Factors Determining Choice of Clean Domestic Energy by Households: Evidence from Nakuru Municipality, Kenya

Philemon K. Langat[1*] Lawrence K. Kibet[2] Prof. Gideon A. Obare[3]
1. Consultant, UN Habitat, Nairobi and Researcher, Department of Agricultural Economics and Business Management, Egerton University, P.O. Box 536-20115, Egerton, Kenya
2. Senior Lecturer, Department of Economics, Egerton University, Kenya
3. Professor of Agricultural Economics Department of Agricultural Economics and Business Management Faculty of Agriculture, Egerton University, Kenya

Abstract
As in most developing countries, many attempts have been made and are continuously made to in Kenya to reduce dependence of forests as a source of energy through introduction of bans on logging and campaigns to households to shift to cleaner energy sources. Attempts through rural electrification program as envisaged in the energy policy of Kenya have been geared towards expanding clean energy access to previously unconnected sections of the population. Yet the majority households in urban areas as exemplified by Nakuru municipality residents of Kenya continue to depend on semi-clean fuels as primary source of energy. Using survey data from 300 randomly selected households in Nakuru Municipality, we sought to empirically determine the factors that influence household choice of clean domestic energy. A Multinomial logit model results showed that household's choice between clean and semi-clean fuels was influenced by Socio-economic and demographic factors, and government energy policies. In particular, the likelihood of clean fuels was significantly higher in households with higher relative incomes while the likelihood of use of "dirty" and semi – clean fuels was higher with middle and low income households. Based on the study results we draw policy implications.
Keywords: Energy, Choice and Domestic Fuels, Multinomial Logit, Kenya, Nakuru Municipality

1. Introduction

It is estimated that approximately 2.5 billion people in developing countries rely on biomass fuels to meet their cooking needs, and that for many of these countries, more than 90 percent of total household fuel is biomass (ESMAP, 2003). Moreover, in the absence new policies, the number of people that rely on biomass fuels is expected to increase to 2.6 billion by 2015, and 2.7 billion by 2030 due to population growth (IEA, 2006). It is recognized that access to modern energy services including electricity, geothermal, LPG, solar, wind and biogas are important for achieving the Millennium Development Goals (MDGs).

Furthermore, it has been shown that household's consumption levels of biomass fuels compared to clean fuels (i.e. electricity and LPG) is considerably higher in Sub-Sahara Africa in comparison to other regions in the world (Cifor, 2003).For example, Kiplagat *et al.,* (2011) found that biomass is the main source of energy for both rural and urban households in Kenya. Additionally, Ngui *et al.,* (2011) also found that the fuel consumed is largely influenced by its price and income of the household in Kenya. This scenario is replicated in other developing countries in sub-Sahara countries that depict households as largely dependent much on biomass fuels with associated negative impacts on their health and the environment (Akpalu *et al.,* 2011). Obviously, there must be critical drivers to this state of affairs in spite of the consequential outcomes. For instance, in Malawi the distance to fuel source was the main driver of intensified firewood fuels by the households (Jumbe and Angelsen, 2011). However, in Bangladesh, households choice of fuel use was influenced by Socio-economic factors such income and education and in particular, in poorer households, biomass fuel was the option available to them (Miah *et al.,* 2010).

In Kenya firewood fuel has remained the most important source of energy and meets over 70 per cent of the country's total energy consumption needs (Kituyi, 2002; Ministry of Energy, 2004). Yet, it is evident that the use of clean fuels reduces outdoor air pollution, forest degradation (ESMAP, 2000; Heltberg, 2005). The dependence on biomass fuels by households in urban and rural areas increase risk acute respiratory infections through indoor pollution (Ezzati and Kammen, 2002; Bhattacharya and Abdul Salam, 2002; Kilabuko *et al.,* 2007; Miah et *al.,* 2009) as a result of smoke from firewood.

Kenya together with development partners have embarked on comprehensive programmes to improve generation and access of energy to households Ministry of Energy (2004). For example, in Kenya funding on renewable sources of energy, including electricity, solar, wind, biogas and geothermal energies was increased so as to encourage households to switch to cleaner sources of energy (Gok, 2006) to address the acute energy deficits in the country.

Yet, it is still unclear whether the urban and peri-urban households, as exemplified by those in Nakuru municipality, have been able to shift from the un-clean sources of fuel, considering the level of investments towards that cause. Our objective in this study was to determine the effect of socio-economic and demographic factors on choice of clean and semi – clean fuels by households' in Nakuru Municipality. Such a study is especially justified considering that the use of un-clean fuels has real and potential negative effect on agriculture through loss of loss forest covers, loss of bio-diversity, ecosystem disturbance and global warming.

The rest of the paper is organized as follows: in the next section we provide a theoretical framework upon which the study is underpinned; in section 3 we highlight the methodology and analytical procedures used, while in section 4, we present the results and discuss them. Finally, we conclude and draw implications.

2. Theoretical Framework

Assuming that a consumer is first faced with consumption bundles *q* in set *Q*. In the bundle *Q* the consumer is assumed to have preferences of the consumption bundles, meaning that the consumer can rank the bundles. Furthermore if the consumer is able to order bundles *q* in *Q* according to preference axioms of consumer theory then a continuous utility representing preference exist. Given these assumptions and axioms, a household, to which the consumer belongs attempts to maximize utility $u_1(q) = u(q_1, \dots, q_n)$ from the consumption of commodities $q_1, \dots, q_n$ that satisfy the budget constraint and also generate more utility, $u_2(q_1, \dots, q_m)$ $(m > n)$ than from bundle $q_1, \dots, q_n$ within the consumption possibilities available to the consumer. The household budget x limits the expenditure of the household and given prices $p_1, \dots, p_n$ of the commodities, the household is faced with the problem:

Max $u(q)$ subject to $\sum_{i=1}^{n} p_i q_i = x$

A household's choice of domestic energy can be understood by analysing its decision in a constrained utility maximization framework subject to a set of economic and non-economic constraints (Browning and Zupan, 2003; Amacher *et al.,* 1999). Economic factors include market price of fuel, and household money income. Non-economic factors include a set of household demographic and infrastructure factors as mentioned above.

$$U = U[(Q_W, P_\alpha, I, \varphi) Q_W((Q_W, P_\alpha, I, \varphi)] \qquad (1)$$

where; $U^*(P_W, P_\alpha, I, \varphi)$ is the maximum attainable utility; Q_W, is the units of firewood purchased P_W, is the per unit price of firewood; P_α, is the unit price of firewood alternatives I, is the household income; φ, is the set of social factors; Q_α, indicates the units of firewood alternatives purchased.In the above equation one household's choice of domestic energy is affected by a set of social factors φ. We considered social factors such as: gender, average age of household members, the level of education, occupation status, and household size. Ownership of the dwelling unit and welfare status were also considered.

3. Materials and Methods

Nakuru Municipality that is the study area is located in Nakuru County, 160 km northwest of Nairobi, Kenya. The total area of the municipality is about 300 km^2, some 60% of which is covered by the world-famous Lake Nakuru National Park. Between 1969 and 1999, the population of Nakuru increased five times from 47,000 to 239,000 and 307,990 in 2009 (KNBS, 2009). Over the period 1994 to 1997, the prevalence of absolute poverty in the town increased from 30% to 41% (KNBS, 2009).

The population in this study was the urban households in Nakuru municipality estates. The study used cross-sectional data to analyse the household choice and access to clean domestic energy. Stratified sampling was used to stratify estates in the municipality and purposively select five of them and finally simple random sampling was used to obtain 300 households.

The sample for the study was representative of the estates namely: Baruti (Barut east and Barut west estates); Kaptembwa, Rhonda and Posta estates, and Lanet (Section 58 and Naka estates).The estates are inhabited by residents of different socio-economic, demographic and geographical characteristics. As regards the choice of different energy sources, the study required the respondents to indicate the main fuel type that the household uses.

To determine the factors influencing choice of clean domestic energy by households, we adopted a multinomial logit model. The model allows for the identification of the likelihood of household choices in presence of random / stochastic utility. We elicited responses from households on choices between 5 alternatives of domestic energy sources including: firewood fuel, charcoal, kerosene, LPG and electricity. The choices were coded with five different levels of satisfaction for each individual household and one was to postulate the rational choices represented by a utility function. The study considered a case where the level of utility is stochastic and is described by a function $U(\cdot)$depending on a random term. For each alternative $(j = 1 \dots 5)$ the utility of individual i is expressed in the following form:

$$U_{ij} = U(X_{ij}, \varepsilon_{ij}) = V(X_{ij}) + \varepsilon_{ij} \qquad (3)$$

where is $V(.)$ a deterministic continuous function and where ε_{ij} is a random variable. The random disturbance ε_{ij} is independent and identically distributed McFadden (1974). A categorical variable is assumed to take 5 alternatives according to the choices of individual i, $i = Y_j = j$ if individual i chooses the j^{th} alternative fuel $(j = 1, \dots, 5)$ consequently, the probability that individual i choose the alternative j fuel corresponds to the probability that this alternative confers to him/her higher utility than all the other fuel alternatives that are offered to him. It can be shown that the probability that individual i choose the alternative j, is defined by:

$$Prob(Y_i = j) = \frac{\exp[v(x_i, j)]}{\sum_{i=0}^{j} \exp[v(x_i, j)]} \quad (4)$$

where: $Prob(Y_i = j)$, is the probability of choosing charcoal, kerosene, gas or electricity with firewood as the reference cooking fuel category; j is the number of fuels in the choice set; $j = 0$ is fire wood. x_i, is a vector of explanatory social factors conditioning the choice of the jth alternative fuel.

In the function $v(X_{ij})$ several models can be considered. The multinomial Logit is obtained when function $v(\,)$ is a linear function and whose parameters β_j differ according to the alternatives of the explanatory variables to the individuals.

$$\text{Let } V(X_{ij}) = x_i \beta_j \quad (5)$$

where β_j= a vector of the estimated parameters.

We can further define the probability that individual i choose alternative j in the following way:

$$Prob(Y_i = j) = \frac{\exp(x_i, \beta_j)}{\sum_{i=0}^{j} \exp(x_i, \beta_j)} = \frac{\exp(x_i, \beta_j)}{1 + \sum_{i=0}^{j} \exp(x_i, \beta_j)} \quad (6)$$

where the vector β is normalized to zero, that is, $\beta_0 = 0$; then the probability associated to the reference category is defined as:

$$Prob(Y_i = 0) = \frac{1}{\sum_{i=0}^{j} \exp(x_i, \beta_j)} = \frac{1}{1 + \sum_{i=0}^{j} \exp(x_i, \beta_j)} \quad (7)$$

The parameters of the multinomial logit model were estimated by using the maximum likelihood method. Finally the estimates of the parameters of the multinomial logit model β_j were then be obtained by maximizing log-likelihood with respect to the parameter vector as follows;

$$\log L(Y, \beta_1, \beta_2, \dots \dots \dots, \beta_j) = \sum_{i=0}^{N} \sum_{j=0}^{J} Y_{ij} \, [Prob(Y_i = j)] \quad (8)$$

where $Y_{ij} = 1$ then $Y_i = 1$ and 0 otherwise, and where the probabilities $Prob(Y_i = j)$ are defined as specified in equations respectively. In the specification of the multinomial logit model two properties are important: The standardization assumption and the independence of irrelevant alternatives assumption (Judge *et al.,* 1985). Under the standardization assumption $\beta_0 = 0$ by convention and the probability of the reference category is as specified in equation eight.The independence of irrelevant alternatives assumption stipulates that the ratio of two probabilities associated to two alternatives j and k is independent to other alternatives (McFadden, 1974). The dependent variable is the cooking fuel choice with firewood as the reference category.

A positive estimated coefficient implied an increase in the likelihood that a household will choose the alternative fuel, while a negative coefficient indicates that there is less likelihood that the household will change to an alternative fuel. Marginal effects measured the estimated change in the Logit for a one-unit change in the explanatory variable while the other predictor variables are held constant.

We use the following empirical model to estimate the parameters of the theoretical with dependent variable given in Table 1.

$$Y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + \beta_8 x_8 + \beta_9 x_9 + \varepsilon_i \quad (9)$$

Table 1: Description and measurement of variables to be used in the model above

		Description	Expected sign
	Dependent variable (Y_i)	1 = Electrified ; 0 = otherwise	+/-
(X_i)	Independent variables		
X_1	Age of household head	Continuous years number	-
X_2	Gender of household head	1= Male; 0 = otherwise	+/-
X_3	Household size	Continuous	-
X_4	Education levels	Categorical	+
X_5	Employment status	Categorical	+/-
X_6	Dwelling status	1 = Own; 0 = Otherwise	+/-
X_7	Total household income	Continuous	+/-
X_8	Total energy expenditure	Continuous	+/-
X_9	Distance	Continuous	+/-

Source; own conceptualization

3. Results and Discussions

Multinomial Logit was used to analyze the choice of clean domestic fuels by the households and the results of electricity, charcoal and kerosene as compared to firewood are presented in Table 2. Electricity, LPG were clean fuels while charcoal, kerosene were semi-clean fuels and firewood a dirty fuel. Households' size was expected to have negative influence on fuel choice away from firewood. However the results were negative and statistically significant, this showed that with an increase in the family size households will less likely shift away from firewood use. The results were consistent with (Barnes *et al.,* 2005) who found that that household size indirectly influence energy use by changing income and resource availability hence encourage fuel stacking.

According to Peng *et al.,* (2008) found that affordability; availability, accessibility and reliability of energy supplies are found to influence household fuel choice. This was justified as households that indicated electricity as main source of fuel were influenced by household size and distance of family house to the power lines. Households with fewer members tended to use more electricity than households with more members. Additionally households located far from the electricity grid were less likely to be connected to electricity (ESMAP, 2003).

Table 2: Multinomial logit results for households' choice of main domestic fuel

Variables	Electricity	LPG	Charcoal	Kerosene
Gender	-1.0365	-1.7614**	-0.7420	-0.3684
	(0.6643)	(0.8319)	(0.6234)	(0.8189)
Age	0.03610	-0.0456	-0.0473**	-0.0104
	(0.0233)	(0.04114)	(0.0232)	(0.0301)
Education	0.9675*	2.4708***	0.1868	-0.0240
	(0.3726)	(0.7128)	(0.3404)	(0.4537)
Household size	-0.5554***	0.1298	-0.2442*	-0.8817***
	(0.1631)	(0.2016)	(0.1480)	(0.2426)
Employment	-0.2665	-1.1124*	-0.5248	-0.4535
	(0.4509)	(0.6048)	(0.4197)	(0.5585)
Distance	-1.9187***	-0.6632	-1.922***	-1.6856**
	(0.5458)	(0.5481)	(0.4626)	(0.8139)
Constant	1.4764	-3.9931	6.9139***	5.5697**
	(2.0206)	(3.2864)	(1.8911)	(2.4490)

*, ** and *** represent significance at 10*, 5% and 1%, respectively. Figures in parentheses are standard errors and Firewood fuel was the reference category.

Households that used LPG as main source of fuel were influenced by gender and level of education of the household head at 5 percent level significance. Male headed households shown that majority of them used LPG as the main source fuel. This was contrary to the findings of Pachauri (2004) who found that gender 'female' heads determined the fuel used in the house. This was attributed to male household head shyness to cook using firewood and charcoal. They perceived that firewood and charcoal are dirty fuels. Household's heads with higher levels of education used more LPG than households with lower levels of education. This means that higher education will influence households to use the fuel because of the efficiency of LPG.

Choice of charcoal fuel was influenced by age, distance and others factors outside the model. Age was expected to be a significant factor in determining household fuel choice. In that an increase in the age of the household the less likely chance of the household abandoning firewood. The results showed that age had negative statistically significant coefficients which satisfied theoretical expectation. The older the household head meant that the choice of charcoal was feasible. The high availability and price of charcoal fuel also influence the high usage of the fuel. However there were other factors that influenced the household's choice of charcoal fuel, this included cheaper cooking jikos (stoves) and easy to use among un-educated households.

Narasimha Rao and Reddy (2007) found that if household size is larger than poorer households cannot afford modern fuels because their incomes are lower. This was consistent with results in this study that showed that kerosene fuel use was influenced by household size, distance, distance to the market and other factors outside the model. Higher household sizes had a negative influence on further choice of kerosene fuel. The further the distance to the market, influenced the choice of kerosene fuel negatively. Households that were located further away from the market demonstrated less choice of kerosene fuel.

The multinomial logit risk ratios are presented in table 3; they indicate the relative probabilities of an individual choosing a single fuel. The probabilities give an ease way determining choice of any one household fuel choice. Gender and age of the households' heads had statistically significant results for LPG and charcoal fuels respectively. As households' age increases the less likely will be choice of charcoal fuel by the households. Education of the household head was significant at 10% and 1% respectively. Household heads with more years of schooling the more likely the choice will be electricity and LPG.

Households' size was expected to have negative influence on firewood alternatives. The results showed that with increase in the size of family, the less likely firewood alternatives to be chosen. Distance from the market was statistically significant and the risk ratios shown that the choice of firewood alternatives was less likely among charcoal and kerosene users.

Table 3: Multinomial risk ratio results for households' choice of domestic fuel

Variables	Electricity	LPG	Charcoal	Kerosene
Gender	0.3547	0.1718**	0.4761	0.6918
	(0.2356)	(0.1429)	(0.2968)	(0.5665)
Age	1.0368	0.9554	0.9538**	0.9896
	(0.0241)	(0.0395)	(0.0221)	(0.0297)
Education	2.6313***	11.8318***	1.2054	0.9762
	(0.9803)	(8.4336)	(0.4100)	(0.4429)
Household size	0.5738***	1.1386	0.7833*	0.4141***
	(0.0935)	(0.2295)	(0.1159)	(0.1005)
Employment	0.7660	0.3288*	0.5917	0.6353
	(0.3454)	(0.199)	(0.2483)	(0.3549)
Distance	0.1468***	0.5152	0.1463***	0.1853**
	(0.0801)	(0.2824)	(0.0677)	(0.1508)

*, ** and *** represent significance at 10*, 5% and 1%, respectively. Figures in parentheses are standard errors and Firewood fuel was the reference category.

6. Conclusion and Implications

This study has established that households in the study area prefer charcoal because of its cost, low smoke emission, easily available and easy to use. The main challenge affecting the full adoption of charcoal by households are the policies currently in place banning its commercial exploitation and this should be addressed.

The use of LPG is low but households indicated it as more preferred except for the cost among the households who indicated they do not use the fuel. Though preferred for its efficiency and maintenance of environmental quality, the main impediment for its slow adoption is cost of acquisition of gas cylinders.

Electricity had a good coverage among the households sampled mainly due the government's rural electrification programme and "stima" credit facility by the Kenya power and lighting company. Majority of the households utilized electricity for lighting and operation of electronic gadgets while others used it additionally for cooking, boiling and heating. The major challenge encountered by the households in using electricity was the persistent power black outs, power surges and its safety due to associated fires and deaths.

From the study it is evident that there is need to design policy framework and advocacy programme that will reduce the cost of electricity to the urban poor. This implies that support in research and development aimed developing cheaper and safer sources of energy will provide insights into ways and means of addressing the energy cost challenges. For example the development of efficient charcoal stoves and sustainable charcoal production to meet the growing needs of the urban poor will contribute to efficient and innovative energy serving. The government should also consider subsidizing the acquisition costs of gas cylinders as this will encourage the households to shift to cleaner fuel. The chain of distribution of LPG fuel should be improved and middle men removed so that the cost does record high price variations. Market distance should also be reduced by encouraging trade on the clean fuels.

Kerosene a largely predominant fuel for the middle class and low income households should be given more tax reductions so as to reduce the per unit cost of the fuel in turn enable many households to afford it. This will greatly influence the households to shift from wood fuel.

Moreover, there is need for continuous investment in infrastructural development within the energy sector so as to make the cost of electricity cheaper compared to the other fuels. This is consistent with the renewed interest in the development of renewable energies should be greatly supported as this will improve the energy situation of Kenya.

References

Akpalu, W., Dasmani, I., & Aglobitse, P. B. (2011). Demand for cooking fuels in a developing country: To what extent do taste and preferences matter?. Energy Policy, 39(10), 6525-6531.

Amacher, G. S., Hyde, W. F., & Kanel, K. R. (1999). Nepali fuelwood production and consumption: Regional and household distinctions, substitution and successful intervention. The Journal of Development Studies, 35(4), 138-163.

Barnes, D. F., Krutilla, K., & Hyde, W. F. (2005). The urban household energy transition: social and environmental impacts in the developing world. Rff Press.

Bhattacharya, S. C., & Abdul Salam, P. (2002). Low greenhouse gas biomass options for cooking in the developing countries. Biomass and Bioenergy, 22(4), 305-317.

Browning, Edgar K., and Mark A. Zupan. (2003). Microeconomics: Theory and Applications.8th ed. Hoboken, N.J, John Wiley & Sons.

Cifor - Center for international forestry (2003). Center for international forestry research, info brief No. 6, 2003 Bogor.

ESMAP - Energy Sector Management Assistance Programme (2000) Photovoltaic applications in rural areas of the developing world. ESMAP Technical Paper 009, Washington, DC: World Bank.

– 2003). Household Energy Use in Developing countries. A Multicounty study. Joint UNDP/World Bank Energy Sector Management Assistance Programme, Washington, DC.

Ezzati, M., & Kammen, D. M. (2002). Evaluating the health benefits of transitions in household energy technologies in Kenya. Energy Policy, 30(10), 815-826.

GoK - Government of Kenya (2006) Economic survey 2006, Government of Kenya, Nairobi.

Heltberg, R. (2004). Fuel switching: evidence from eight developing countries. Energy Economics, 26(5), 869-887.

- (2005). Factors determining household fuel choice in Guatemala. Environment and development economics, 10(3), 337-361.

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

Judge G.G, Hill R.C, Griffiths W.E, Lűtkepohl H and Lee T.C (1985). Theory and practice of econometrics. John Wiley and Sons, New York.

Jumbe, C. B., & Angelsen, A. (2011). Modeling choice of fuelwood source among rural households in Malawi: A multinomial probit analysis. Energy Economics, 33(5), 732-738.

Kenya National Bureau of Statistics (KNBS), (2000). Household energy consumption

Kenya National Bureau of Statistics (KNBS), (2009). Kenya population and housing census.

Kilabuko, J. H., Matsuki, H., & Nakai, S. (2007). Air quality and acute respiratory illness in biomass fuel using homes in Bagamoyo, Tanzania. International journal of environmental research and public health, 4(1), 39-44.

Kiplagat, J. K., Wang, R. Z., & Li, T. X. (2011). Renewable energy in Kenya: Resource potential and status of exploitation. Renewable and Sustainable Energy Reviews, 15(6), 2960-2973.

Kituyi E (2002). Lost opportunities: Wood fuel data and policy development concerns in Kenya. Energy Policy Opinion Paper, WSSD Edition, Nairobi: African Centre for Technology Studies.

Kothari, C. R. (2004). Research methodology: methods and techniques. New Age International.

McFadden D (1974). Conditional logit analysis of qualitative choice behavior. In Zarembka P (ed). Economic Theory and Mathematical Economics. Academic Press, New York. Page 105-142.

Miah, M. D., Al Rashid, H., & Shin, M. Y. (2009). Wood fuel use in the traditional cooking stoves in the rural floodplain areas of Bangladesh: a socio-environmental perspective. Biomass and Bioenergy, 33(1), 70-78.

Miah, M. D., Kabir, R. R. M. S., Koike, M., Akther, S., & Yong Shin, M. (2010). Rural household energy consumption pattern in the disregarded villages of Bangladesh. Energy Policy, 38(2), 997-1003.

MoE - Ministry of Energy (2004). The Energy Bill, 2004. Nairobi: Ministry of Energy, GoK.

Narasimha Rao, M., & Reddy, B. S. (2007). Variations in energy use by Indian households: An analysis of micro level data. Energy, 32(2), 143-153.

Ngui, D., Mutua, J., Osiolo, H., & Aligula, E. (2011). Household energy demand in Kenya: An application of the linear approximate almost ideal demand system (LA-AIDS). Energy Policy, 39(11), 7084-7094.

Pachauri, S., Mueller, A., Kemmler, A., & Spreng, D. (2004). On measuring energy poverty in Indian households. World Development, 32(12), 2083-2104.

Peng, W., Hisham, Z., & Pan, J. (2010). Household level fuel switching in rural Hubei. Energy for Sustainable Development, 14(3), 238-244.