OPEN ACCESS
Saudi Journal of Engineering and Technology
Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) |ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: http://scholarsmepub.com/sjet/

Original Research Article

A Study of the Household Energy Consumption Pattern in Ondo State, Nigeria

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| **Received:** 17.03.2019 | **Accepted:** 27.03.2019 | **Published:** 30.04.2019
DOI:10.21276/sjeat.2019.4.4.4

Abstract

Ondo State is a state in Nigeria with an abundant energy reserve in petroleum and woodfuel resources, contributing significantly to the nation's overall energy output. This study reports a comprehensive survey of Household Energy Consumption pattern in this state. It examined various household energy-consuming appliances and usage time across different Building Types, economic class, and Household Sizes. Its findings revealed that: annual Household Energy Consumption across all household types in towns and villages is 10,993 kWh. Of this figure, cooking accounts for 47%, refrigeration accounts for 28%, Thermal Comfort 12%, Electric Lighting 10% while Sundry (other appliances) and Brown Goods (TV, VCD/DVD set) account for 1% and 2% respectively. A number of households were found to use a combination of two or more cooking energy resource. Kerosene served as the most commonly used means of cooking, representing 84% of the survey population, while Liquefied Petroleum Gas (LPG) represents 40%, electricity - 30%, wood – 19%, and charcoal – 7%.
Keywords: Energy management, energy audit, household energy, cooking fuels, thermal comfort.
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INTRODUCTION

Energy availability is pivotal for national development. The backbone of modernization, industrialization and good governance is the ability to make energy available to keep the industries running, and social amenities delivered, without compromising the right of the common citizen to accessible energy at reasonable cost. Industries (small, medium and large scale) rely on energy availability to minimize production cost. Schools need power for better knowledge delivery; to facilitate quality research, conducive learning environment, and general student development. The homes also need energy to make life comfortable. Everyone in the society requires power in one way or the other thus making energy matters a key issue. In fact, national GDP has been linked with energy resource abundance [1]. Appetite for energy consumption increased rapidly during the industrial revolution due to increased use of mechanized production techniques. It was not until 1970 public concerns started to arise on energy usage [2]. It soon became clear that usable energy comes at a cost and that the world energy reserve coming from fossil fuels is starting to deplete faster than its replenishment rate. Various energy conservation measures and energy policies have since then been adopted. One crucial step in this energy management process is the determination of energy consumption of a community.

In developed nations, due to efficient record keeping and database management systems, energy data is easily accessible. However, in a developing nation such as Nigeria, not much attention has been given to this. Only few researchers have taken the challenge to estimate this in small defined study areas.

In their work, [3] studied the household demand for fuels and electricity as energy sources and their effect on socio-economic characteristics across six communities in Ijebu Division of Ogun State, Nigeria. The study concluded that an improvement in income would cause an increase in demand for electricity and petroleum products in the study area, but worsening real income would place greater demand on biomass fuel. [4], in investigating the consumption pattern in Jos city, found that cooking accounted for the largest percentage of energy demand representing about 42% of the average household demand. 37.9% of the cooking energy is derived from kerosene and an additional 28.2% from charcoal. Multiple ownership of cooking appliances and fuels was found prevalent across all house types. About 80% of the sample indicated regularly using at least two different cooking appliances using different fuels. [5], studied the cooking energy demand in the rural households of Enugu State, Nigeria, and found that in comparison with occupation and income, the probability that a person uses fuelwood was significant and negatively related to occupation and significant and positively related to income respectively. In the case of kerosene demand, in comparison with occupation and income, the probabilities that a person uses kerosene was found to be positively related to occupation and income. [6], in their study of selected rural areas of Benue State, [6] found that the estimated average daily fuelwood and kerosene consumption per household ranged between 9 - 20 kg and 0.02 - 0.1 litres respectively. The average annual income of the respondents ranged between 270 - 800 USD, and that the correlation coefficients between Household Size and quantities of fuel wood and kerosene consumed by respondents are 0.914 and 0.812 respectively so their relationships are statistically significant at 5 % probability level. [7] studied the rural households' demand for domestic energy in Odeda Local Government Area (LGA) of Ogun State, Nigeria. They found that the largest proportion of the respondents use kerosene for cooking and lighting. Households that use fuel wood for cooking spend less on kerosene and electricity. On studying the household energy use between the urban and rural areas of Umuahia North Local Government Area of Abia State, it was found that the critical and significant determinants of urban domestic energy use include household income, occupation of respondents, quantity of energy and cost of substitute energy while that of the urban include household income, Household Size, occupation of spouse, quantity of energy and cost of substitute energy. "The own price elasticity of demand showed mild elastic coefficient for charcoal (-1.2), unitary elastic for fuel wood (1.0), kerosene (1.0), LPG (1.1) and inelastic for electricity (0.2) for urban respondents. The own price elasticities for rural respondents showed inelastic coefficient for charcoal (-0.8), fuelwood (-0.7), kerosene (0.5), LPG (-0.6) and mild elastic coefficient for electricity (-1.2). The result of the cross elasticity of demand showed that the domestic energy types are close substitutes to each other in both rural and urban areas" [8]. In their analysis of the electricity consumption in the southeast geopolitical region of Nigeria, [9] identified twelve socio-economic and physical determinants. It was revealed that electricity consumption in the region is not affected by sectoral consumption usage (residential, commercial and residential).

However, none of these studies has considered this South-Western state as a case study even though it contributes considerably to the sustainable energy reserve and economic output of the nation being an oil-producing state and having a number of gas power stations. This study therefore examines the Household Energy Consumption pattern in towns and villages in Ondo state, Nigeria. It is aimed at (i) estimating household total energy requirement for cooking, lighting, refrigeration, Thermal Comfort, brown and Sundry Appliances; and (ii) examining the influence of socio-economic indicators (Building Type, income level and Household Size) on overall energy consumption.

METHODOLOGY

The Study Area

The study area for this work is Ondo State. The map of the state is presented in Fig-1.

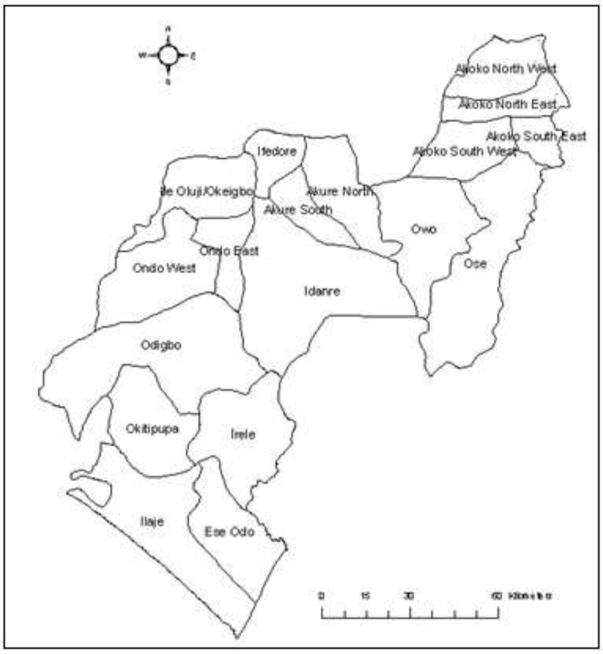

Fig-1: Map of Ondo State showing the 18 LGAs

Source: [10]

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Ondo State, Nigeria, was created on 3rd February 1976 from the former Western State. The State lies between latitude 5° 45' and 7° 25' North and longitude 4° 45' and 6° East. This means that the State lies entirely in the tropics. It has a land area of about 14,798.8 Square km [10].

The climatic condition is that typical of tropics with temperatures low and high being 21° and 38° respectively [11]. It is therefore unsurprising to see one or more temperature control means often adopted. That is, energy is required for ventilation and air-conditioning for humans and for sensitive electronic equipment and medical supplies. A thirst for chilled drinks during very hot afternoons translates to a household energy demand by refrigeration. This is however subject to household income level as the state power supply is quite unpredictable and mostly unavailable.

"The vegetation consists of coastal forest and mangrove swamp forest in the south, moist lowland forest, and the forest savannah in the north" [10]. It is home to a great woodfuel energy resource which mostly rural dwellers exploit to meet their cooking energy needs.

The state has eighteen Local Government Areas with a 2010 projected population estimate of 3,895,367. Table-1 presents their population distribution by local government based on 2006 census.

Table-1: The Population Distribution of Ondo State by Local Governments

Local Government Area	Population
Akoko North-West	213,792
Akoko North-East	175,409
Akoko South-East	82,426
Akoko South-West	229,486
Ose	144,901
Owo	218,886
Akure North	131,587
Akure South	353,211
Ifedore	176,327
Ile Oluji/Okeigbo	172,870
Ondo West	283,672
Ondo East	74,758
Idanre	129,024
Odigbo	230,351
Okitipupa	233,565
Irele	145,166
Ese Odo	154,978
Ilaje	290,615
TOTAL	3,441,024

Source: [11]

Survey Methodology

Twelve local governments were randomly selected from the state's eighteen. A well-structured questionnaire was prepared and administered to a total of 524 respondents spread across the selected local government areas. The number of questionnaires each Local Government Area received was made to correspond to its population size of the sample as seen in Table-1. A total of 509 questionnaires were recollected with 15 discarded for inconsistencies representing 97% response rate.

Method of Energy Quantification

The household energy measured includes energy demand in:

- Cooking
- Refrigeration
- Thermal Comfort
- Lighting
- Brown Goods
- Sundry Appliances

Brown Goods refer to "relatively light electronic consumer durables such as TVs, radios, digital media players, and computers, as distinct from heavy consumer durables such as air conditioners, refrigerators, stoves, which are called white goods." Sundry Appliances are other appliances, which for this study is limited to: washing machine, blender, pressing iron, water pump, microwave oven, dish washer and water dispenser. "Thermal Comfort" refers to energy used up for providing ventilation by fans and for air conditioning.

Cooking

The annual energy demand for the various means of cooking was determined thus.

Electric Cooking

For cooking by electricity, this is determined from equation (1) [12]

$E = 365\,P\,t\,e$ .... (1)

Where *P* is the nameplate power rating of appliance in kilo Watts, *t* is the total duration of cooking in hours per day, *e* is power expectancy or power availability factor (a factor obtained by determining the average number of hours electric power is available in a day for a survey area by 24 hours) and 365 is the number of days in the year. *E* is the annual energy consumption of electricity in kWh.

To determine the value of cooking duration *t*, a cooking time study was conducted. The two most common meals in the survey region which are taken to be Rice and Beans and the common pepper stew, were prepared on the common "ORL" Electric cooker, the durations of which were recorded. The duration of cooking being a function of food quantity, which in turn is a function of Household Size, the experiment was conducted for:

- 170 g of rice and 500 ml stew for the Household Size of <3.
- 468 g of rice and 1.5 litres stew for the Household Size of the range 4-7
- 935 g and 3 litres stew for the Household Size of the range 8-14
- 150 g of beans for the Household Size of <3
- 413 g of beans for the Household Size of the range 4-7
- 825 g of beans for the Household Size of the range 8-14

The duration of cooking for rice and stew and that of beans are summed up and an average is obtained. The average obtained gives us what we term morning cooking time t_m. Most residents cook Rice or Beans in the morning and the African steam-rolled cassava flour (locally called *eba*) or steam-rolled yam flour (locally called *Amala*). This requires just the heating up of water to boiling point, some few minutes' allowance of time and then soup preparation. The time for this is also determined and called evening cooking time t_e. Thus, total daily cooking time per day t is given by equation (2).

$t = t_m + t_e$ .... (2)

Table-2 shows how the values chosen for cooking time t were arrived at for each household for electric cooking. Though these figures may vary depending on various cooking conditions, environment, food type; these assumptions are fairly reflective of the real life scenario. For households above 14, the time study was conducted by limiting the Household Size to 15 since we have slim chances of having household population figures higher than this.

Table-2: Selected Values for Cooking Duration Based on Household Size

Household Size	Duration of Cooking (minutes)		
	Morning t_m	Evening t_e	Total *t*
<3	83.5	32	115.5
4-7	110.5	54	164.5
8-14	150	74	224
>14	180	105	285

Non-Electric Cooking

For energy consumption via Kerosene, the amount of the fuel consumed per day is obtained in litres and then converted to mass with equation (3) [13].

$m = 10^{-3}\,\rho\,v$ .... (3)

Where *m* is daily mass consumption rate in kg/day, ρ is density of kerosene (taken as 790 kg/m^3), v is volume consumed in litres per day as obtained from the survey. The 10^{-3} term is inserted to convert the volume in litres to m^3. The heating value of kerosene is 43.1 MJ/kg (lower) and 46.2 MJ/kg (higher).

Annual energy consumed *E* (in kWh) as the fuel is burnt, for charcoal, kerosene, Cooking Gas (LPG) and wood can be determined from equation (4) [14].

$E = 101.4\,m\,CV$ .... (4)

Where *CV* is the calorific value of the fuel (kerosene, wood or charcoal) and *m* is the daily fuel consumption rate in kg/day. 101.4 is a unit conversion factor The net calorific value of oven-dry wood is 18.5 MJ/kg, while that of wood logs mostly used as firewood, 14.4 MJ/kg. Cooking Gas (LPG) has a specific energy of 94 MJ/m3 or 46.4 MJ/kg, while that of charcoal is 29.6 MJ/kg [15].

Electric Lighting

The energy consumed in lighting the house by bulbs and fluorescent tubes is calculated from equation (5) as given by [12].

$E_{lighting} = 365\,n\,P\,t\,e$ .... (5)

Where n is the number of bulbs of a particular wattage used, P is the wattage rating of the bulb (kW), t is the mean usage time per day in hours, and e, the power expectancy.

Other Energy Forms

For other energy consumption in the house, (refrigeration, Thermal Comfort, sundry and Brown Goods) equation (5) is used. In the case of Sundry Appliances, the power expectancy factor e is ignored since users of these appliances (washing machine, pressing iron etc.) will usually wait till electricity is restored to use them.

RESULTS & DISCUSSIONS

Distribution of Respondents

Participation of respondents by Gender, Household Size, Building Type and Monthly Income Range is as presented in Table-3.

From the table, males represent a higher percentage of 53% than the females with 47%. Majority of respondents in the survey are of the Household Size of 4-7 with a high 61%. 19% have less than 3 members. 14% have 8 to 14 members, while only 6% have above 14 members. 56% of the respondents dwell in Flats, 14% in self-contained houses, 19% in Single Rooms, 1% in duplexes and 10% in others. Table 4 shows the definition of Building Types as used in this survey. 30% of respondents earn between N18,000 ($ 91) to N60,000 ($ 305); 27% earn in the range N60,000 ($ 305) to N100,000 ($ 508); 27% earn below or exactly N18,000 ($ 91); 13% earn above N100,000 ($ 508) and 3% were not willing to disclose their income range. Exchange rates are as obtained from the Central Bank of Nigeria (CBN) monthly average of January, 2016 [16].

Table-3: Distribution of Respondents

Gender	Male	53%
	Female	47%
Household Size	< 3	19%
	4 – 7	61%
	8 – 14	14%
	> 14	6%
Building Type	Single Room	19%
	Self-Contained	14%
	Flat	56%
	Duplex	1%
	Others	10%
Income	$Inc \leq$ ₦ 18000 ($ 91)	27%
	₦ 18000 ($ 91) $< Inc \leq$ ₦ 60000 ($ 305)	30%
	₦60000 ($ 305) $< Inc \leq$ ₦100000 ($ 508)	27%
	$Inc >$ ₦100000 ($ 508)	13%
	Undisclosed	3%

Table-4: Definition of Building Types as Used in the Survey

Building Type	Definition
Flat	A Single-family dwelling unit in which facilities for each dwelling unit are arranged on one floor. They can be 2-bedroom, 3-bedroom, 4-bedroom or even 5-bedroom flats. They also have bathroom, toilet facilities, and kitchen.
Self-Contained	A mini-flat but with only a single bedroom
Single Room	A low-cost housing unit with at maximum, a single room and a small parlour, often called by local residents “face-me-i-face-you”
Duplex	A free standing luxurious single family dwelling on two or more floors connected by at least one internal staircase

Breakdown of Household Energy

Fig-2 shows the annual Household Energy Consumption broken into components. Cooking is seen to account for 47% (5183 kWh) of household energy demand in all Building Types, Income Ranges, Household Sizes and Local Government Areas. 28% (3116 kWh) of total household energy is spent on Refrigeration, 12% (1325 kWh) energy is used in providing Thermal Comfort, 10% (1116 kWh) on Electric Lighting, 2% (173 kWh) on Brown Goods and 1% (81 kWh) on Sundry Appliances. Cooking accounts for the highest percentage of household energy demand across all people in the state because it is a form of energy resource that is required in every home irrespective of income level, Building Type or rural/urban location. Not all can afford to get expensive gadgets for Thermal Comfort; not all can afford a refrigerator; electric power availability varies from one area to another affecting the usage of electrical appliances, but cooking is one form of energy demand that is common to all, hence its high percentage. Refrigeration is next highest because of the number of homes that own a refrigerator/freezer. The hot tropical climate zone in which the state falls in makes a refrigerator a must in nearly every home. Brown Goods are seen to take a low 2% due to their low power consumption. Sundry Appliances account for 1% due to their usually short period of usage.

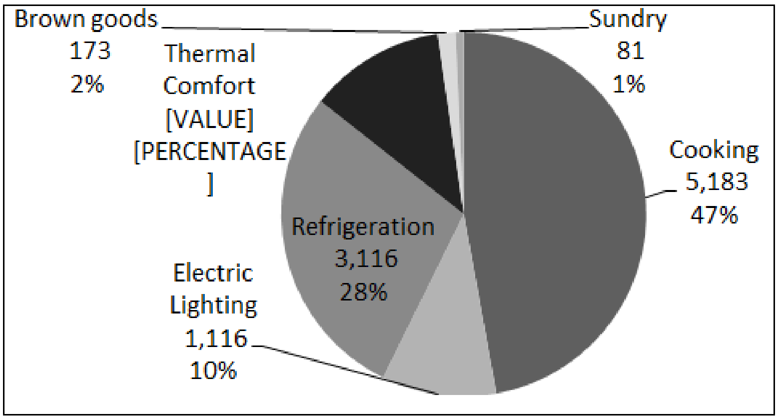

Fig-2: Household Energy by Components

Household Energy versus Size

Fig-3 shows how Household Size affects energy demand for cooking. Energy demand per household is seen to rise with increasing Household Size. However, the increment upon successive Household Size is seen to diminish. This is because a house having more members does not necessarily mean an equivalent increase in energy consumption. For instance, because a household is composed of 16 members does not mean they will use 16 different TVs, or use more lighting energy 16 times that expected of a one-member house. However, there will be some increase in refrigeration energy. For instance, since a more opening and closing of refrigerator doors will be expected; more load will be put on refrigerators, air-conditioners, fans etc. More cooking will expectedly be done as well.

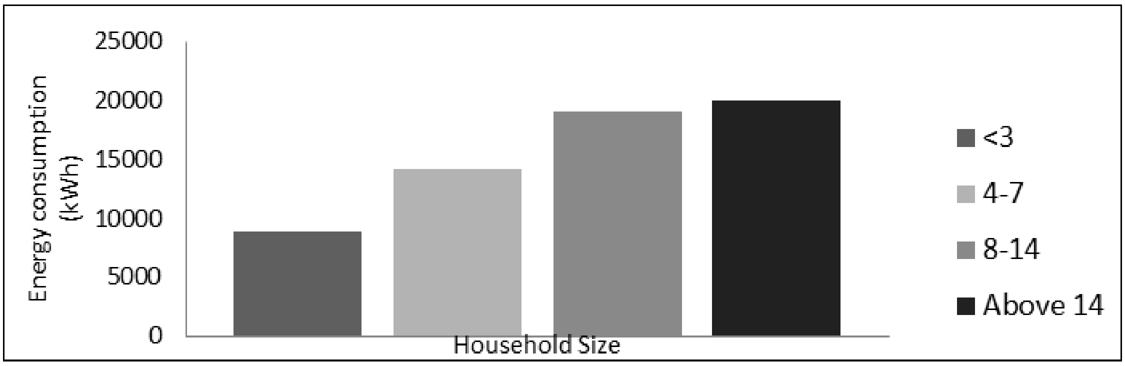

Fig-3: Energy vs Size

Breakdown of Cooking Energy Resource

Fig. 4 shows householders' preferred cooking energy resource. Kerosene is found to be the most commonly used means of cooking in 84% of the households. This is because it is seen as a more reliable and available back-up resource. It can be observed that the summation of the percentages does not add up to 100. This is because several households use a combination of two or more cooking energy resources to overcome the limitations and exploit the advantages of one cooking means over the other. For example, electricity is seen to be cheap but usually unreliable. Wood is readily available for rural dwellers but usually unusable in rainy conditions. Kerosene, however, is perceived to be a more balanced and reliable cooking energy means, hence its preference. It also possesses qualities of lightness (unlike wood), ease of transport (unlike wood, charcoal and Cooking Gas) and being relatively safe (compared to LPG). Cooking Gas (LPG) is next with 40%, electricity - 30%, wood - 19% and then the least used, charcoal 7%. Unreliability stands as a barrier to popular usage of electricity. Some respondents, in fact, reported having been cut off from the grid supply for over a year running with no hope of reconnection. This has made many to rule out the ownership of electric cooking means.

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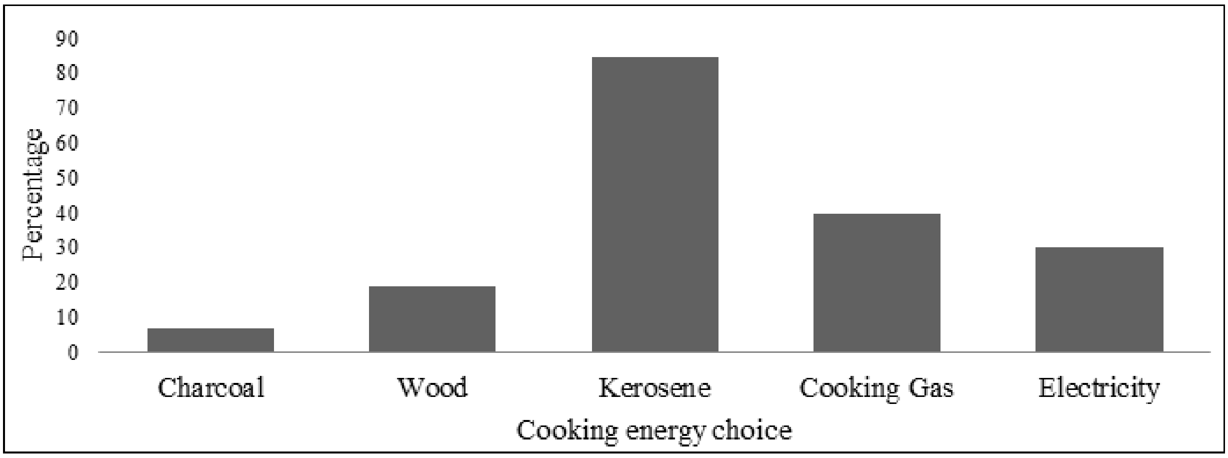

Fig-4: Distribution by Preferred Choice of Cooking Energy

Cooking Energy Resource and Household Income

Fig-5 shows the energy demand for cooking across the various income ranges. 44% of energy usage by charcoal come from the low-income earners of < $91. Expectedly, it is least used by high income earners >$508 with only 13%. The highest users of LPG are the high income earners >$508 taking 33% of total LPG energy resource usage. It is also least used by low-income earners <$91. Electricity is seen to be used by almost equally all income groups with 24-26%. Middle income groups $91-$305 and $305-$508 are seen to occupy intermediate usage rates in all cooking energy means.

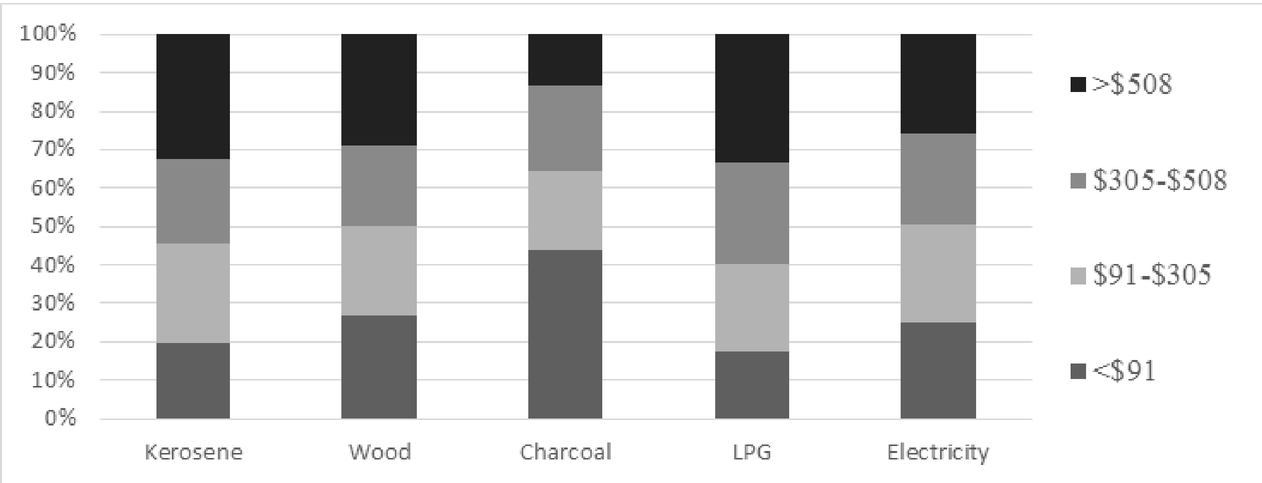

Fig-5: Household Income vs Energy Demand

Respondents' Choice of Cooking Energy Resource

Fig-6 shows the percentage of respondents' answer to the reason for their choice of cooking energy. The 39% of electricity users voted "Cheapness" as the reason for its preference. 65% believe LPG is time-saving; 53% use wood for its cheapness; 61% also chose charcoal for the same reason. However, the gap is not too wide between those who voted kerosene for the reason of availability and those who voted it for cheapness. Availability is highest with 37%, while cheapness is next with 35%.

"Availability" is highest for Kerosene (37%) and closely followed by Wood (36%). This is due to the ease of access rural dwellers often gain into the forests which they tend to deplete unrestrainedly due to the ineffectiveness of the anti-deforestation laws.

"Interest" is highest for Electricity (13%) and then for Cooking Gas (11%) and least for charcoal. This shows that most households will choose Electricity only if it could be available and reliable. Cooking Gas, another cleaner fuel is admired by many too. However, nobody (0%) wants to use charcoal except that households that use it consider it to be cheap (61%).

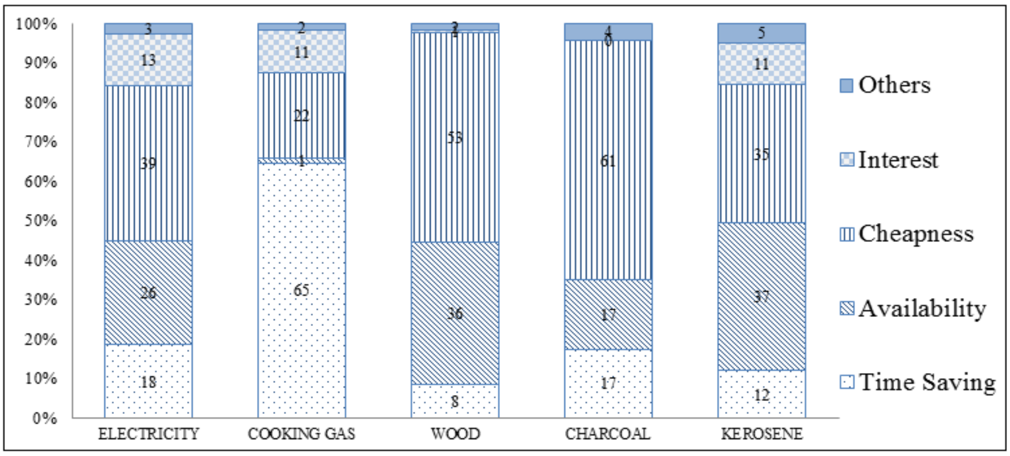

Fig-6: Householders Reason for their Choice of Cooking Energy

Factors Influencing Energy Consumption

Several factors were thought to affect domestic energy demand and use. These include: Building Type, income as well as Household Size. The result of the Spearman's rho correlation between Building Type, Income, Household Size and Household Energy components is presented in Table-5.

Table-5: Correlation between Variables

		Energy in Cooking	Electric Lighting	Refrigeration	Space Cond & Vent.	Brown Goods	Sundry	Total Energy
Building	Corr.	0.150**	0.411**	0.054	0.381**	0.083	0.384**	0.243**
	Sig.	0.002	0.000	0.331	0.000	0.104	0.000	0.000
Income	Corr.	0.128**	0.020	-0.043	0.019	0.002	0.002	0.010
	Sig.	0.005	0.691	0.427	0.700	0.970	0.965	0.824
Household Size	Corr.	0.494**	0.290**	0.022	0.254**	0.022	0.087	0.391**
	Sig.	0.000	0.000	0.678	0.000	0.656	0.070	0.000

** Correlation is significant at the 0.01 level (2-tailed).

A correlation exists between Building Type and Cooking, Lighting, Space Conditioning & Ventilation, Sundry Goods and hence total energy in varying degrees. It is weak but positive and significant between Building Type and Energy in Cooking (r=0.15). It is also weak with Income Range (r=0.128). It is however, stronger with Household Size. This is because Household Size is a more direct determinant of household cooking volume. Higher income earners and more luxurious building dwellers also tend to cook more. Overall, everyone cooks whether rich or poor, only that the poor may choose a cheaper means, hence the positive correlation with these socio-economic characteristics.

Electric Lighting Energy was also found to be positively correlated with Building Type (r=0.411) and Household Size (r=0.290). This is because the energy or number of lamps required to sufficiently light up a building depends on the area of space required to be illuminated. This is obviously higher in bigger buildings. Furthermore, since larger buildings tend to contain a larger number of occupants, it is no surprise Household Size is correlated to lighting energy. The probing issue is how lighting energy is not significantly correlated to income group unlike how it is correlated to cooking. One factor that may have weakened out this correlation is the fact that the higher income earners tend to be the more educated ones with well-paying jobs. Their education level may have influenced their energy conservation awareness. It is also important to note that these energy-saving bulbs are more expensive, hence the poor may not be able to afford it. The high cost of acquiring electricity meters also may have restricted its usage mostly to high-income earners while those who cannot afford it run on direct connection and are billed by estimation by the Utility company. Hence, unmetered households tend to be wasteful in their usage of electric energy.

Refrigeration energy demand is not significantly influenced either by Building Type, Household Size or by Income Size. The ownership of a refrigerator seems to be nearly general across all households irrespective of socio-economic status.

Space Conditioning and Ventilation is positively correlated to Household Size and Building Type, but not with income group. This is because a larger building definitely has more space to be conditioned and ventilated, unlike 'single room' buildings. A larger household also tends to seek more means of Thermal Comfort because of its likely-higher population size. A low-income source, however, does not necessarily mean non-usage of ventilation gadgets since they are considered as a part of necessary home gadgets. This is the same reason Brown Goods have no significant correlation with any of these socio-economic characteristics. Brown Goods (TVs, radios, DVD players etc.) are considered a necessary requirement of every home. Energy consumption by Sundry Goods is significantly correlated only with Building Type. This is because they are mostly seen as luxury home items and possessed more by dwellers in luxurious buildings.

Overall Household Size and Building Type dominantly affect household energy. There are understandably more activities in a larger and more populated house. However, the effect of income size on overall energy consumption is not sufficiently significant. A poor man will only seek out an alternative way of getting things done. For instance, a low-earning household may not cook by Cooking Gas or kerosene, but will opt for wood-fuel. He may not be able to afford an air-conditioner, but he will have more fans that will work for longer and at a higher speed. These are considerations that seem to weaken the correlation between these two variables.

Conclusion

Household Energy Consumption, choice of cooking energy resource and underlying reasons has been determined for households in Ondo State, Nigeria. Cooking represents 47% of Household Energy across all house types in towns and villages, refrigeration accounts for 28%, Thermal Comfort 12%, Electric Lighting 10% while sundry (other appliances) and Brown Goods (TV, VCD/DVD set) account for 1% and 2% respectively. It was found out that householders often combine two or more cooking energy resource to leverage on the relative advantages and limitations of one cooking means over the other. Kerosene was found to be the most used and is found in four of every five homes, while charcoal is least used in only 7% of the households visited. Preference for kerosene was attributed to various reasons but majorly (37%) to availability while that of charcoal was attributed to cheapness by 61% of its users. 47% of energy demand in the homes goes for cooking alone while refrigeration accounts for 28%, Thermal Comfort, Electric Lighting, Sundry and Brown Goods taking 12%, 10%, 1% and 2% respectively. All energy components were found to be positively correlated with Building Type and Household Size except for Refrigeration and Brown Goods since ownership of these items are general. Sundry Goods also do not correlate with Household Size.

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