An Appraisal of Household Cooking Fuel Consumption and their Carbon related Emission in Zaria Metropolis, Nigeria

[a]Borisade, E., [a]Stanley, A. M., [a]Dadu, D.W., [b]Sani, I.F. and [c]Abah, A.M.
[a]Department of Building, Ahmadu Bello University, Zaria, Nigeria
[b]Advanced Aircraft Engineering Laboratory, National Space Research and Development Agency, Gusau, Zamfara State, Nigeria
[c]Department of Building, Niger Delta University, Wilberforce Island Amasoma, Bayelsa State, Nigeria
Correspondence email: stanleywond@yahoo.com

Abstract

An increase in energy consumption largely from fossil fuel combustion is often accompanied by a significant increase in CO_2 *emissions which contributes to climate change. This study assesses energy consumption and its related green gas emission from household cooking activities in selected areas of Zaria metropolis. One hundred (100) well-structured questionnaires were used to collect data from the households within the study area and 83% response rate was received. The questionnaire sourced information associated with respondent's profile and household characteristics, choice and type of cooking fuel, frequency of cooking activities, etc. the quantity of fuel used to boil 3.5 litres of water was determined for each fuel type which were used to the estimation of carbon emitted. Results show that most household (63.86%) prefer to use kerosene for cooking because of the stove type (16.9%) they use and the cost of the fuel (53%). wood has the highest carbon emission of 1170.57g/J. It takes time 9.43 minutes and consumed 354.29g of firewood to boil the water while* Liquefied Petroleum Gas (LPG) *consumed 11.43g of fuel in 5.43 to emit 34g of carbon. Electricity from the national grid took 7.43 minutes and consumed 0.44Kwh with no emission at the point of use. LPG indicates to have less carbon emission and takes lesser cooking time compared to firewood which is in line with the respondent opinion. It is recommended that advocacy to discourage the use of firewood as cooking fuel should be intensified even though it is the cheapest energy source.*

Keywords: Carbon emission, Cooking fuel, Household, Zaria metropolis, LPG

INTRODUCTION

Household energy consumption according to Statistics Finland (2016) is classified under; lighting, power and cooking. It is generated from renewable sources such as solar, hydropower, nuclear, wind, geothermal, etc. or non-renewable source such as kerosene, petrol, diesel, coal etc. Cooking is one of the most important aspect of household activities which consumes substantial amount of energy from these sources (Ben, 2016). According to Courtney (2010) sources of energy for household cooking activities include firewood (wood and charcoal), solar power, coal, kerosene gas and electricity. It was observed in Dilip *et al.* (2014) that in developing countries about 2.5 billion rural dwellers solely depend on biomass (firewood, charcoal, agricultural waste and animal dung) to meet their daily energy needs. These account for over 90% of the household energy needs. Firewood has been identified to be the least expensive energy source and

Liquefied Petroleum Gas (LPG) more expensive for most households in developing countries (Anoziea *et al.*, 2007).

With the exception of solar, nuclear, hydropower as sources of household energy, every other source is associated with emission of carbondioxide (CO_2) and other pollutants which associated with environmental pollution and health related issues (Andrew *et al.*, 2011; Dilip *et al.*, 2014). Stanley *et al.* (2013) established that 29.2% households in Zaria metropolis rely solely on firewood for cooking which have been rated as the highest killer compared to any other disease in developing countries. The types of fuel used in the households for cooking affects the indoor air quality (IAQ). IAQ is the air quality within the building especially as it relates to the health and comfort of the building occupants (EPA, 2016). According to Andrew *et al.* (2011), IAQ is associated with indoor air pollution from cooking activities and the likes which are heavily impacted by ventilation and combustion performance of the fuel. Exposure to such air pollutants in building indoor environment for long period of time result to ill-health and other associated problems (Stanley *et al.* (2013). Studies have attributed stillbirth, infant low birth weight, adverse pregnancy outcomes in women, chronic obstructive lung disease, lung cancer, irritation, headache, dizziness as well as fatigue etc. to poor IAQ (EPA, 2016; Pope, 2016).

Increase in household energy consumption (largely fossil fuel) is often accompanied by a significant increase in CO_2 emissions which contributes to climate change (Hunt, 2005). Climate change may be attributed to changes in atmosphere composition as a result of human activity (IPCC, 2016). It puts the people, the economy and natural resources at risk while increasing weather variability, more frequent extreme weather events and shifting rainfall patterns are among key threats (EPRD, 2006). Smoke in the form of black carbon (soot) from incomplete combustion of fuels ranks the second most important contributor to climate change with a global warming potential of several magnitudes greater than CO_2 (Tami and Sun, 2005). As an aerosol, smoke has global climate impacts as well as decisive regional climate effects on precipitation and on temperature in the form of heat waves (Tressol *et al.*, 2008). It takes many decades for the effects of reductions in CO_2 emissions to become apparent (Grieshop *et al.*, 2009), but reductions in the emissions of smoke would have immediate effects and beneficial synergies all the way from an individual and local scale to regional and global levels.

Domestic energy consumption represents one area where the links between global environmental problems and individual behaviour are clearly identifiable, even if consumers do not immediately recognize the connection. As more energy is consumed and more by- products are created, and since by-products are considered as pollutants and most of them go into the atmosphere, there is a direct relationship between energy consumption and carbon emissions (Lagaris and Herrick, 1971). Reducing this CO_2 emissions in Zaria metropolis will play important role in decreasing its contribution to global carbon emissions. The aim of this paper is therefore to assess household cooking fuel consumption and its related green house gas emission in selected households of Zaria metropolis with a view to establishing the household contribution to GHG emission and climate change.

Household Energy

The energy requirement of building largely depends on the household living standard. Cooking activities account for the high energy consumption in household which is a potential source of indoor air pollutants and global warming. Table 1 shows common household energy sources and their uses in developing countries.

Table 1: Fuels and their common household uses

Fuel	Household Use
Firewood, animal dung, and Others biomass	Cooking and hot-water heating
Charcoal	Cooking and hot water heating
Candles	Lighting
Kerosene	Lighting (wick and hurricane lamps) and Cooking
Biogas	Cooking
Liquefied petroleum gas (LPG)	Cooking and lighting (less often)
Diesel	Lighting (wick and hurricane lamp and electricity (diesel generators)
Gasoline	Transport (motors bikes and cars) and electricity
Distinct heating	Space heating
Natural gas	Cooking and space heating

Firewood consumption has been estimated to about 1.55 billion cubic meters by about 3 billion people as their primary source of energy globally. In developing countries about 2 billion rural dwellers rely solely on firewood for heating and cooking. The inefficient and incomplete combustion of firewood releases a number of hazardous pollutants, including carbon monoxide, sulphur and nitrogen oxides, and particulate matter. In many households, poor ventilation exacerbates the effects of these pollutants, and women and children are often exposed to them at significant levels for 3 to 7 hours each day (Bruce *et al.*, 2000).

Coal is much higher quality fuel compared to firewood due to its efficiency and ease of storage. Although coal smoke has considerable amounts of pollutants not ordinarily found in most traditional fuels including sulphur oxides, inorganic ash particles and heavy metals including lead (Bruce *et al.,* 2000).

Kerosene is used in lamps for lighting, as well as in stove for heating and cooking. It contains hydrocarbon substances that contain only hydrogen and carbon, exposure to kerosene leads to an increase in respiratory symptoms. The quality of kerosene can vary, and is determined by the impurity content, sulphur and aromatics in particular, which reduce combustion efficiency and increase noxious emissions during combustion.

Solar energy is a product of direct radiation from sunlight used in solar cooker to heat, cook or pasteurize food or drink. It reduce fuel costs, air pollution, deforestation and desertification caused by other forms of non-clean energy. Solar cookers exist in many forms such as parabolic solar cookers, solar ovens, and panel cookers (Calen, 2009).

Masera *et al.* (2000) identified following are the factors that affect household's choice of cooking fuel; a) cost of fuel, stove type and accessibility to fuels; b) technical characteristics of stoves and cooking practices; c) cultural preferences, and d) the potential health impacts.

The household cooking fuels are associated with emission of substances into the environment. Emission emerges from combustion activities during cooking which can be characterized by oxidation of materials inside a contraption (IPCC, 2006).

Smith *et al.* (2000) noticed that household cooking fuels especially solid fuels are hard to burn in straightforward combustion devices, for example, household cooking and heating stoves without substantial emissions of toxins, principally on the grounds that the trouble of completely premixing the fuel and air amid burning, which is done effectively with fluid and gaseous fuels. Therefore, an impressive portion of the fuel carbon is changed over to results of incomplete combustion, to be specific, mixes other than a definitive result of carbon dioxide that outcome from complete combustion (Smith *et al.*, 2000).

The results of the incomplete combustion include GHG. The most important GHGs directly emitted by cooking activities include Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O) and other gases (EPA, 2016). The primary GHG that contributes to climate change is CO_2. Burning of fossil fuels release large amounts of CO_2, which initiate its concentrations in the atmosphere (EPA, 2016).

METHODOLOGY

The study reviewed relevant literatures related to household energy consumption for cooking activities and their emission. Checklist and questionnaire were also used to obtain data on fuels and cooking characteristics of the households. The study area was Zaria metropolis, one of the cities in Kaduna state. It comprises of two (2) local government areas: Sabon Gari and Zaria. It is location is centred at latitude 11°07'51" N and longitude 7°43'43" E with a population of 406,990 and 291,358 for Zaria and Sabon-Gari Local Government Areas respectively (Oladimeji and Ojibo, 2012).

The household population of Zaria metropolis is 139,669 (NPC, 2006). This was based on the 2006 census average household population of 6 persons. A sample size was determined from the total number of household by using the formulae proposed by Yomen (2000);

$$SS = \frac{N}{1+N(e)^2}$$

Where:
SS = sample size from finite population
N = population size
e = tolerable error (the maximum error in the population that researchers are willing to accept)

N = 139669, e = 0.1

$$SS = \frac{139669}{1+139669\,(j0.1^2)} = 99.9 \approx 100$$

Based on the sample size calculated, 100 households were randomly selected for the study. Structured questionnaire was designed and administered to various household representatives. The questionnaires contain twenty two (22) questions intended to get the households' responses on energy consumption for cooking activities. The questionnaires identified the respondent's demography, types of cooking fuel used by the household, factors that determinate selection of cooking fuel, exposure to indoor air pollution due to cooking fuels and its effects on the building occupants.

Measurement of quantity of fuel

Simulation test was conducted for the different fuel types studied by the heating and boiling of water to established parameters for estimating the quantity of carbon emitted. This method allows easy computation and quantitative analysis of data hence it can give exact values of parameters to measure;

A fixed Quantity of water (3.5litres) was boiled by using different fuel (charcoal, firewood, kerosene, electricity and gas) subjected under the same environmental condition and use of the same cooking pot. The time taken by each fuel to boil the water was recorded as well as the quantity of fuel used.

The amount of carbon emitted was estimated using the formula postulated by Guide (2012) shown below;

$$Carbon\ emission = QMB \times NCV \times CEF$$

Where;

QMB = Quantity of mass of the burnt fuel
NCV = Net calorific value of the fuel
CEF = CO_2 emission factor for the fuel

The mass of fuel was gotten from the simulation test based on the various quantity of fuel burnt during heating of the water. The collected data was analysed using descriptive statistical analysis tools such as percentile method as well as frequencies within SPSS. Charts and tables were used for data presentation.

RESULTS AND DISCUSSION

One hundred questionnaires (100) where self-administered to households within Zaria metropolis and eighty three (83) were returned representing a response rate of 83%.

Table 2 shows the respondents' profile. It can be observed that majority of the respondents are females with frequency of 63.9%, while the male represent 36.1%. This result is associated to the fact that female in most African setting are the dominants in household activities as observed by Anoziea *et al.* (2007). Respondents' age bracket with the highest frequency observed was 45.8% who are of the age bracket of 26 and 31. This indicates that more adult's females are involved in cooking activities. The highest education level attended was tertiary with the highest frequency (77.1%) and occupation with the highest frequency (41%) observed was business.

The table also shows that majority of the households with the highest frequency of 43.4% are of 4 to 6 household members. This is a clear depiction of African setting where household comprises of six or more individual living together. The average monthly income of the households is above ₦50, 000 with the highest frequency of 37.3% which indicates that most household could bear the cost of various cooking fuel. The result is similar to the findings of Stanley *et al.* (2013).

Table 2: Respondent's Profile

S/N	Variable	Options	Frequency (No)	Percentage (%)
1	Gender	a) Male	30	36.1
		b) Female	53	63.9
		Total	83	100.0
2	Age group	a) <21	7	8.4
		b) 21-25	25	30.1
		c) 26-35	38	45.8
		d) >35	13	15.7
		Total	83	100.0
3	Highest level of education attained	a) Tertiary	64	77.1
		b) Secondary	13	15.7
		c) Primary	4	4.8
		d) None	2	2.4
		Total	83	100.0
4	Occupation	a) Business	34	41.0
		b) civil services	25	30.1
		c) others	24	28.9
		Total	83	100.0
5.	Family size	a) <4	19	22.9
		b) 4-6	36	43.4
		c) >6	28	33.7
		Total	83	100.0
6.	Monthly income in Naira (₦)	a) <5000	10	12.0
		b) 5000 - 2,000	23	27.7
		c) 20,000 -50,000	19	22.9
		d) >50,000	31	37.3
		Total	100.0	100.0

Table 3 shows the various fuels types used by the households and the factors that determine the choice of fuel type. Cost of fuel having the highest frequency of 44 (53%) was observed to be the most dominant factor that determines households' type of fuel used for cooking which is similar to the findings of Anoziea *et al.* (2007) and Stanley *et al.* (2013). Despite the preference of fuel based on the cost, majority of the respondents with frequency of 53 used kerosene for cooking which could be attributed to the study area (urban centre). The choice of fuel type was followed by stove type with frequency of 14(16.9%) and follow by 8(9.6%) for accessibility of fuel.

Technical characteristics of stove and cooking practices were ascertained by 3(3.6 %) while 2(2.4%) and 4(4.8) ascertain that cultural practice and potential health effect respectively were factors determinate for choice of fuel. Furthermore the taste of food had a frequency of 5 (6%). The results are similar to the findings of Stanley *et al.* (2013).

Table 4: Household fuel type and Factors that determine fuel preferences

S/N	Variables	Options	Frequency (%)	Percentage (%)
1.	Fuel type	a). Firewood	33	39.76
		b). Kerosene	53	63.86
		c). LPG	27	32.53
		d). Electricity	29	34.93
2.	Factors:	a). Cost of fuel	44	53.0
		b). Stove type	14	16.9
		c). Accessibility to fuel	8	9.6
		d). Technical characteristics of stove	3	3.6
		e). Cooking practice	3	3.6
		f). Cultural preference	2	2.4
		g). The potential health impacts	4	4.8
		h). Taste of food	5	6.0
		Total	83	100

Cooking characteristics

From Table 4, most of the respondent cook three times in a day, and most spend less than 2 hrs in the kitchen. This is unlike the study of Stanley *et al.* (2013), where majority of the households cook their meals between 2 – 3 hours. However, it is still obvious that there is a high pollutants emission from the various households due to their active participation in cooking activities. It was also observed that cooking activities are carried out in the kitchen with a high frequency of 83.1%.

Table 4: Cooking Characteristics

S/N	Variables	Options	Frequency (No)	Percentage (%)
1	Frequency of cooking per day:	a) once	4	4.8
		b) twice	31	37.3
		c) three	44	53.0
		d) four	4	4.8
		Total	83	100
2	Amount of time in hour spent for cooking:	a) <2	40	48.2
		b) 2-3	37	44.6
		c) 3-5	6	7.2
		Total	83	100
3	Location of cooking:	a) kitchen	69	83.1
		b) living room	6	7.2
		c) outdoors	8	9.6
		Total	83	100

Simulation Test

Table 5 shows the result of the simulation test that was carried out to ascertain mass of various cooking fuel consumed alongside its duration for boiling. Carbon emission formulae were used to compute the carbon emission from the individual fuel.

Table 5: Quantity of fuel consumed, carbon emitted and time taken to boil water

S/N	Fuel type	Time (minutes)	Quantity of fuel/energy consumed/litre	Carbon emission (g/J)
1.	Firewood	9.43	354.29g	1,170.57
2.	Kerosene	7.14	17.14g	53.71
3.	LPG	5.43	11.43g	34
4.	Electricity	7.43	0.44Kwh	0

From Table 5 result shows that firewood has the highest carbon emission of 1,170.57g/J, its take more time (9.43 minutes) and 354.29g of fuel consumed to boil a litre of water. LPG took lesser time (5.43 minutes) to boil the water and emit 34g/J of carbon which consumed 11.43g of fuel. Electricity took 7.43 minutes to boil the water and consumed 0.44Kwh with no carbon emission at the point of use. Also Kerosene took 7.14 minutes to boil the water consuming 17.14g of fuel with emission 53.71g/J carbon.

Table 6: Respondent's contribution to carbon emission in boiling a litre of water

S/N	Fuel type	Frequency of Respondents (No)	Quantity of fuel/energy consumed/litre	Carbon emission (g/J)
1	Firewood	33	11,691.57g	38,628.81
2	Kerosene	53	908.42g	2,846.63
3	LPG	27	308.61g	918
4	Electricity	29	12.76Kwh	0

Table 6 shows firewood with the highest carbon emission of 38,628.81g/J constituting the major air pollutant from cooking in the metropolis. This was followed by kerosene with 2,846.63g/J and LPG with 918g/J. Electricity used for cooking activities was recorded 0. From the outcome of the analysis, it was established that household energy consumption for cooking activities emits CO_2 which contribute to climate change. This is in view with the respondents' opinions that carried out frequent cooking activities (Table 4) and the findings of similar study by Dilip *et al.* (2014).

CONCLUSION

The study established that firewood, kerosene, gas and electricity were identified as the major cooking fuels used by the various households in the study area. The cost of fuel was identified as a key determinant for selecting fuel type by the households. Firewood has the highest carbon emission of 1,170.57g/J to boil 1 litre of water in 9.43 minutes and with consumed 354.29g of firewood.

It was concluded that; kerosene is the most predominant cooking fuel used by the households and cost has a great impact on their choice. LPG is the most sustainable cooking fuel due to it less carbon emission compared to the other fuel types. Electricity has no emission at the household level but due to the epileptic nature of power supply in the country; constant supply from the national grid is not feasible. The study recommends that the use of LPG for household cooking activities should be encouraged due to its low carbon emission. The issue of inconsistent power supply in the nation should be addressed to encourage its use for cooking since it has no CO_2 emission at the point of use.

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