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Clean versus Dirty Energy: Empirical Evidence from Fuel Adoption and Usage by Households in Ghana

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Abstract

There are few studies on the determinants of energy consumption of households in Africa, particularly in Ghana. Thus, this study identifies the drivers of households' fuel consumption for domestic purposes and examines two fuel categories ('clean' fuels versus 'dirty' fuels). The study used Demographic and Health Survey data that has a sample of 11,835 households across Ghana. Binary categorical models (binary logistic and binary probit) were used to investigate whether a household uses 'clean fuel' or 'dirty fuel', which are estimated with socio-economic variables and spatial disparity (regional location). The results suggest that households' energy consumption is affected by socio-economic variables and rural households are more deprived than urban households in adopting clean fuels. Also, male-headed households have a higher likelihood than female-headed households to adopt clean fuels. Many households choose clean fuels for lighting than they do for cooking as wealth status improves. However, solid fuels such as charcoal and firewood remain the dominant fuel used for cooking by the majority of households. The use of these dirty fuels could hamper the health status of households because of indoor pollution. The study recommends that policies should be geared towards the provision of clean and better energy sources to households.

Keywords**:** 'Clean' fuels, 'Dirty' fuels, household fuel adoption, household fuel consumption, Energy usage, Ghana.

JEL Codes**:** O13, P28, Q42

1. Introduction

This study identifies the drivers of households' fuel[1] consumption. We looked at how socio-economic factors determine household adoption and use of fuel for domestic purposes. Clean versus dirty fuels categories were examined to ascertain the nature of household adoption and usage in Ghana and as to whether it exhibits the energy ladder hypothesis. In this study, clean fuel (modern fuels) refers to fuels that are clean in terms of the gaseous emissions they create. Clean fuel refers to these categories of fuels: kerosene, Liquefied Petroleum Gas (LPG), electricity. In contrast, dirty fuels refer to fuels that are in their solid-state that emit a lot of toxic substances and smoke. They include firewood, charcoal, animal dung, crops, grasses, biomass resources which comprised of residues from agriculture harvests from the forest (in the form of firewood, charcoal, residues), crop residue, energy crops, animal manure, residues from agro-industrial and food processes, municipal solid wastes, and other biological resources (International Energy Agency - IEA 2010).

Globally, the majority of households are deprived of clean energy sources for their household energy needs, and this is more pronounced in sub-Saharan Africa. Household energy demand and usage is mostly part of their essential needs as it uses for multipurpose benefits ranging from the cooking of meals, lighting to heating. A household which is deprived of clean energy (i.e. the use of hazardous energy) for household needs may have its members being probable susceptible to smoke-related diseases (Legros *et al*.,2009; Egebtokun, Osabuohien and Akinbobola, 2018; Karakara and Dasmani, 2019; Egbetokun *et al.,* 2020).Clean energy is considered as a critical component of a sustainable development strategy. The Sustainable Development Goals (SDGs) of the United Nations (UN), SDG Goal 7, seeks to ensure access to "affordable, reliable, sustainable and modern energy for all". Without sufficient clean fuels (energy sources) for cooking, women mostly in Sub-Saharan Africa will continue to be exposed more than anyone to indoor air pollution and its health effects. It is estimated that some 2.4 billion people will continue to rely on traditional biomass for energy to cook and heat. This means that such persons will continue to be exposed to indoor air pollution and its attended respiratory problems. It is estimated that 4 to 5% of global diseases are a consequence of indoor air pollution (United

[1]The words energy and fuel are use interchangeable in this paper. This is because in the attendant literature both terms refer to same thing especially on household consumption for domestic use.

Nations Development Programme-UNDP, 2004).Africa's traditional biomass use is likely to increase sharply by 2030 unless there is a significant increase in access to cleaner and affordable energy carriers for cooking (International Energy Agency-IEA, 2006; Akinyemi *et al.*, 2017; Akinyemi *et al.*, 2019a; Akinyemi *et al.*, 2019b; Karakara and Osabuohien, 2019a; Karakara and Osabuohien, 2019b).

Ghana's Ministry of Energyin 2010 estimated that about 66% of the Ghanaian populace has access to electricity. In the same year, the IEA (2010) ranked Ghana 50th out of 80 countries in Energy Development Index (EDI) that uses as its indicators; households' access to clean cooking fuels and electricity access indicator. About 80% of households in Ghana depend directly on wood fuels (firewood, charcoal, and other biomass) for cooking (Ghana Energy Commission, 2012) which are sources of indoor air pollution with its health implications. Fuelwood is a significant driver of forest degradation and subsequently the release of Green House Gas (GHG) emissions in Ghana (UNEP RISOE, 2013a). Respiratory infections, cardiovascular diseases, lung cancer, reduced lung function, carbon monoxide poisoning and immune system impairment are among the diseases caused by indoor air pollution. There is an urgent need for policy to change the pattern of usage of cooking fuels in Ghana, particularly for the rural areas, to tackle the disease burden, scale of deaths that are or could potentially be arising from this source and deforestation.

There are studies (e.g. Aitken, 2007; Pachauri *et al.*, 2010; Faisal *et al.*, 2013; Tchereni, 2013) that used income as the only determinant of fuel adoption, which may not reflect the reality, especially in developing countries. Using income or expenditures as the only measure of energy adoption and usage could be subject to bias, because poor households may rely on cheap but inferior biomass for their energy needs. In contrast, wealthy households may use dirty fuel because its supply is sure and cost-effective in terms of extensive cooking. While other studies (e.g. Abebaw, 2007; Kwakwa and Wiafe, 2013; Onoja and Idoko, 2012; and Tchereni, 2013) used only two different fuel type or one fuel type to find the drivers of household fuel adoption and use. However, households consume various kinds of fuels such as; firewood, charcoal, kerosene, LPG, coal, lignite, electricity. To concentrate on only one or two could bias the results. On this note, this study uses the Demographic and Health Survey data that contains 11,835 households' energy consumptions such as firewood, charcoal, grasses, LPG, electricity, and kerosene. The fuel sources listed above are categorised into clean versus dirty fuel, to help ascertain the pattern of adoption and use of clean or dirty fuel by households in Ghana.

Given the above background, this study investigates the major determinants of household fuel adoption and usage. The following research questions guide the study: What are the reasons for a household to adopt particular fuel for cooking or lighting? What are the patterns of clean fuels versus dirty fuel adoption and usage? Does the energy ladder hypothesis hold for Ghanaian household fuel adoption? Do regional disparities matter in household access to and adoption of fuel for domestic use? The rest of the paper is structured as follows: Section 2 presents background and insights from previous studies, while Section 3 reports the data and methodology used in the study. Section 4 presents the empirical results and discussions, while Section 5 concludes with policy implications and recommendations highlighted.

2. Background and Insights from the Literature

2.1 Background of the Studied Country

The Republic of Ghana lies along the Gulf of Guinea in West Africa with a population of 29.6 million as of March 2018.The country recorded its highest annual average GDP per capita growth rate of 5.89% between 2010 and 2014.The economy is broadly divided into three sectors: agriculture, industry and services. The country can be said to be a Service-Sector led economy as the services sector recorded the highest growth rate of 5.7%, followed by agriculture (3.0%) and the industry (-1.4%) sectors(Ghana Statistical Service, 2017). The cost of environmental degradation is estimated at 9.3% of GDP. The cumulative total cost of climate change adaptation from 2012 to 2050 is estimated to be US$2.7 billion. The Country's Tropical weather continues to get warmer whereas rainfall remains uncertain. The total national emission in 2012 was 33.7MtCO2e. Agriculture, Forestry and Other Land Use (AFOLU) and Energy sectors are the two largest sources with residential contributing 32% of the total energy sector emissions (Ghana Energy Commission, 2012). In 2012, CO_2 was dominant gas, which contributed 44% (14.81Mt) of the total net emissions (including AFOLU). Out of the total net emissions for 14.81Mt, energy sector contributed 85% (12.59Mt), and industrial processes and products use – IPPU (2.4%, -

0.35%). When the emissions from AFOLU are excluded from the national totals, carbon dioxide made up 70.1% (12.95Mt) of the emissions in the same year (Government of Ghana-GoG, 2015).

Ghana's total forest cover has dwindled from 8.2million hectares at the turn of the last century to less than 1.6million hectares in 2011. The decline in the forest cover is mainly human-induced deforestation estimated at 2% per annum (GoG, 2015). The government of Ghana 2015 climatic change report identified key agents of deforestation as; agricultural expansion (50%), harvesting of wood (35%), population and development pressures (15%) and mineral exploitation and mining (5%). Wood removal for fuelwood and charcoal production is estimated at 30million m^3 per year, while forest timber logging and harvesting from regulated sector amount 3.72million m^3 per year for export. The estimated percentage of the total land area of Ghana prone to desertification is 64.97% representing about 165,000km^2 with the upper east region and eastern part of the northern region facing the greatest desertification threat on an area of approximately 78,718km^2 (GoG, 2015).

Wood-based biomass is the dominant source of energy for sub-Saharan Africa, and fuelwood consumption per capita in Africa is higher than any other continent. In Ghana, the bulk of energy consumption is based on fuelwood, and 90% is obtained directly from natural forests. Therefore, the demand for wood is a significant driver of forest degradation, and subsequently, the release of GHG emissions in Ghana (UNEP-Riso, 2013b).Most Ghanaians depend on biomass fuel sources, particularly wood fuels and charcoal, for household needs. Government statistics place the consumption of biomass fuels at slightly more than 60% of total energy consumption in Ghana.

Biomass fuels emit toxic substances by way of indoor air pollution, which are sources of many diseases. Air pollution from indoor sources is the single most significant contributor to the adverse health effects of air pollution in Ghana. Indoor air pollution causes an estimated 14,000 deaths every year and 3000 deaths in children below 5years. It is a major risk factor in Non-communicable diseases in Ghana and perhaps the leading risk factor for rural women (Ghana Health Services Burden of Disease, 2010). Respiratory infections, cardiovascular diseases, lung cancer, reduced lung function, carbon monoxide poisoning and immune system impairment are among the diseases caused by indoor air pollution.

2.2 Insights from Empirical Literature[2]

There are quite many studies on household fuel adoption and use. Different studies are adopting various methods in different locations and in different periods with different conclusions being drawn. A synchronic/thematic review of the literature shows mixed results in different case scenarios of the determinants of household fuel adoption and usage for domestic purposes. Using similar variables as determinants, different effects (positive or negative) are found by various studies as factors that influence household adoption of fuels for domestic use.

Many studies (e.g. Aitken, 2007; Pachauri *et al.,* 2010; Faisal *et al.,* 2013)fall in line with the 'energy ladder hypothesis', which had income as the primary determinant of household fuel consumption. That higher income or expenditures calls for the adoption of clean fuels like electricity, LPG and lower levels of income calls for dirty fuel adoption like firewood, charcoal, grasses, and animal dung. Faisal *et al.*,(2013) going strictly by the income approach in determining household adoption of fuel in Ghana, found that wood dominates the energy used for cooking, with some LPG and very little kerosene. Using a cross-sectional data (Ghana Living Standards Survey - GLSS5) of 8,687 households and doing a descriptive, tables and chart analysis of household fuel usage, it was found that there is a positive and significant relationship between charcoal or LPG and income levels. However, wood is found to be harmful at all income levels. They found electricity (45.88%) and kerosene (52.32%) as the primary source of lighting for households in Ghana with electricity as a source of lighting is positive with income. However, kerosene is negative with income (Faisal *et al.,* 2013).Also, Aitken (2007) compared household energy consumption and expenditure across three provinces (Eastern Cape, West Province, and KwaZulu Natal) in South Africa, and found that between 77% and 98% of households in each of the provinces use wood as their primary source of fuel. Kerosene was found to be mostly used in Eastern Cape and North West, while LPG is mostly used in KwaZulu Natal. Therefore, as expenditure increases, households shift from dirty fuels to clean fuels, confirming the energy ladder hypothesis.

[2] This study mainly covered empirical literature since it is an empirical study and more importantly due to space constraint.

Besides, Tchereni (2013) analysed the behaviour of households as they make decisions on which fuel facility to choose for home use in South Lunzu Town of Malawi —using an Engel function, where household consumption of fuelwood is part of total household consumption. The author found a negative and significant relationship between income and energy budget share of fuelwood. Again, Tchereni (2013) found home size, age of household head and education of household head also to have a negative and significant association with fuelwood expenditure.

Socio-economic factors such as the age of household head, the gender of household head, size of household, educational level of household head, and place of residence of household (rural or urban) are used to study the determinants of household fuel adoption and usage by different authors in different countries. Abebaw (2007) examined household determinants of fuelwood choice in urban Ethiopia as a case study of Jimma Town. The author employed a Tobit model focusing on household fuelwood consumption, and found that household size and age of household head have a significant positive relationship with firewood consumption but negative with charcoal consumption. Education and gender of the household head both are significantly and negatively related to firewood usage. He also found that homeownership is consistent with using clean fuel (i.e. charcoal in the author's case). Kwakwa and Wiafe (2013) also assessed fuel usage among rural households in Ghana by interviewing 207 households and using logistic regression. They found that firewood and charcoal were mainly used as a source of energy for cooking and that the probability of using firewood has a negative relationship with the variables gender, age, age squared and electricity by respondents. Kwakwa and Wiafe (2013) also concluded that employment status, income and usage of liquefied petroleum gas (LPG) were the most significant variable explaining household firewood usage. If the household head is employed, it reduces the probability of using firewood. As incomes of household increases, it reduces the likelihood of using firewood, and if a household is found to be using LPG, it reduces the probability of using firewood.

Furthermore, Mensah and Adu (2014) analysed household energy choice in Ghana by employing an ordered probit model with socio-economic variables. They found that household size and age of household head have a negative effect on the probability of using clean fuels over inefficient fuels. Education is positive to fuel (electricity and LPG) use; thus, having access to education increases the probability of using clean fuels. All the socio-economic variables except being poor are significant in explaining fuels used by households. Onoja and Idoko (2012) also carried out an econometric analysis of factors influencing fuelwood demand in rural and Peri-urban farm households of Kogi State in Nigeria. Their focus was to find out the drivers and variables influencing fuel wood demand in that state; they found that an increase in the price of fuelwood would decrease quantity demanded by 76%. Income and distance to the source of fuelwood were found to be negatively related to fuel wood consumption. Grimm *et al.* (2014), investigated the take-up behaviour and changes in people's living conditions after an introduction of Pico-PV solar kits as a means of meeting the energy demands of households in rural Rwanda. The authors used a randomised control trial, where respondents were divided into treated group and control group for the research experiment. They found that 47% of the treated group use Pico-PV lamp exclusively. Households use the Pico-PV lamp more for lighting than other services it provides like charging of mobile phones. Also, Mangizvo (2014) investigated the significance of culture as a household energy determinant in Chiwundura Communal Area in Zimbabwe. Using a purposive sampling technique of 10 households, the role was to show that certain marginalised or traditional socio-cultural practices determine household energy choice. The author found that behavioural and cultural practices, lifestyle, food preferences are critical in determining household energy choice among the household sampled.

Akpalu, Dasmani and Aglobetsi (2013) established that demand for fuel by households is not a derived demand and that households may map taste and preferences of cooked food to fuel type used to cook it, only preferences matters. They test the hypothesis that there are no preferences in fuel use type. They found that households get locked into specific fuel types, as there are significant differences among preferences for various fuel types. The most preferred fuel type was LPG with kerosene being the least preferred; hence the energy ladder hypothesis does not hold. Demand for fuels (except kerosene) is inelastic, an increase in prices of fuels leads to less than proportionate change in fuels bought. The authors (Akpalu, Dasmani and Aglobetsi, 2013) indicated that households substitute kerosene and firewood for charcoal if the price of either of these two fuels increases. The demand for firewood is not responsive to changes in the price of other fuels, so if other fuels are subsidised demand for firewood might still be the same. Finally, demand for fuels is not derived demand.

Ogwumike *et al.,* (2014), examined energy use and energy ladder hypothesis and how socio-economic variables affect household energy use in Nigeria. By employing a multinomial logistic model, they found that energy use and expenditure affirms the energy ladder hypothesis. However, it is energy stacking and not energy switching. Urban sector (the type of residence) is found to be inversely related to firewood use and positive of kerosene, LPG and electricity usage for cooking and, household size was found to have a positive relation to firewood and LPG use but inverse to kerosene usage. Ogwumike *et al.* (2014) further asserted that male-headed households are likely to use LPG and kerosene for cooking but not firewood than their female counterpart. Again, the age of household head has been found to have a significant positive influence on firewood use but have a significant negative impact on kerosene usage (Ogwumike *et al.,* 2014). Father's education is inversely related to firewood usage, while poverty levels are positive to firewood usage.

Kimemia and Annegarn (2011) carried out a case study of Setswetla, focusing on urban society that uses woody biomass as one of their significant sources of energy in Johannesburg, South Africa. They use both quantitative and qualitative methods and employ triangulation after interviewing 103 households and ten firewood vendors. They sought to find out whether there are sections of the urban population who depend on biomass fuel to balance their fuel budget. They found that 99% of the urban dwellers use paraffin (kerosene) as one of their fuels. Also, 61% of them use firewood, which was principal fuel for commercial cooking and beer brewing. Furthermore, 24% of them use solid fuels for cooking, while 66% of them use solid fuels for heating. They concluded that there is a frequent switch between solid fuels and liquid fuels within the same households.

3. Data and Method of Analysis

3.1 Data

The study uses the Ghana Demographic and Health Survey data (GDHS VI) for 2014 conducted by Ghana Statistical Service. GDHS followed a two-stage sample design. The first stage involved selecting sample points (clusters) consisting of enumeration areas (EAs). A total of 427 clusters were selected, 216 in urban areas and 211 in rural areas. The second stage is where households were systematically sampled. A random selection of households was made after a listing operation was undertaken in all of the selected EAs in January – March 2014.

Total sample sizes of 12,831 households were chosen. For approximately equal sample sizes in each region, weighting factors have been added to the data file so that the results will be proportional at the national level. Three questionnaires were used for the 2014 GDHS: The Household Questionnaire, the Woman's Questionnaire, and Man's Questionnaire. A total of 12,831 households were selected for the sample, of which 12,010 were actually picked to participate in the survey, and 11,835 were successfully interviewed, yielding a response rate of 99%. There were missing observations for specific variables, and thus our sample size reduced to 11,362 households, which captures the full observations for all our variables of interest. The data capture six different types of fuel. These are electricity, LPG (including biogas), Kerosene, wood, charcoal, and others (animal dung, grass, crops).

The dataset captures the major fuel type a household uses for cooking. We categorised these fuel types into clean (electricity, LPG, and kerosene) and dirty (wood, charcoal & others) fuels, which was coded as dummies of a household having access to clean fuel as equal one and with no access equal zero. For example, if a household adopts any of the clean fuel types, it is coded one and zero otherwise. Other variables which were coded zero-one are; sex of household head (0=female 1=male), the residence of household (0=rural, 1=urban), marital status of household head (1=not currently married, 0=currently married), wealth status (0=poorest, 1=poorer, 2=middle, 3=richer, 4=richest). Continuous variables were; the age of household head and the size of household. These were not coded since they are continuous.

3.2 Specification of the Empirical Model

Using a binary logistic model, the expression could be, Let P_i represent the probability of a household adopting clean fuel, such that the probability of not adopting clean fuel is given as 1-P_i. We do not observe P_i, as Y is a latent variable, but we observe the outcome Y=1 if the household adopts clean fuel and Y=0 if he does not, then we have the following model specification.

$$P_r(Y_i = 1) = P_i \qquad (1)$$

$$P_r(Y_i = 0) = 1 - P_i \qquad (2)$$

The probability of a household adopting clean fuel is therefore given as equation 3, and the probability of not adopting clean fuel is given in equation 4:

$$Pi = E(Y = 1|X) = \frac{1}{1 + e^{(\beta_0 + \beta' Xi)}} \qquad (3)$$

$$(1 - Pi) = E(Y = 0|X) = \frac{1}{1 + e^{(\beta_0 + \beta' Xi)}} \qquad (4)$$

X is a vector of independent variables, and β is a vector of their respective coefficients. Equation 3 is thus simplified as follows

$$Pi = E(Y = 1|X) = \frac{e^{(\beta_0 + \beta' Xi)}}{1 + e^{(\beta_0 + \beta' Xi)}} \qquad (5)$$

In Equation 5, P_i varies from0 to 1 and is non-linearly related not only to the regressors but also to the parameters, and this causes some estimation problems if ordinary least squares (OLS) estimation technique is applied (Karakara and Osabuohien, 2020a, 2020b).Reformulating these equations in terms of the odds ratio of the probability of a household adopting clean fuel to the probability of the household not adopting clean fuel can be expressed as follows:

$$\left[\frac{Pi}{1 - Pi}\right] = \frac{1 + e^{(\beta_0 + \beta' Xi)}}{1 + e^{-(\beta_0 + \beta' Xi)}} \qquad (6)$$

$$\left[\frac{Pi}{1 - Pi}\right] = e^{(\beta_0 + \beta' Xi)} \qquad (7)$$

Taking natural logarithms of the equation 7 to get our logit model and observe that the log of the odds ratio, L, is not only linear in X, but also in the parameters; *L* is called the logit**,** and thus it is logit model as like (8).

$$Ln\left[\frac{Pi}{1 - Pi}\right] = Li = \beta_0 + \beta' Xi \qquad (8)$$

We used the following socio-economic variables; household size, the gender of household head, age of household head, wealth status of the household, marital status of household head, educational level of household head, residence nature (rural/urban) and region of residence.

3.3 Measurement of variables

This section looked at the measurement of the variables used in the estimation. Table 1capturesthe variables type, their measurement and explanation on the reason for the inclusion of such variables in the model estimation of the paper are provided herein.

Household size

These variables are chosen for this study based on theory and empirical studies of other authors. However, they have found diverse results regarding the effect and direction of these variables in determining household demand for a particular fuel for cooking. Household size, usually measured by numbers of occupants in the household, is uniformly found to be significant and positively signed in the studies analysed. That is, the higher the number of occupants in a household, the greater the level of energy consumed (or forms of energy, e.g. if the study is looking at electricity in particular). Braun (2010) found that household size is positively related to the presence of multiple heating modes in the home. A further aspect of this is that studies find evidence to suggest economies of scale in household size (Chambwera and Folmer, 2007; and Filippini and Pachauri, 2004; Karakara and Osabuohien, 2019a). So, energy consumption increases (and type of energy changes) as the number of persons in a household increase but at a decreasing rate.

***Age of household head*[3]**

Age is another variable that most studies included in analyzing household demand for energy. Majority of the studies find a positive relationship between the age of the head of household and energy consumption. This finding was especially prevalent in electricity demand studies, indicating that person will need to use more energy, especially for heating purposes as they get older because they are at home more often and because they require a higher heating requirement.

[3]The square of the age (to check functional form of the model) was not included because the study is mainly concerned with the likelihood of clean fuel versus dirty fuel adoption. However, preliminary analysis (not reported) indicate that there was no substantial difference in the results.

The educational level of the household head

The educational level of an individual (household head in this case) is also deemed to affect the choice of fuel for domestic use. This variable is captured as a categorical variable to show variation in the choice and use of various fuels between various levels of education. The inclusion of this variable is to observe how education affects the choice and use of fuels for domestic consumption in Ghana. Some studies include education, which is found to have a positive effect on electricity consumption (Chambwera and Folmer, 2007) and gas (Braun, 2010).

Residence/Location

Most studies also include a location variable based on the urban/rural divide. Perhaps as expected, urban areas are found to consume relatively more electricity (Filippini and Pachauri, 2004) and gas (Bernard *et al.*, 1996) while living in rural areas increases a households' gasoline consumption (Manzan and Zerom, 2010; Yatchew and No, 2001). Rural areas are known to have abundant fuelwood, grasses, animal dung, crops, which are collected free of charge (no monetary cost), which is not the case in urban areas. We include this variable to capture differences emanating from rural-urban disparities.

Wealth status of household

Income earning or wealth status also determines the likelihood of some fuels being consumed than others by households. The level of wealth of an individual or household could determine which fuel is likely to be adopted and use. This variable is categorical and is included to show how differences in wealth status could affect the likelihood of using different fuels by households in Ghana. Wealth status of the household is measured based on a scale of poorest, poorer, middle, richer and richest. The poorest household is one who is far below the national poverty line and has income less than the national average and without household assets like TV, and radio set. A richer household is one that is far above the poverty line and earns income far more than the national average. We include the wealth status of household drawing from other studies (Karakara and Dasmani, 2019; Karakara, 2018).

Sex of household head

This variable is included to observe the effect of gender disparities between the household heads and how it affects the choice and use of fuels for cooking and lighting. Sex of household head cannot be left out since most male-headed households have economic potential than female-headed ones. Households' heads that are married can easily pool resources together to afford certain fuels than other households' heads that are not married.

Regional location

To control for variation in the use of fuels that may arise as a result of regional differences, a set of dummy variables are introduced to capture the regional effect. Ghana has ten administrative regions[4] with which region having its unique characteristics in terms of geographical endowment, the composition of ethnic groups, and access to different fuels at a different rate.

TABLE 1 ABOUT HERE

4. Results and Discussion

4.1 Descriptive Statistics and Distribution of Variables

The descriptive statistics and distribution of the variable are shown in Table 2. The finding on clean versus dirty fuel for cooking shows that 21.18% of the households adopt clean fuel (i.e. electricity, LPG, kerosene) for cooking while the majority of them (78.82%) adopt dirty fuel (wood, charcoal, grass, and animal dung). Concerning the adoption of fuel for lighting, it is encouraging, as 71.26% of the households adopt clean fuel (electricity, generator) for lighting. In comparison, 28.74% of them adopt dirty fuel (candles, lantern, and grass) for lighting. It is so because Ghana was placed 3rd after Mauritius and South Africa to have higher electrification rate in Sub-Sahara Africa-SSA (Kemausuor *et al.*, 2011).

Male-headed households consist of 66.56% as against 33.44% female-headed households. The residence nature of a household shows almost the same proportion of rural (50.44%) and urban (49.56%) divide. Wealth distribution shows that 42.49% of the households are at most a poorer

[4]Ghana currently has 16 regions, as 6 more regions were created by referendum in February 2019.

household as against 36.02% who are at least a richer household. The majority (63.97%) of the households are within poorest to middle wealth status.

The results in Table 2 further show that majority (64.69%) of the household heads are currently married and living together as against 35.31% of the household heads who are not currently married (divorce, widowed, single). For the educational level of household head, the findings show that the majority (57.09%) of them have completed at least secondary education with 28.88% of them having no education or no pre-schooling. On regional distribution, five regions (Eastern, Greater Accra, Brong-Ahafo, Western and Ashanti) account for 55.08% of the total households while the other five regions account for 44.92%. Upper West region has the lowest of 7.65% and Eastern region highest of 11.26%.

TABLE 2 ABOUT HERE

This paper looked at the wealth status and adoption of clean/dirty fuels, as shown in Table 3. It shows that among the poorest households (2,486), 99.52% of them adopt dirty fuel for cooking with only 0.48% adopting clean fuel for cooking. Also, 76.99% of them (poorest households) adopt dirty fuel for lighting. For poorer households (2,342), 98.93% of them use dirty for cooking, and only 1.07% adopts clean fuel for cooking. However, with the adoption of fuel for lighting, 57.17% of the poorer households utilise clean fuel as against 42.83%who adopts dirty fuel for lighting. The richest households (1,959) constituting 78.76% of them adopt clean fuel for cooking, and 99.80% of them adopt clean fuel for lighting. It shows that the wealth status of household matters in fuel adoption. From the results in the Table, as we move from poorest to richest households, that rate of clean fuel adoption increases for both cooking and lighting. This finding is in line with the so-called energy ladder hypothesis as verified by Heltberg (2003), Aitken (2007), Mekonnen and Kohlin (2008), and Ogwumike *et al.*,(2014). However, the rate of adoption of clean fuel for cooking versus lighting is not the same as wealth status improves. Clean fuel adoption for lighting is higher than the rate of clean fuel adoption for cooking, which is partly explained by the rural electrification programme that brought electricity to many homes. As of 2011, Ghana was rated 3rd after Mauritius and South Africa to have a higher percentage of its people having access to electricity (Kemausuor *et al.*, 2011). Also, it is costly to use electricity for cooking; hence, many homes may have electricity for lighting but resort to other fuels for cooking.

TABLE 3 ABOUT HERE

The results in Table 3 further show that 93.19% of the total number of rural households (5,731) adopts dirty fuel for cooking and only 6.81% of them adopt clean fuel for cooking, with 53.90% adopting clean fuel for lighting as against 46.10% of them adopting dirty fuel for lighting. For the urban households (5,631), constituting 35.80% of them adopt clean fuel for cooking, which is far higher than the rural figure of 6.81% who adopt clean fuel for cooking. Also, 88.94% of the urban households adopt clean fuel for lighting as against the rural number of 53.90% who adopt clean fuel for lighting. This result suggests that urban households have more access to clean fuels than rural households, and hence they (urban households) use clean fuel more than rural homes. Nevertheless, this difference is more pronounced in the adoption of cooking than for lighting, which is attuned to the finding of Ogwumike *et al.*, (2014).

4.2 Econometric Results

Table 4 shows the regression results for our logit and probit models. A male-headed household has 2% less likely to adopt clean fuel for cooking compared to a female-headed household. This result is significant at 1% level for both models (logit and probit), and male-headed household has 0.3% reduction in the probability to adopt clean fuel for lighting but is not significant. This might be so because men are mostly not those in the kitchen who are directly involved in cooking and thus may not see much the importance of adopting clean fuels. This finding is in line with what Abebaw (2007), Kwakwa and Wiafe (2013), Mensah and Adu (2013), Mekonnen and Kohlin (2008),Karakara (2018) and Ogwumike *et al*., (2014) found in their various studies. As the age of household head increase by one, the probability of adopting clean fuel for cooking reduces by 0.2%. It, however, increases the likelihood of adopting clean fuel for lighting by 0.1%. This finding is consistent with Abebaw (2007), Demurger and Fournier (2007), Ogwumike *et al.*, (2014).

TABLE 4 ABOUT HERE

Table 4 further reveals that a household head with secondary education has a 5% increase in the probability of adopting clean fuel for cooking and 2.5% more likely to adopt clean fuel for lighting. These are all significant at 1% level. Thus, educated persons might earn enough to adopt clean fuel than an uneducated person. Also, educated persons might be much aware of the dangers of using dirty fuels and will avoid its usage. However, a household from the rural area has 6% likelihood of a reduction in adopting clean fuel for cooking and 0.34% less likely to adopt clean fuel for lighting. This result conforms to those of Abebaw (2008); Mekonnen and Kohlin (2008); Mensah and Adu (2013); Ogwumike *et al.,* (2014); and Tchereni (2013). The size of household members is positively and significantly related to clean fuel adoption. If the size of household increases by one member, the probability of adopting clean fuel for cooking declines and adopting clean fuel for lighting increases. In Table 4, as the number of households' members increased by one, it reduces the probability of adopting clean fuel (say electricity) for cooking by 2%. It increases the probability of adopting clean fuel for lighting by 1%.Itimplies that larger households call for more substantial food cooking, and hence using clean fuel (electricity, LPG) to cook could be of a high cost than other fuels like charcoal or wood (Karakara & Dasmani, 2019). Also, using clean fuel like electricity for lighting by larger households is less costly than using other fuels like lantern or candle for lighting. The above finding is in tandem with other studies like Abebaw (2007); Mekonnen and Kohlin (2008); Ogwumike *et al.,* (2014); Onoja and Idoko (2012).The household head who is currently not married and not living together has a lesser probability of adopting clean fuel for cooking and lighting. However, it is only the lighting dimension that is significant at 5% level, which is in line with Kwakwa and Wiafe (2013), and Tchereni (2013).

On the wealth status of household and fuel adoption, it shows that wealth status is much significant in determining clean/dirty fuel adoption by households. The results in Table 4 indicate that the poorest household is the base category from which the other households are compared. It shows that a poorer household is 1% and 39% more likely to adopt clean fuel for cooking and lighting, respectively more than the poorest household. A middle level wealthier household has 8.3% and 68.3% more chance to adopt clean fuel for cooking and lighting respectively than the poorest household. For a richer household, it is 34.8% and 78.5% more likely, than poorest household, to adopt clean fuel for cooking and lighting respectively. The richest household has 80% increases in the likelihood of adopting clean fuel for both cooking and lighting than poorest household. This finding underscores that as wealth status improves; households adopt clean fuels and abandon dirty ones. The result is similar to findings of Aitken (2007), Heltberg (2003), Mekonnen and Kohlin (2008), Ogwumike *et al.*,(2014), Onoja and Idoko (2012), and Tewathia (2014).

For regional disparity, Western region is the base category upon which the other regions are compared. Compared to households from the Western region, a household from the Greater Accra region has 2.2% more likely to adopt clean fuel for cooking and 6% less likely to adopt clean fuel for lighting. Households form Eastern, Ashanti, Northern and Upper West regions have 4%, 2%, 8.2% and 4.2% respectively fewer probabilities to adopt clean fuels for cooking than households from the Western region. In comparison, households from Volta and Upper East regions have 3.3% and 8.9% respectively of more likely to adopt clean fuel for cooking than households from the Western region. This finding is in line with Karakara (2017). The logit model was reaffirmed by the probit model, which ascertained the robustness of the logit model. The predicted probabilities of the logit model were estimated and found it to be between 0.05 and 0.97.

5. Conclusion and Recommendations

5.1 Conclusion

There are limited studies on the determinants of household energy consumption, particularly in Ghana. Thus, this study identifies the drivers of households' fuel consumption concerning poverty incidence. It surmises that households who use non-modern energy sources (because such fuels mostly have health implications) are poorer and will remain so compared to those who use modern energy sources. The study used Ghana Demographic and Health Survey (2014) data with a binary logistic regression model of whether household uses clean fuel or dirty fuel, which is estimated with socio-economic variables and spatial disparity (regional location). To check the robustness of the model, the study used the logit and probit models were estimated for consistency as well as the predicted probabilities for the explanatory variables.

The households' energy consumption is affected by socio-economic variable, and rural households are more deprived than urban households in terms of access to and use of modern fuels (clean fuels). The results exhibit the energy ladder hypothesis, as the wealth of households improves; they adopt clean fuels and abandon dirty fuels. Also, male-headed households have a higher probability than female-headed household to adopt clean fuels. However, solid fuels such as charcoal and firewood remain the dominant fuel used for cooking by the majority of households. There are differences in the rate of adoption of clean fuel for cooking and lighting. Many households adopt clean fuel for lighting than they do for cooking.

5.2 Recommendations

Forest biomass is one of the predominant sources of energy for Ghanaian households, and improved use efficiency would inevitably affect the economy and the health of the families, as the use of traditional earth kilns in charcoal production is a significant source of GHG emissions. For instance, to improve the production and use of charcoal as well as achieve sustainability across the country, providing people with cleaner charcoal, that is produced sustainably and used more efficiently, will have critical environmental dividends. Charcoal production in Ghana is still predominantly informal, with charcoal produced in rudimentary kilns. The wood-to-charcoal conversion rate is highly inefficient; this can be increased significantly through drying wood and the use of efficient kilns. The use of efficient mobile kilns such as Casamance kilns, as well as very efficient installed kilns such as retort kilns.

There are various other types of kiln technology that are available globally, including metal kilns which have been used in East Africa. Retort kilns and portable kilns which have the advantage of being easily transported to the source of the wood and which have a shorter carbonisation cycle. Briquettes from biomass waste can also be produced. Technologies, which utilise biomass waste, reduce emissions in two ways: through a reduction in the use of wood; and by a decrease in the release of methane produced from inorganic decomposition. The government will need to work towards a coherent policy that combines sectors such as forestry, agriculture, land use, energy, trade, and finance, all sectors that are relevant to biomass production and consumption.

Solar energy technologies are another form of energy that could be harnessed to solve household energy demand problems. The average duration of sunshine in Ghana varies from a minimum of 5.3 hours per day at Kumasi in the Ashanti region, which is in the cloudy semi-deciduous forest region, to 7.7 hours per day at Wa in the Upper West region, which is in the dry savannah region. The monthly average solar irradiation in different parts of the country ranges between 4.4 and 5.6kWh/m2 /day (16-20 MJ/m /day)(Ghana Energy Commission - SE4All, 2012). Solar energy technologies could help households adopt clean fuels and help reduce GHG emissions in Ghana.

Wind energy is another energy technology that can be adopted for household needs. Annual average wind speed along the Ghana-Togo border is above 8m/s. It is currently reliably projected that over 300 MW installed capacity of the wind farm could be established at the coastal part to generate over 500 GWh to supplement the nation's energy supply. Also, waste-to-energy technologies are emerging technologies that use solid waste to produce energy. Ghana produces a lot of waste, which could be gathered to help generate power for use.

Thus, the study recommends that policies should be geared towards the provision of clean and better energy sources for households. The use of LPG subsidy for household use; free distribution of LPG cylinders, among others should be pursued. Different energy technologies (wind, solar, improved cooking stoves, and improved biomass production) should be vigorously pursued to help provide clean energy for households. There should be a public-private partnership in harnessing technologies for sustainable production of fuels, mainly charcoal, which is the primary fuel demanded by a majority, including urban households. Sustainable ways of producing charcoal are; Casamance kilns, retort kilns and portable kilns. Other measures like improved cooking stoves should be a pursuit to help reduce the quantity of fuelwood demand and subsequently the stress on the environment.Other energy technologies that are not common in Ghana should be pursued. These are; wind energy technologies, tidal energy technologies, and solar energy. Such can be done with a public-private partnership arrangement.

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References

Abebaw, E, D. 2007. "Household determinants of fuelwood choice in urban Ethiopia: A case study of Jimma Town". *The Journal of Developing Areas, 41 (1): 117 – 126.*

Aitken, R. 2007. "Household energy use: a comparison of household energy consumption and expenditure across three provinces". *Journal of Energy in Southern Africa, 18 (1): 20 – 28.*

Akinyemi, O., E. Osabuohien, P. Alege,and A. Ogundipe2017. "Energy Security, Trade and Transition to Green Economy in Africa". *International Journal of Energy Economics and Policy,* 7(3): 127-136.

Akinyemi, O., U. Efobi., S. Asongu., andE. Osabuohien. 2019a."Renewable energy, trade performance and the conditional role of finance and institutional capacity in sub-Sahara African Countries". *Energy Policy, 132* , 490-498.DOI: https://doi.org/10.1016/j.enpol.2019.06.012

Akinyemi, O., U. Efobi., E. Osabuohien., and P. Alege,2019b. "Regional Integration and Energy Sustainability in Africa: Exploring the Challenges and Prospects for ECOWAS". *African Development Review*, 31(4), 517-528. DOI: https://doi.org/10.1111/1467-8268.12406

Akpalu, W., I. Dasmani, andP.B. Aglobetsi, 2011. "Demand for cooking fuels in a developing country: To what extent do taste and preferences matter?"*Energy Policy, 6525 – 6531*

Bartels, F. L. 2007. "Energy, Industry Modernisation and Poverty Reduction: a review and analysis of current policy thinking". *UNIDO Staff Working Paper # 06/2007.*

Braun, F. G. 2010. "Determinants of households' space heating type: A discrete choice analysis for German households"*Energy Policy 38 (10): 5493-5503.*

Bernard, J. T., D. Bolduc, andD. Bélanger, 1996. "Quebec Residential Electricity Demand: A Microeconometric Approach" *The Canadian Journal of Economics / Revue canadienne d'Economique 29(1):* 92-113.

Chambwera M. and H. Folmer, 2007. "Fuel switching in Harare: An almost ideal demand system approach"*Energy Policy 35(4) 2538-2548.*

Egbetokun, S., E. Osabuohien, O. Onanuga.,T. Akinbobola.,O. Gershon., andV. Okafor,2020. Environmental Pollution, Economic Growth and Institutional Quality: Exploring the Nexus in Nigeria. *Management of Environmental Quality,31 (1),* 18-31. *DOI: 10.*1108/MEQ-02-2019-0050.

Egbetokun, S., E. Osabuohien, and T. Akinboloa 2018. "Feasible Environmental Kuznets and Institutional Quality in North and Southern African Sub-regions". *International Journal of Energy Economics and Policy*, 8 (1): 104-115

Faisal, W.A., A. Brew-Hammond.,andE. E. Osei 2013. "Relationships between energy use and income levels for households in Ghana". *European Scientific Journal 9(6): 233 – 245.*

Filippini, M. and S. Pachauri 2004. "Elasticities of electricity demand in urban Indian households"*Energy Policy 32(3): 429-436*.

Ghana Energy Commission 2012. "Sustainable Energy For All Action Plan". http://energycom.gov.gh/files/SE4ALL-GHANA%20ACTION%20PLAN.pdf Assessed 16 December 2017.

Ghana Statistical Service 2016. "Newsletter Quarterly Gross Domestic Product (QGDP) Third Quarter 2017". Retrieved on 20/01/2018 from http://www.statsghana.gov.gh/docfiles/new_PPI_pdfs/2016/PPI%20Newsletter_October%202016.pdf

Government of Ghana 2015."Ghana's First Biennial Update Report 2015". Ghana Government submission to the United Nations Framework Convention on Climate Change, June, 2015.

Grimm, M., A. Munyehirwe., J. Peters, and M. Sievert 2014. "A first step up the energy ladder: Low cost solar kits and household's welfare in rural Rwanda". *Institute for the study of labour (IZA), Discussion Paper No. 8594*.

Heltberg, R. 2003. "*Household fuel and energy use in developing countries – A Multi-country study".* Draft for discussion. Oil and Gas Policy Division. The World Bank, 1 – 86

IEA, 2006. "World Energy Outlook 2006". International Energy Agency (IEA), Paris.

IEA, 2010."Energy Poverty – How to Make Modern Energy Access Universal?" World Energy Outlook 2010. International Energy Agency (IEA), Paris

Karakara, A. A., and E. S. Osabuohien, 2020a. "Categorical Dependent Variables Estimations with Some Empirical Applications".InSloboda, B.W.*&*Sissoko, Y. *(*Eds*) "Applied Econometric Analysis: Emerging Research and Opportunities" (*pp. 164–189).*IGI Global* DOI: https://doi.org/10.4018/978-1-7998-1093-3.ch008

Karakara, A. A. andE. Osabuohien, 2020b.“ICT Adoption, Competition and Innovation of Informal Firms in West Africa: Comparative Study of Ghana and Nigeria”. *Journal of Enterprising Communities*, 14(3), 397-414. DOI:https://doi.org/10.1108/JEC-03-2020-0022

Karakara, A. A. 2018. “Energy-Poverty Nexus: Conceptual framework analysis of cooking fuel consumption in Ghanaian Households”. *Developing Country Studies, 8 (11), 1 – 10.*

Karakara, A. A.and I. Dasmani2019. “An econometric analysis of domestic fuel consumption in Ghana: Implications for poverty reduction”. *Cogent Social Sciences, 5 (1). DOI: https://doi.org/10.1080/23311886.2019.1697499.*

Karakara, A. A. and E. Osabuohien 2019a.“Households’ ICT Access and Bank Patronage in West Africa: Empirical Insights from Burkina Faso and Ghana”. *Technology in Society*, 56, 116-125. DOI: https://doi.org/10.1016/j.techsoc.2018.09.010.

Karakara, A. A. and E. Osabuohien 2019b.“Households’ ICT Access and Educational Vulnerability of Children in Ghana. *Cogent Social Sciences, 5(1)*. DOI: http://dx.doi.org/10.1080/23311886.2019.1701877.

Karakara, A. A. 2017. “Determinants of Fuel Consumption for Domestic use and Patterns of Energy Deprivation in Ghana”. *Unpublished Master’s Thesis. Department of Economics, University of Cape Coast, Ghana.*

Kemausuor, F., J. Y. Obeng., A. Brew-Hammond and A. Duker 2011. “A review of trends, policies and plans for increasing energy access in Ghana”. *Renewable and Sustainable Energy Reviews 15, 5143– 5154.*

Kimemia, D. and H. Annegarn2011. “An urban biomass energy economy in Johannesburg, South Africa”. *Energy for Sustainable Development, 15, 382– 387.*

Kwakwa, P. A. and E. D. Wiafe 2013. “Fuelwood usage assessment among rural households’ in Ghana”. *Spanish Journal of Rural Development, IV (1): 41-48, 2013*

Legros, G., I. Havet.,N. Bruce and B. Sophie 2009. “The energy assess situation in developing countries: A review focusing on the Least Developed Countries and Sub-Saharan Africa”. UNDP & WHO 2009. http://www.undp.org/content/dam/undp/library/Environment%20and%20Energy/Sustainable%20Energy/energy-access-situation-in-developing-countries.pdf Assessed 16 December 2017

Mangizvo, V. R. 2014. “The significance of culture as a household energy determinant: The case of Chiwundura Communal Area, Zimbabwe”. *Journal of Human Ecology, 46(3): 343-349*

Manzan S. and D. Zerom 2010. “A Semiparametric Analysis of Gasoline Demand in the United States: Reexamining the Impact of Price”*Econometric Reviews 29(4): 439-468.*

Mensah, T. J. and G. Adu 2013. "An empirical analysis of household energy choice in Ghana". Swedish University of Agricultural Sciences, *Department of Economics working paper No. 06/2013*

Mekonnen, A. and G. Kohlin2008. "Determinants of household fuel choice in major cities in Ethiopia". Environment for Development. *Discussion Paper Series. EfD DP 08 – 18.*

Ministry of Energy – Ghana 2010. "National Electrification Scheme (NES) Master Plan Review (2011–2020)". http://www.mida.gov.gh/pages/view/NES_Master_Plan_Review_Executive_Summary_Main_Report.pdf/111 Assessed 19 December 2017

Ogwumike, F.O., U. M. Ozughalu and G. A. Abiona 2014. "Household energy use and determinants: Evidence from Nigeria". *International Journal of Energy Economics and Policy, 4 (2): 248 – 262.*

Onoja, A. O., and O. Idoko2012. "Econometric analysis of factors influencing fuelwood demand in rural and peri-urban farm households in Kogi State, Nigeria". *The Journal of Sustainable Development, 8(1): 115 – 127.*

Pachauri, S., T. Ekholm., V. Krey and K. Riahi2010. "Determinants of Household energy consumption in India". *Energy Policy 38, 5696 – 5707.*

Tchereni, B. H. M. 2013. "An economic investigation in to fuelwood demand behaviour in South Lunzu Township in Malawi". *Developing Countries Studies 3 (4): 153 – 159.*

United Nations Development Program (UNDP) in Ghana, Environment and Energy 2004. Liquefied Petroleum Gas (LPG) Substitution for Wood Fuel in Ghana – opportunities and challenges: a brief analysis of the LPG sector in Ghana. https://energyaccess.wikispaces.com/file/view/Infolink_LPG_Ghana(2004).pdf. Assessed 24 December 2017

United Nations Environmental Program (UNEP) – Riso Center 2013a. "Understanding the Concept of Nationally Appropriate Mitigation Action. National Laboratory for Sustainable Energy". Technical University of Denmark. http://orbit.dtu.dk/files/57802310/understanding_the_concept.pdf. Assessed 24 December 2017.

United Nations Environmental Program (UNEP) – Riso Center 2013b. "Emissions Reduction Profile – Ghana". http://orbit.dtu.dk/files/57802310/emissions_reduction_profile_ghana.pdf assessed 10 March 2018.

Yatchew A. and J. A. No 2001. "Household Gasoline Demand in Canada" *Econometrica 69 (6): 1697-1709.*

Table 1: Variables used in the model estimation

Variable name	Type of variable	Expected sign
Clean Fuel	Electricity, LPG and Kerosene	Dependent variable
Dirty Fuel	Wood, Charcoal, and Others*	
Sex of Household Head	Gender of household head (1=male, 0=female)	Negative/positive
Age of household head	Age of household head in years (continuous)	Negative
Size of household	Number of household members (continuous)	Negative/positive
Educational level of household head	Years of formal schooling (Dummy variable)	Positive
Wealth status of household	Poorest, Poorer, Middle, Richer &Richest (Dummy variable)	Positive
Marital status of household head	Currently married, not currently married (Dummy variable)	Negative/positive
Residence of household	Residence where household stay (0=urban, 1=rural)	Negative/positive
Western	(Yes=1, No=0)	Negative/positive
Central	(Yes=1, No=0)	Negative/positive
Greater Accra	(Yes=1, No=0)	Negative/positive
Volta	(Yes=1, No=0)	Negative/positive
Eastern	(Yes=1, No=0)	Negative/positive
Ashanti	(Yes=1, No=0)	Negative/positive
Northern	(Yes=1, No=0)	Negative/positive
Upper West	(Yes=1, No=0)	Negative/positive
Upper East	(Yes=1, No=0)	Negative/positive

Note: Others* refer to, animal dung, grass, and sticks

Source: The Authors.

Table 2: Descriptive Statistics and Distribution of Variables

Variable	Measurement	Response	%	Obs.
Energy type for cooking	Category of fuel consumed	Clean fuel	21.18	2,406
		Dirty fuel	78.82	8,956
Energy type for lighting	Category of fuel consumed	Clean fuel	71.26	8,097
		Dirty fuel	28.74	3,265
Sex of household head	Male	Male	66.56	7,562
	Female	Female	33.44	3,800
Residence	Residence nature of household	Rural	50.44	5,731
		Urban	49.56	5,631
Wealth status	Wealth status of household	Poorest	21.88	2,486
		Poorer	20.61	2,342
		Middle	21.48	2,441
		Richer	18.78	2,134
		Richest	17.24	1,959
Marital status of household head	Currently married	CM.	64.69	7,350
	Not currently married	Not CM.	35.31	4,012
Educational	Educational level of household head	No education	28.88	3,281
		Primary	14.03	1,594
		Secondary	46.77	5,314
		Higher	10.32	1,173
Region	Region of residence of household	Western	10.94	1,243
		Central	10.49	1,192
		Greater Accra	11.20	1,273
		Volta	9.57	1,087
		Eastern	11.26	1,279
		Ashanti	10.60	1,204
		Brong-Ahafo	11.08	1,259
		Northern	8.59	976
		Upper East	8.63	980
		Upper West	7.65	869

Note: C.M.=currently married; Obs=observation

Source: Authors' computation using GDHS data with STATA 13

Table 3: Wealth status/Residence and clean/dirty fuel consumption

Wealth status / Residence	Fuel for Cooking Clean (%)	Dirty (%)	Fuel for Lighting Clean (%)	Dirty (%)	Total
Poorest	0.48	99.52	23.01	76.99	2,486
Poorer	1.07	98.93	57.17	42.83	2,342
Middle	7.41	92.59	87.46	12.54	2,441
Richer	30.22	69.78	98.22	1.78	2,134
Richest	78.76	21.24	99.80	0.20	1,959
Rural	6.81	93.19	53.90	46.10	5,731
Urban	35.80	64.20	88.94	11.06	5,631

Source: Authors' computation using GDHS data with STATA 13

Table 4: Marginal effects at representative values of logit and probit of clean versus dirty fuel

Variable		Logit		Probit	
		Cooking	**Lighting**	**Cooking**	**Lighting**
Sex of household head (Male)		-0.019***	-0.003	-0.02***	-0.003
		(0.007)	(0.01)	(0.007)	(0.01)
Age of Household head		-0.002***	0.001***	-0.002***	0.001***
		(0.003)	(0.004)	(0.003)	(0.004)
Educational level of household head (Secondary)		0.0496***	0.025***	0.048***	0.025***
		(0.005)	(0.004)	(0.005)	(0.004)
Residence (Rural)		-0.06***	-0.0034	-0.055***	-0.0003
		(0.01)	(0.01)	(0.008)	(0.01)
Size of household		-0.018***	0.01***	-0.017***	0.005***
		(0.002)	(0.001)	(0.002)	(0.001)
Marital status of household head (not currently married)		-0.002	-0.019**	-0.002	-0.016*
		(0.01)	(0.01)	(0.007)	(0.01)
Wealth Status of Household					
Poorest (Base category)					
Poorer		0.010*	0.387***	0.01**	0.388***
		(0.004)	(0.015)	(0.005)	(0.015)
Middle		0.083***	0.683***	0.083***	0.683***
		(0.01)	(0.014)	(0.01)	(0.014)
Richer		0.348***	0.785***	0.333***	0.783***
		(0.023)	(0.015)	(0.021)	(0.015)
Richest		0.797***	0.80***	0.786***	0.798***
		(0.02)	(0.015)	(0.02)	(0.015)
Regional Difference					
Western (Base category)					
Central		-0.012	0.002	-0.011	-0.002
		(0.011)	(0.014)	(0.011)	(0.014)
Greater Accra		0.022**	-0.06***	0.023**	-0.057***
		(0.011)	(0.02)	(0.011)	(0.018)
Volta		0.033***	-0.004	0.031**	-0.006
		(0.012)	(0.014)	(0.013)	(0.014)
Eastern		-0.038***	-0.033**	-0.041***	-0.036***
		(0.011)	(0.014)	(0.011)	(0.014)
Ashanti		-0.019*	-0.028*	-0.02*	-0.032**
		(0.011)	(0.016)	(0.011)	(0.014)
Brong_Ahafo		-0.012	-0.049***	-0.016	-0.050***
		(0.013)	(0.014)	(0.013)	(0.014)
Northern		-0.082***	0.065***	-0.077***	0.063***
		(0.017)	(0.014)	(0.017)	(0.014)
Upper East		0.089***	-0.009	0.087***	-0.0123
		(0.018)	(0.015)	(0.018)	(0.015)
Upper West		-0.042**	0.088***	-0.041**	0.085***
		(0.02)	(0.14)	(0.016)	(0.014)
Predicted Probabilities	Min.	0.05	0.05	0.008	0.008
	Max.	0.97	0.98	0.98	0.982
Pseudo R^2		0.523	0.419	0.520	0.419
Prob>Chi^2		0.0000	0.0000	0.0000	0.0000
Log Likelihood		-2805.446	-3958.832	-2813.634	-3959.801
Observations		11,362	11,362	11,362	11,362

Note: standard errors are within brackets; ***; ** and * denote significant at 1%, 5%, 10%, respectively

Source: Authors' Computation using GDHS dataset with STATA 13