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Factors Affecting the Number of Household Energy Sources in Kenya: Generalized Linear Model

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Abstract: **This paper applies Generalized Linear Approach to model the factors affecting number of household energy sources for lighting and cooking in both peri urban and rural Kenyan households. The model uses data from 560 households to predict the number of household energy sources for lighting and cooking. Generalized linear model (GLM) on the factors affecting household's number of used energy sources showed income as the principal determinant factor for both cooking and lighting. In addition, distance to the nearest firewood supplying shop and household sizes are the main influencing factors for cooking among rural dwellers while distance to the nearest LPG supplying shop and distance to the nearest charcoal supplying shops were also found to be the determinants among the peri urban dwellers. The results for lighting on the other hand indicate that household's number of energy sources for lighting is sensitive to solar use, age and gender of the household head. Households' number of energy sources is mainly controlled by income. Policy makers require enough information on modeling of household energy use to come up with strategies for sustainable development.**

Keywords: **Household energy, Generalized Linear model, lighting, Cooking, rural, Peri urban, Kenya.**

I. INTRODUCTION

Access to adequate, clean and affordable household energy sources is essential for social economic development of any nation especially developing countries. Global statistics show that about 2.7 billion people consume solid biomass for cooking [1]. Continued dependence on conventional energy sources by households will have a serious impact on human health from indoor air pollution [2] [3] [4]. It will likewise affect the environment by forest degradation and enhanced carbon emissions in the atmosphere resulting from wood-fuel consumption [5] and that is why worldwide energy policies are increasingly focused on sustainable and renewable energy (RE) development.

The East African region is reported to be one of the fastest growing areas in Africa but remains highly dependent on non-clean energy sources (about 80 percent) [6] [7]. The above trends clearly show the extent to which clean energy potential benefits and opportunities are lost, particularly among the population. Biomass has been reported as the dominant source of energy in Kenya for decades, accounting for about 68% of the energy used [8]. Close to 75% of the population of Kenya relies on biomass sources to meet their cooking, heating and lighting requirements [9]. For these reasons the Kenyan government has embarked on a vigorous electrification programme to connect every household by the year 2022 expanding current connection which stands at 70%.The government is also encouraging a shift to other modern fuels such as LPG and renewable energy (solar and biogas) especially in areas far from the national grid where electrification is not practical [10].

Household energy consumption accounts for 18% of total energy end-use worldwide beside industrial sector 51% and commercial sector 20% [11]. Household energy changing behaviour has been considered by numerous researchers and is now recognized as a vital tragedy for human society owing to its growing prevalence. Most studies have researched into the household energy utilization patterns and factors affecting the fuel choices using correlations [12] [13] [14] [15] [16]

[17] [18] [19] [20]. Despite the importance of renewable energy technologies in the daily lives of people, very few empirical studies of renewable energy consumption exist [21]. Furthermore, no attempts have been made to quantify the association between renewable energy consumption and other factors that influence the number of energy sources used in household. Also, little [22] [23] or no attention has been paid to model the complex interrelationships that exist among the various variables involved, especially for the effect of number of household energy sources.

Relations between variables affecting household number of energy use are often more complex than simple bivariate relations between a predictor and a criterion.Analyzing household number of energy sources using GLM may be useful, as it describes simultaneous examination of the effects which are significant and allows for the investigation of more complex research [23]. GLM is used to test the association of an outcome with a predictor or to quantify the degree of association for given values of the predictors. The GLM suggested illustrates the overall impacts of explanatory variables that lead to predicting the outcome (number of household energy sources utilized). Therefore, it is a single model capable of helping researchers to better understand the relations and provide an overall evaluation of the constructs by utilizing a combination of characteristics.

A better understanding of the different factors that affect the number of household energy sources will help to design interventions by both governmental and nongovernmental organizations working on energy and energy related issues.The study will also contributes to the limited but growing empirical evidence of household energy factors affecting the number of household energy sources.

II. METHODOLOGY

Data on energy consumption behavior was collected by means of a household survey conducted in 2017 and 2018, using semi-structured questionnaires. Also, focus group discussions with local communities in both counties were conducted to provide additional information on household energy consumption. More specifically, the surveys included the collection of data on household sizes, number of energy sources used, gender of household head, average income, main livelihood, type and number of energy sources used, level of household satisfaction with energy sources, renewable energy use and accessibility (distance to nearest fuel collection point and number of energy sources supplying selling shops in the village).

A generalized linear model was used to assess which factors have a significant effect on the number household of energy sources used by households at the study sites. In modeling, households are assumed to be rational in their behavior when making household energy-choice decisions on the number of household's energy sources to be used for cooking or lighting. The assumption is that a household selects a certain number of household energy sources in such a way as to maximize its satisfaction [25] and enhance energy security.Where a household makes a choice j at a time, then Y_{ij} is the maximum utilized number of the fuel sources. The estimated GLM is as follows:

$$P(Y_{ij}) = \alpha_o + \beta_1 GND_i + \beta_2 AGE_{ii} + \beta_3 HHS_i + \beta_4 INC_i + \beta_5 LOC_i + \beta_6 RED_i + \beta_7 ACC_i + \beta_8 REN_i + \beta_9 DIS_i + \beta_{10} NOS_i + \beta_{11} LOS_i + e \quad (2)$$

Where; P (Yi_j) = the probability of choosing one of the number of household energy instead of the based category variable; i = the individual household; α = intercept, β = weights of the factor, GND_i = gender of the head of household i; AGE_i = age of the head of household i; HHS_i = size of the household i; INC_i = Average income of the of household i; LOC_i = home location of the household i; RED_i = Residential status; ACC_i = distance to the nearest energy source supplying shops; REN_i = Renewable energy use; DIS_i = Distance of the household i to energy source; NOS_i = Number of suppliers in the village i; LOS_i = level of satisfaction; X_i = other factors; e = error term.

Generalized linear modelsare nonlinear regressionand used to test the association of an outcome with a predictor, to quantify the degree of association, or to estimate the mean value of the outcome for given values of the predictors.

III. RESULTS AND DISCUSSIONS

Characteristics of households in the survey

Table 1(**see appendix 1**) presents the results show household characteristics between rural households and between peri-urban in both counties. The regions were merged into two; peri-urban and rural household from both counties.

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Number of different energy sources

Table 1 presents the Number of different energy sources used for cooking and lighting. The study participants of both Peri- urban and rural under study had on average three number of household energy for cooking with low deviations from the mean. On the other hand, residences have two different energy sources for lighting on average.

TABLE I: NUMBER OF DIFFERENT ENERGY SOURCES

	Number of different energy sources used for	
Parameters	***Cooking***	***Lighting***
Peri-urban / rural	***Mean (SD)***	***Mean (SD)***
Peri-urban	2.77 (0.85)	1.93 (0.78)
Rural	2.79 (0.99)	2.44 (0.86)

The results shows high diversification for energy sources for cooking than for lighting.

Model for cooking

Estimated models for rural and peri urban areas were generated using generalized linear model for the number of household (HH) energy sources for cooking. The overall model was significant when the omnibus test was applied for both peri urban and rural households (p – values were both 0.000 < 0.01).The equation for rural is as follows:

$$y = 63.337 + 34.55HHs + 239.22\ INC + 27.4\ AGE + 57.49\ DFW + 29.47NCS + 24.58\ NLS + 52.58\ DLPG + 4.7\ SLPG + 12.988DISL + 10.559DISF + e \quad (2)$$

The equation for peri – urban is as follows

$$y = 62.02 + 55.67HHs + 254.9\ INC + 20.19\ AGE + 66.73\ DFW + 81.01\ DCS + 33.52NFS + 18.86 + 24.58\ NLS + 84.03\ DLPG + 20.15DISF + e \quad (3)$$

Where ; y = the number of household energy sources, HHs = Household size, INC = Average income earned per day in KSH, AGE = Age of HH head, DFW = Distance to nearest firewood supplying shop in km, NCS = Number of charcoal supplying shops in village, NFS = Number of fuel wood supplying shops in village, NLS = Number of LPG supplying shops in village where respondent lives, , DCS = Distance to nearest charcoal supplying shop in km, DLPG = Distance to nearest LPG supplying shop in km, SLPG = Satisfaction with use of LPG, DISL = Dissatisfaction with use of LPG and DISF = Dissatisfaction with use of fire wood, e = random error term.

Generalized linear model showed the number of household energy is positively related to income level, household size, age of HH head, distance to nearest fuel supplying shop in km especially for charcoal and firewood, number of supplying shops in village for LPG, charcoal and fire wood and level of satisfaction of fire wood in both rural and peri urban areas. On the other hand, level of satisfaction on firewood and LPG is positively associated with the increased use of charcoal and also positively and significantly related with the increase in the household fuel portfolio.

Model for lighting

Estimated models for rural and peri urban areas were generated using generalized linear model for the number of household (HH) energy sources for lighting. The overall model was significant when the omnibus test was applied for both peri urban and rural households (p – values were both 0.000 < 0.01).The equation for rural is as follows.

$$y = 71.2 + 127.3\ INC + 12.5\ AGE + 3.5\ GND + 43.4REN_S + e$$

The equation for peri – urban is;

$$y = 95.7 + 140\ INC + 5.1GND + 77.92REN_S + e$$

GLM results showed that the number of household energy is strongly influenced by income level. In addition, solar lamps use, age of HH head and gender of HH head are the main influencing factors for lighting among rural and peri urban dwellers while age of the household head was found not to affect number of household energy among the peri urban dwellers. The results also showed that the number of household energy used increase with increasing use solar which concurs with other reseraches [26][27].

Model Validation Tests

Model Validation Tests is the process of testing the soundness and accuracy of the model structure while instituting confidence in the helpfulness of the model [23]. Hence, this exercise proves the reliability of the model outputs and ascertains that the results accurately represent reality. To confirm the association among the study variables various tests; T–test, Spearman's, Pearson's correlations and paired sample correlations were performed. These results are presented in table 3.

TABLE II: FACTORS AFFECTING THE NUMBER OF ENERGY SOURCES USED BY RESPONDENTS

Variable	***Test***	***Null hypothesis***	***Relation to number of energy sources used***		***References for Null hypothesis***
			Result	***Evaluation***	
Gender	T-test	Women use a higher number of energy sources than men	0.064***	Confirmed	Martinez and Stephens, 2016
Household size	Pearson's R Spearman's	Number of HH energy sources reduce with increase in household size	-0.11** -0.092**	Confirmed (P< 0.05)	Link, Axinn and Ghimire, 2012
Income	T-test	Income increases the number of energy sources	10.501***	Confirmed (P< 0.01)	Niu, Jia, Ye and Li, 2016
Renewable energy	Pearson's correlations	RE use reduces the number of energy sources	-0.073*	Confirmed (P< 0.10)	Eurostat, 2018
Accessibility	Paired sample correlations	Increase in distance to nearest fire wood selling shops reduces number of energy sources	-0.144***	Confirmed (P< 0.01)	Rahut *et a.l*, 2016, 2017
Age	T-test	The older the household head the lower number of energy sources	-20.927***	Confirmed (P< 0.01)	Romanach *et al.* 2017

Source: Author's (2019)

Results shows that women use a higher number of energy sources than men and the number of HH energy sources reduce with increase in household size. Further the table provides evidence that income increases the number of energy sources and RE use reduces the number of energy sources especially for cooking. it also shows that increase in distance to nearest fire wood selling shops reduces number of energy sources and the older the household head the lower number of energy sources. These results provide robust verification of the GLM regression results.

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IV. CONCLUSION

The results of GLM show that the number of household energy sources for cooking and lighting is influenced strongly by income level. The uptake of renewable energy sources such as solar lamps also increase number of energy sources and hence increase energy security by reducing dependence on fossil fuels, charcoal and others which are vulnerable to price fluctuations. There is need for research on the influence of the level of education on household energy diversification. The findings from the study may be useful in household energy policy making in energy planning sector.

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REFERENCES

[1] Oseni, M. O. (2012). Improving households' access to electricity and energy consumption pattern in Nigeria: Renewable energy alternative. Renewable and Sustainable Energy Reviews, 16(6), 3967- 3974.

[2] Duflo, E., Greenstone, M., & Hanna, R. (2008). Indoor air pollution, health and economic well-being. SAPI EN. S. Surveys and Perspectives Integrating Environment and Society, (1.1).

[3] Fullerton, D. G., Bruce, N., & Gordon, S. B. (2008). Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. Transactions of the Royal Society of Tropical Medicine and Hygiene, 102(9), 843-851.

[4] Ezzati, M., & Kammen, D. M. (2001). Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure-response study. The Lancet, 358(9282), 619-624.

[5] Rahut, D. B., Ali, A., & Behera, B. (2017). Domestic use of dirty energy and its effects on human health: empirical evidence from Bhutan. International Journal of Sustainable Energy, 36(10), 983-993.

[6] Couture, S., Garcia, S., & Reynaud, A. (2012). Household energy choices and fuelwood consumption: An econometric approach using French data. Energy Economics, 34(6), 1972-1981.

[7] Kimutai, S. K., Muumbo, A. M., Siagi, Z. O., & Kiprop, A. K. (2014). A study on agricultural residues as a substitute to fire wood in Kenya: a Review on Major Crops.

[8] Mai-Moulin, T., Dardamanis, A., & Junginger, H. M. (2016). Assessment of Sustainable Lignocellulosic Biomass Potentials from Kenya for export to the European Union 2015 to 2030.

[9] Panel, A. P. (2015). Power people planet: seizing Africa's energy and climate opportunities: Africa progress report 2015.

[10] Ministry of Energy and Petroleum, Kenya, 2018. Last Mile Connection Project . energy.go.ke

[11] Mamita Dash (2013).An Economic Analysis of Household Energy Consumption of Urban Odisha ,International Journal of Science and Research, 4 (7), 2149-2156

[12] Louw, K., Conradie, B., Howells, M., & Dekenah, M. (2008). Determinants of electricity demand for newly electrified low-income African households. Energy policy, 36(8), 2812-2818.

[13] Ruiz-Mercado, I., & Masera, O. (2015). Patterns of stove use in the context of fuel–device stacking: rationale and implications. EcoHealth, 12(1), 42-56.

[14] Van der Kroon, B., Brouwer, R., & Van Beukering, P. J. (2013). The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. Renewable and Sustainable Energy Reviews, 20, 504-513.

[15] Smith, M. G., & Urpelainen, J. (2014). The effect of feed-in tariffs on renewable electricity generation: An instrumental variables approach. Environmental and resource economics, 57(3), 367-392.

[16] Mutua, J., & Kimuyu, P. (2015). Household energy conservation in Kenya: estimating the drivers and possible savings. Environment for Development Discussion Paper-Resources for the Future (RFF), (15-04).

[17] Musango, J. K. (2014). Household electricity access and consumption behaviour in an urban environment: The case of Gauteng in South Africa. Energy for Sustainable Development, 23, 305-316.

[18] Choumert, J., Motel, P. C., & Le roux, L. (2017). Energy Ladder or Energy Stacking: A Panel Data Analysis of Tanzanian Households' Energy Choices.

[19] Lusambo, L. P. (2016). Households. Income Poverty and Inequalities in Tanzania: Analysis of Empirical Evidence of Methodological Challenges'. J Ecosys Ecograph, 6, 183.

[20] Mbaka, C. K., Gikonyo, J., &Kisaka, O. M. (2019).Households' energy preference and consumption intensity in Kenya.Energy, Sustainability and Society, 9(1), 20.

[21] Omri, A., Mabrouk, N. B., & Sassi-Tmar, A. (2015). Modeling the causal linkages between nuclear energy, renewable energy and economic growth in developed and developing countries. Renewable and Sustainable Energy Reviews, 42, 1012-1022.

[22] Moallemi, E. A., &Malekpour, S. (2018). A participatory exploratory modelling approach for long-term planning in energy transitions.Energy research & social science, 35, 205-216.

[23] Motawa, I., & Oladokun, M. (2015). A model for the complexity of household energy consumption. Energy and Buildings, 87, 313-323.

[24] Faraway, J. J. (2010). Generalized linear models. In International Encyclopedia of Education (pp. 178-183). Elsevier.

[25] Soytas, U., & Sari, R. (2009). Energy consumption, economic growth, and carbon emissions: challenges faced by an EU candidate member. Ecological economics, 68(6), 1667-1675.

[26] Ma, C., Rogers, A. A., Kragt, M. E., Zhang, F., Polyakov, M., Gibson, F., ... & Tapsuwan, S. (2015). Consumers' willingness to pay for renewable energy: A meta-regression analysis. Resource and Energy Economics, 42, 93-109.

[27] Johansson, B. (2013). Security aspects of future renewable energy systems–A short overview. Energy, 61, 598-605.

APPENDICES - A

Table 1: Descriptive statistics on household characteristics across the study locations.

Household characteristics	Uasin Gishu		Bungoma		Peri urbans			Rurals		
	Peri-urban	Rural	Peri-urban	Rural	KW-Test	T-Test	Pearson's R	KW-Test	T-Test	Pearson's R
N (sample size)	100	124	200	136						
Mean age of HH	32	35	30	31		***	-0.138**		****	-0.286***
Household size	5	6	5	5	***	***	-0.128**	0.00***	***	-0.239**
Female HH head (%)	21	15	38	29		***			***	0.165**
Tenure of house										
Permanent (%)	70	76	76	75			0.007***		***	
Rental (%)	8	0	16	17		***			***	
Marital status										
Single (%)	7	8	27	29		***	0.001***		***	0.006**
Married (%)	79	83	65	65		***	0.001**		***	0.006**
Household composition										
Children under 5 years%	33	42	43	47		0.202			***	
Youth 6-14 years %	56	64	56	54			0.05**		**	
Female 15-50 years%	90	93	85	91		***	0.00***		***	0.00***
Male 15-50 years %	86	93	67	68		***	0.00***		***	0.00***
Female over 50 years %	30	22	34	35		***			***	0.012***
Male over 50 years %	30	20	34	48		***			***	0.00***
Assets										
Mean Cars	< 1	< 1	< 1	< 1	0.809	***		0.000***	***	
Cattle	4	18	3	4	0.41	***		0.00***	***	0.021**
Income characteristics										
Mean household income						***	0.102		***	0.034
Permanent employed (%)	4	2	61	65.4		**	-0.594**		***	-0.696**
Business (%)	61	42.2	60.4	50.7		**	-0.176**		***	-0.529**
Farmer	49	84	65.3	61.8		**	-0.164**		***	0.251***