the inclusion criteria would have been higher if we were able to go round the length and breadth of the LGA. In the third stage, we set out to select households connected to the distribution line from each village. It is also important to mention here that the connection of households in rural areas to the distribution lines do not necessary follow the standard connection procedure prescribed by the distribution company covering the geographic area in the sense that some connections are without approvals and households may get connected to the 400V low voltage distribution line informally. Nevertheless, our concern was with households that use electricity in their houses.

Primary data were obtained from the households with the support of a structured questionnaire which was designed to probe the level of electricity use in the homes. We field-tested the questionnaire through a pilot survey to understand how respondents will understand the questions and the questionnaire was finalized on the basis of suggestions and comments obtained from the pilot survey. We included a statement of informed consent in the questionnaire and this was read and explained to all potential respondents. The questionnaire was designed to ensure data protection and was divided into three sections as follows:

(a) Socio-economic profile of households: household information such as age, sex, highest educational qualification, monthly income range of head of household and household size.
(b) Characteristics of home (the number of rooms in the house): a room is defined as an area in the house enclosed by a wall, floor, and ceiling. This includes bedrooms, parlor, dinning, kitchen, bathroom, toilet, etc. A verandah is also regarded as a room because verandahs usually have lighting points.
(c) Purpose of electricity use, stock of appliances, and duration of use of appliances: the questionnaire provided a table which listed several commonly used electrical appliances and respondents were asked to select the appliances they own; to provide the number of each appliance owned and the average duration of use of each selected appliance if electricity is available all day and every day.[2] The duration of use of bulbs, television, DVD/VCD, antenna, music player/radio, and refrigerator was expressed as intervals in hours/day as follows: 0.1–3 hours, 4–7 hours, 8–12 hours, 13–16 hours, and above 16 hours. Similarly, the duration of use of electric iron, hot plate, electric kettle, and blender were expressed as intervals in minutes/day as follows: 1–30 minutes, 31–60 minutes, 61–90 minutes, 91–120 minutes, and above 120 minutes. In addition, we note that for some appliances the duration of use may differ significantly depending on the room such appliances are located (e.g. fan, bulb):[3] for such appliances, the duration of use of the appliance located in the sitting room or any other room that is most frequented by the members of the household is adopted. The study also acknowledges that duration of use of electrical appliances on weekends is usually different from those on weekdays. Nevertheless, we treat weekday and weekend use equally.

The study set out to cover 200 households in each village and the respondents were recruited through a door-to-door solicitation procedure; however, we encountered a relatively high non-response rate. Many households declined completing the questionnaire citing no personal benefit; in other cases, prospective respondents were not at home even on a Saturday. In all, the study covered 106 and 134 households in *Adeleye* and *Adewumi* villages respectively which are statistically large to validate the result of the survey. The survey was carried out in February, 2015.

2.3. Data analysis

The study seeks to estimate the electricity consumption of rural households using the bottom-up approach which involves summing up the total electricity consumed by each appliance with a given capacity used for a particular end-use of electricity, for all types of appliances and for all end-use of electricity. Mathematically, this may be expressed as:

$$\sum_{j=1} \sum_{k=1} \sum_{l=1} P_{jkl} * Q_{jkl} * T_{jkl} \quad (1)$$

Where: P_{jkl} is the *kth* type of appliance with *lth* capacity used to achieve the *jth* purpose of electricity use (for example, a 60W [capacity] incandescent bulb [type of appliance] used for lighting [purpose of electricity use]; Q_{jkl} is the number of P_{jkl}; T_{jkl} is the duration of use of each

P_{jkl}; while *j, k, l,* are counters for purposes of electricity use, types of appliance, and capacities of appliances respectively. We present in **Figure 1** an example of the approach.

Our pilot survey showed that most respondents do not know the power consumption capacities of the appliances in their homes therefore we assume that the different types of appliances used for different purposes have the same capacities. This implies that $P_{jkl} = P_{jk}$; $Q_{jkl} = Q_{jk}$; and $T_{jkl} = T_{jk}$. Therefore eqn (1) becomes:

$$\sum_{j=1} \sum_{k=1} P_{jk} * Q_{jk} * T_{jk} \quad (2)$$

We use the capacities of the appliance that are prevalent in the study area as presented in **Table 1**.

For the duration of use of the appliances, we code the time intervals as follows: 0.1–3 hours = 1.5 hours; 4–7 hours = 5.5 hours; 8–12 hours = 10 hours; 13–16 hours = 14.5 hours, above 16 hours = 18 hours; 0–30 minutes = 0.25 hours; 31–60 minutes = 0.75 hours; 61–90 minutes = 1.25 hours; 91–120 minutes = 1.75 hours; and above 120 minutes = 2.25 hours. A major setback with this approach is that households are not fully conscious of the number of hours or minutes per day each appliance is used and therefore their estimates may not be accurate. Therefore, the accuracy of our result is contingent on the reliability and accuracy of the information provided by the households Murthy *et al.* (2001). After estimating the electricity consumption for all households in each village, we present the descriptive statistics of the household electricity consumption level for each village.

Table 1: Assumed power consumption capacities of the different electrical appliance.

Appliance	Wattage	Appliance	Wattage
Lighting		TV Antenna	15
Incandescent	60	Music player	100
Energy saving*	20	Refrigerator**	400
Television (21")		Electric Iron	1000
Cathode ray tube	100	Hot Plate	1000
LCD	30	Electric kettle	1000
Electric fan	30	Blender	300
DVD/VCD	15	Washing Machine	500

* This include fluorescent and compact fluorescent lamp (CFL) bulbs.

** Refrigerator will use 500W when it compressor is on and 200W when it is off. We assume that in a 24 hour period, the compressor will be on for two-third of the period. We use the weighted average.

3. Result and discussion

This segment is divided into two parts: the first part is the summary of results from the questionnaire; and the second presents the summary of estimates of household electricity consumption.

3.1. Summary of results

3.1.1. Socio-economic profile of respondents

The socio-economic characteristics of individuals (age, sex, educational level, income, average time spent at home, etc) may play an important role in their level of electricity consumption (Zhou & Teng, 2013; Wijaya & Tezuka, 2013). The summary of the socio-economic profile of the respondents is presented in **Table 2**. We observe from **Table 2** that the modal age range of heads of households in our study is 41–55 years for respondents in both villages. In terms of the sex of the respondents, 86% of the respondents in *Adeleye* village was male and 88% of the respondents in *Adewumi* village was male. The level of education of an individual may play a role in the level of electricity use (Rahut *et al.*, 2014). Individuals with higher educational attainment are likely to have more income, may be aware of many electrical appliances and are likely to purchase and own these appliances if they can afford. About 93.4% and 89.6% of respondents in *Adeleye* and *Adewumi* villages respectively have a secondary school certificate.

Household size may play role in the level of household electricity consumption because there will be more

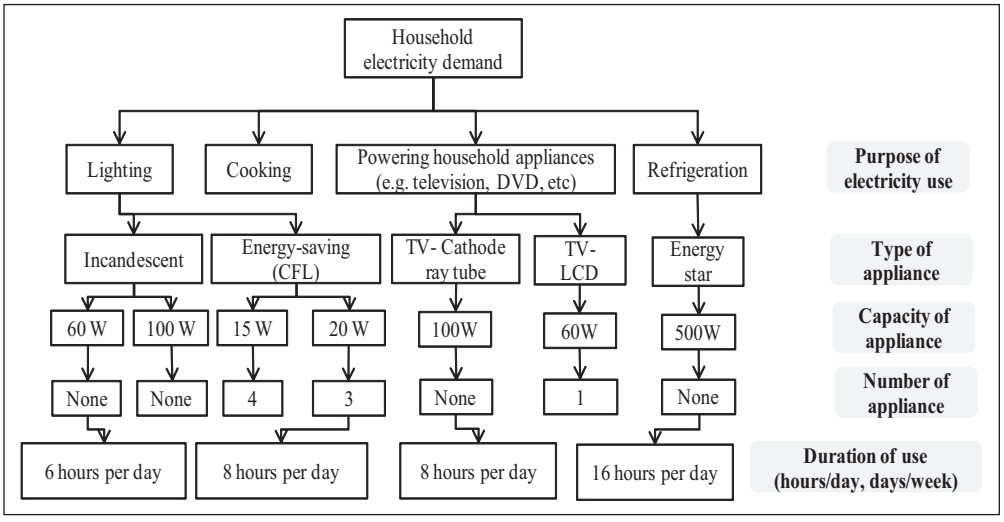

Figure 1: Representation of the bottom-up approach for examining household electricity demand.

Table 2: Socioeconomic characteristics of respondents.

Socio-economic characteristics	Communities (number of respondents)	
	Adeleye (n = 106)	Adewumi (n = 134)
Age of head of households		
Below 25 years	11	14
25–40	37	42
41–55	41	66
55–70	12	11
Above 70 years	5	1
Mean [St. dev.]	*2.65 [0.98]*	*2.57 [0.82]*
Sex of head of households		
Female	15	16
Male	91	118
Highest educational qualification of head of households		
No formal Education	0	0
Primary school completed	7	14
Secondary school completed	37	54
OND[a]/NCE[b]	47	36
B.Sc./HND[c]	15	28
Post graduate qualification	0	2
Mean [St. dev.]	*2.66 [0.80]*	*2.62 [0.98]*
Household size		
1 to 3	12	29
4 to 6	63	79
7 to 9	27	22
10 to 12	4	3
12 and above	0	1
Mean [St. dev.]	*5.57 [1.81]*	*5.06 [2.14]*
Average monthly income*		
Below N10,000	7	19
N10,001–N25,000	31	40
N25,000–N40,000	33	32
N40,00–N55,000	21	25
N55,000 above	8	10
Mean [St. dev.]	*2.92 [1.06]*	*2.74 [1.17]*

a – ordinary national diploma; b – national certificate of education; c – higher national diploma; * not all respondents answered the question.

people in large households to make use of electricity services than in small households. The modal class for household size for both villages in our study is 4–6, with an average household size of 5.63 in *Adeleye* village and 5.06 in *Adewumi* village. The income level of an individual may influence his/her ability to purchase electrical appliances. Persons with higher income are more likely to own more electrical appliance than those with low income. The modal class for monthly income of respondents in *Adeleye* and *Adewumi* villages are ₦25,001–₦40,000 and ₦10,001–₦ 25,000 respectively.

3.1.2. Number of rooms in the house

The second segment sought to know the number of rooms in the homes of the respondents. As highlighted in the Methodology, a room here is defined as an area in the house enclosed by a wall, floor, and ceiling and it includes bedrooms, parlor, dinning, kitchen, bathroom, toilet, verandah, etc. The number of rooms is directly related to the income level of the households because persons with higher income are likely to live in homes with many rooms. It is also related to the level of electricity consumption because homes with many rooms are likely to have

more electrical appliances than those with fewer rooms. For example, it is expected that all rooms in a house will have at least one lighting point. The frequency distributions of the number of rooms for the two villages are presented in **Figure 2**.

3.1.3. Purpose of electricity use, stock of appliances, and duration of use of appliances

We present the summary of the responses for purpose of use and stock of appliance in **Table 3**.

We observe from **Table 3** that all the respondents in both villages use electricity for lighting. Most respondents in both villages also use electricity to power television, DVD/VCD, electric fans and to iron clothes. We expected that the number of households that use electricity for playing music/radio will also be high, however this is not the case. The likely reason for this is that most DVD/VCD players can also be used for playing music and for radio therefore households may not see the need to purchase a separate music player/radio. A substantial percentage of

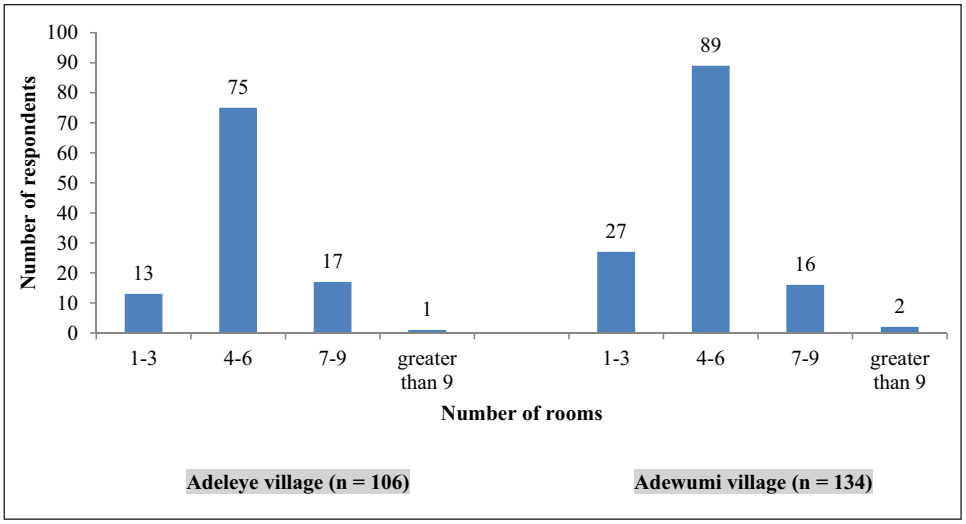

Figure 2: Frequency distribution of number of rooms in homes of respondents.

Table 3: Respondents' purpose of use of electricity and stock of appliances.

Appliance	Stock	*Adeleye* Village (n = 106)	*Adewumi* Village (n = 134)
Bulbs	*% of households that use electricity for lighting*	100.0%	100.0%
	% of Households that owned:		
	(i) only energy savings bulbs	16.0%	10.4%
	(ii) only incandescent bulbs	45.3%	54.5%
	(iii) both energy savings and incandescent bulbs	38.7%	34.3%
	(iv) 1–3 incandescent bulbs	39.6%	29.1%
	(v) 4–6 incandescent bulbs	27.4%	27.6%
	(vi) 7–9 incandescent bulbs	9.4%	20.1%
	(vii) more than 9 incandescent bulbs	7.5%	11.9%
	(viii) 1–3 energy saving bulbs	32.1%	32.1%
	(ix) 4–6 energy saving bulbs	10.4%	9.0%
	(x) 7–9 energy saving bulbs	0.9%	3.7%
	(xi) more than 9 energy saving bulbs	11.3%	0.0%
Television	*% of households that use electricity for television*	94.3%	86.6%
	% of Households that owned:		
	(i) only cathode ray tube	83.0%	73.9%
	(ii) only LCD	5.7%	10.4%

(Contd.)

Appliance	Stock	*Adeleye* Village (n = 106)	*Adewumi* Village (n = 134)
	(iii) both cathode ray tube and LCD	5.7%	2.2%
	(iv) only one cathode ray tube	83.0%	66.4%
	(v) more than one cathode ray tube	5.7%	9.7%
	(vi) only one LCD	11.3%	11.2%
	(vii) more than one LCD	0.0%	1.5%
Fan	*% of households that use electricity for fan*	81.1%	82.1%
	% of Households that owned:		
	(i) only one fan	29.2%	45.5%
	(ii) 2–4 fans	49.1%	30.6%
	(iii) more than 4 fans	2.8%	6.0%
DVD/VCD	*% of households that use electricity for DVD/VCD*	91.5%	83.6%
	% of Households that owned:		
	(i) only one DVD/VCD	72.6%	64.2%
	(ii) more than one DVD/VCD	18.9%	19.4%
TV antenna	*% of households that use electricity for antenna*	46.2%	52.2%
	% of Households that owned:		
	(i) only one TV antenna	40.6%	47.0%
	(ii) more than one TV antenna	5.7%	5.2%
Music player/radio	*% of households that use electricity for music player/radio*	29.2%	44.8%
	% of Households that owned:		
	(i) only one music player/radio	25.5%	27.6%
	(ii) more than one music player/radio	3.8%	17.2%
Refrigerator	*% of households that use electricity for refrigeration*	41.5%	41.0%
	% of Households that owned:		
	(i) only one refrigerator	41.5%	39.6%
	(ii) more than one refrigerator	0.0%	1.49%
Electric Iron	*% of households that use electricity for ironing clothes*	69.8%	70.9%
	% of Households that owned:		
	(i) only one electric iron	69.8%	70.9%
	(ii) more than one electric iron	0.0%	0.0%
Hot plate	*% of households that use electricity for cooking*	8.5%	11.9%
	% of Households that owned:		
	(i) only one hot plate	8.5%	11.9%
	(ii) more than one hot plate	0.0%	0.0%
Electric kettle	*% of households that use electricity for heating water*	21.7%	22.4%
	% of Households that owned:		
	(i) only one electric kettle	20.8%	22.4%
	(ii) more than one electric kettle	0.9%	0.0%
Blender	*% of households that use electricity for blending food items*	10.4%	15.7%
	% of Households that owned:		
	(i) only one blender	10.4%	15.7%
	(ii) more than one blender	0.0%	0.0%

households also own refrigerator and a few of them own more than one. The least end-use of electricity highlighted by the respondents in both communities is for cooking and blending food items. In addition, electricity is also used for pumping water by two households in A*deleye* village and to power a computer by one and two households in *Adeleye* and *Adewumi* village respectively.

In terms of ownership of energy-saving appliances (bulbs and television), we observe from **Table 3** that a substantial percentage of the respondents do own energy saving bulbs and 16.0% and 10.4% of respondents in *Adeleye* and *Adewumi* villages respectively use only energy saving bulbs. Similarly, 5.7% and 10.4% of the respondents in *Adeleye* and *Adewumi* villages own only liquid crystal display (LCD) televisions and 1.5% of the respondent in *Adewumi* village has more than one LCD television. The motivations for owning the energy saving appliances may be diverse: higher quality of output, durability, lower electricity consumption, etc. We did not probe the respondents further to determine their real motivations for owning the low energy appliances; however, the lower energy consumption of the appliances will likely be a motivation if the household owns a backup generator and not because of saving electricity from the grid. We may also deduce from **Table 3** the propensity of households to switch energy sources. The percentage of respondents that use electricity for lighting and cooking re-echoes the findings from literature that access to electricity may cause a switch in energy source for lighting but not necessarily for cooking (IEA, 2010). The percentage of respondents that own blenders also shows that rural households are not likely to switch the source of blending food items. In contrast, the percentage of households that own electric irons shows that rural households are likely to switch from using charcoal irons to electric irons if they have access to electricity.

We present the summary of the duration of use of the appliances in *Adeleye* and *adewumi* villages in **Tables 4** and **5** respectively.

We observe from **Tables 4** and **5** that if electricity is available all day and every day, many households in both villages are likely to be putting on light in their homes for 8–12 hours daily. A large percentage of households in both communities also noted that they will use entertainment/relaxation appliances (television, DVD/VCD, radio/music player, antenna) for up to eight hours daily. When probed further, some of the respondents noted that the entertainment/relaxation appliances are connected to the same socket and all will be powered whenever the socket is on, albeit some may be on standby. In addition, a large percentage of respondents in both villages noted that they will use refrigerator for more than 16 hours/day; and electric kettle and blender for less than 30mins/day respectively.

3.2. Household electricity consumption

We present in **Table 6** the summary of the household electricity consumption from our bottom-up analysis and in **Table 7** the distribution of electricity consumption by appliances for selected households in both villages.

Table 6 shows that the daily electricity consumption for the selected households in *Adeleye* village if electricity is available all day and everyday will range from 0.58 to 18.06 kWh/day, with average and standard deviation of 7.36 kWh/day and 4.8 kWh/day respectively. Similarly, the daily electricity consumption for the selected households in *Adewumi* village if electricity is available all day will be between 0.38 kWh/day and 20.56 kWh/day, with mean and standard deviation of 7.48 kWh/day and 5.17 kWh/day respectively. The frequency distribution shows that the percentage of respondents in both villages with electricity consumption level of 0–5kWh/day will be highest. In addition, the daily consumption level of 0.7% (i.e.

Table 4: Distribution of duration of use of electric appliances in homes of respondents in *Adeleye* village (in %).

	Total number of respondents (n = 106)					
Appliance	**Number of respondents who own appliance**	**Number of hours of use of appliance/day**				
		0–3	**4–7**	**8–12**	**13–16**	**above 16**
Bulb	106	0.0%	14.2%	67.9%	17.9%	0.0%
Television	100	39.0%	49.0%	12.0%	0.0%	0.0%
Fan	86	17.4%	30.2%	30.2%	20.9%	1.2%
DCD/VCD	97	37.1%	54.6%	8.2%	0.0%	0.0%
Antenna	49	34.7%	57.1%	8.2%	0.0%	0.0%
music player/radio	31	48.4%	38.7%	12.9%	0.0%	0.0%
Refrigerator	44	0.0%	0.0%	2.3%	15.9%	81.8%
		Number of minutes of use of appliance/day				
		0–30	**31–60**	**61–90**	**91–120**	**above 120**
Electric Iron	74	63.5%	36.5%	0.0%	0.0%	0.0%
Hot plate	9	0.0%	33.3%	55.6%	11.1%	0.0%
Boiler	23	95.7%	4.3%	0.0%	0.0%	0.0%
Blender	11	100.0%	0.0%	0.0%	0.0%	0.0%

Table 5: Distribution of duration of use of electric appliances in homes of respondents in *Adewumi* village (in %).

Total number of respondents (n = 134)						
Appliance	**Number of respondents who own appliance**	**Number of hours of use of appliance/day**				
		0–3	**4–7**	**8–12**	**13–16**	**above 16**
Bulb	134	0.0%	29.1%	61.9%	7.5%	1.5%
Television	116	30.2%	48.3%	18.1%	0.0%	3.4%
Fan	110	6.4%	18.2%	60.9%	10.0%	4.5%
DCD/VCD	112	48.2%	32.1%	14.3%	0.9%	4.5%
Antenna	70	41.4%	35.7%	14.3%	1.4%	7.1%
music player/radio	60	31.7%	38.3%	26.7%	0.0%	3.3%
Refrigerator	55	0.0%	3.6%	12.7%	20.0%	63.6%
		Number of minutes of use of appliance/day				
		0–30	**31–60**	**61–90**	**91–120**	**above 120**
Electric Iron	95	45.3%	49.5%	2.1%	3.2%	0.0%
Hot plate	16	62.5%	25.0%	0.0%	0.0%	12.5%
Boiler	30	86.7%	13.3%	0.0%	0.0%	0.0%
Blender	21	76.2%	19.0%	4.8%	0.0%	0.0%

Table 6: Household electricity consumption level in the selected villages.

Consumption level/day (kWh)	**Adeleye (n = 106)**	**Adewumi (n = 134)**
Minimum	0.58	0.38
Maximum	18.06	20.56
Average	7.36	7.48
Standard deviation	4.80	5.17
	Percentage distribution	
0–5	45.3%	44.8%
5.01–10	22.6%	20.1%
10.01–15	24.5%	24.6%
15.01–20	7.5%	9.7%
20.01–25	0.0%	0.7%

Table 7: Distribution of electricity consumption by appliances for selected households in both villages.

Appliance	**Share of appliance consumption**	
	Adeleye	**Adewumi**
Bulbs	39.8%	38.9%
Television	6.1%	11.2%
Fan	6.1%	6.1%
DCD/VCD	1.0%	1.1%
Antenna	0.5%	0.5%
Music player/radio	0.9%	1.7%
Refrigerator	38.9%	34.6%
Electric Iron	4.2%	5.1%
Hot plate	1.6%	0.1%
Electric kettle	0.8%	0.4%
Blender	0.2%	0.3%
Total	**100%**	**100%**

only one) of the respondents in *Adewumi* village will be between 20.01 kWh/day and 25 kWh/day. We observe from **Table 7** that lighting and refrigeration contributes the most to the total electricity consumption of the all the selected households in each village. Most households with higher daily consumptions are those that own refrigerators and plan to use the refrigerators for more than 16 hours a day.

4. Policy Implications and Conclusion

Data on the evolution of household electricity demand in communities that have been connected to the grid are largely unavailable and utilities and planners often rely on assumptions. In some cases, these assumptions are usually that electricity will be used for mainly lighting and to power low energy consuming appliances like televisions, electric fans, etc. as confirmed in **Table 3**. However, we also observe from **Tables 3–5** that within the initial 10 years of having access to electricity, rural households are likely to use electricity for other purposes such as refrigeration and ironing of clothes which use appliances with relatively high electric power ratings. This is very likely in rural areas such as the ones used for this study where the electricity utility seldom distribute bills and the households seldom pay for the electricity use. Moreover, we observe from **Tables 4** and **5** that if electricity is available all day and every day, rural households who own refrigerators are most likely to use them for more than 16 hours.

This finding is in line with the findings of (Xiaohua & Zhenmin, 2001) who noted that high electricity consuming appliances such as refrigerators, washing machines, etc. can be found in homes of relatively wealthy rural households. We observe from **Table 6** that some households may consume as low as 0.38 kWh/day which is in line with IEAs assumption of the initial level of electricity consumption of 250 kWh/year, i.e. 0.68 kWh/day (IEA, 2011, p. 12), but we also see that there may be some households in rural communities that may consume up to 20.56 kWh/day. This result is in line with the findings of (Obermaier *et al*., 2012) that low electricity consumption levels give way to higher consumption levels in rural areas after only a few years of rural electrification. The level of consumption by some households is far beyond the lifeline tariff threshold for rural and low-income consumers in Nigeria (which is consumption below 50 kWh/month) and it results in loss of potential revenue for the distribution company in charge of the area. In addition, the duration of use of some appliances as noted by the respondents shows that many rural households with access to electricity are unaware of the impacts of their electricity consumption pattern on the electricity system which is already overburdened. Therefore, rural electrification programmes need to be accompanied with demand-side management education. Finally, the main motivation of this study was to fill the data gap on rural household electricity consumption in Nigeria – a duty that should normally be carried out by the Rural Electrification Agency and Energy Commission of Nigeria. This study calls on these agencies to conduct a comprehensive survey on household electricity use in Nigeria as this will help planners and researchers in rural electrification.

Notes

[1] Nigeria is a federal republic made up of 36 federating units and one federal capital territory and each state is further divided into local government areas. The federal, state, and local government areas are the three main tiers of governance. In addition, the LGAs may be further divided into wards and each ward is made up of villages and/or communities.

[2] Using the present level of electricity use would have been more appropriate if electricity supply was regular; however, the erratic nature of power supply implies that electricity is used only when available and this will not reflect the level of use of appliances. Therefore we use the expected level of use if electricity is available all day and every day.

[3] For example, bulbs in the verandah may be powered all night while those in the bedroom will often be put off; fans in the sitting room may be put on for longer hours than those in the bedroom.

Ethics and Consent

This data collected in this study were collected with the support of a number of subjects who accepted to complete our questionnaire after agreeing to the Informed Consent statement included at the top of the questionnaire.

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Competing Interests

The authors have no competing interests to declare.

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