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Drivers of cooking energy choices by meal-types among smallholder farmers in western Kenya

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Abstract

There are gaps in research needed to enhance policy intervention for rural households' transitions from traditional biomass to cleaner energy sources. This paper reports on a survey among farmers in western Kenya to assess drivers of cooking energy choices for various key meals; to understand agricultural production factors in cooking energy choices; and to assess energy use homogeneity among varied sub-counties. The study sampled 388 respondents from four heterogeneous rural sub-counties differing in altitude, proximity to public forests, and cultural characteristics. The multinomial logit model analysis showed that significant factors influencing the shift from firewood to LPG for breakfast preparation included access to credit, income, formal employment, and the proportion of adults in the household. Shifting from firewood to crop wastes was significant, influenced by distance covered to collect firewood, and desire for warming houses. The shift from firewood to sticks was influenced by firewood cost, houses owned, and reliance on own farm for woodfuel. Determinants of cooking energy choices for breakfast, lunch and supper were identical. Sticks were seen as an inferior cooking energy source. The adoption of cleaner energy was more associated with breakfast than other meals. Despite the sub-counties' heterogeneity, no substantial differences were observed among them on drivers of cooking energy choices. Study outcomes were consistent with other concepts associated with cooking energy usage, including the transition energy ladder and energy stacking.

Keywords: *biomass; subsistence; environment; transition; poverty, Southern Africa*

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1. Introduction

Globally, benign energy sources for domestic, production and industrial purposes are considered a critical socio-economic welfare indicator (UNDP, 2018). Both production and industrial energy sourcing are commercial and are influenced by efficiency returns dictated by technological advancement. Domestic energy sourcing for lighting, cooking and housewarming in developing countries is a priority for policymakers and development agents for several reasons. First, despite efforts to make clean (modern) and more efficient energy sources available, a large proportion of people in developing countries accounting for a third of the global total depend on traditional (biomass) energy sources (Makonese *et al.* 2019: IEA, 2017; UNEP, 2019). Secondly, the seventh United Nations Sustainable Development Goal (SDG), to 'Ensure access to affordable, reliable and modern energy for all' (World Bank, 2018) addresses itself to this critical necessity. Moreover, despite the failure of the SDGs' precursor, the Millennium Development Goals, to directly prioritise domestic energy sourcing, detailed analysis showed energy poverty had repercussions on all the other goals (Vaidya and Mayer, 2016).

Thirdly, biomass cooking energy sources are associated with health problems, environmental degradation, and economic repercussions (Liu *et al.* 2008). Indoor pollution associated with dirty solid energy use globally is estimated to result in about 4.3 million premature deaths annually and in numerous ailments (Frings *et al*, 2018; Edwards *et al*, 2015; De *et a*l, 2014). According to Stanturf (2017), biomass harvesting has led to deforestation and denudation of land cover. These problems can be broadly categorised as hydrological and climatic, biogeochemistry, ecological, and economic. Their impacts threaten agriculture production (Moore *et al*. 2017), household income, and livelihoods (Mwaura and Muwanika, 2018; Zwane, 2019). Fourth, biomass, vegetation and forest are regarded as an essential component in mitigating challenges associated with global warming and climate changes (World Bank, 2016). Sustainable management and enhanced biomass resource production could assure food security, economic welfare, employment, and energy source (FAO, 2013). Nevertheless, biomass as cooking energy by a large proportion of developing countries' populations can account for a significant situation that escapes the attention of an environmental impact assessment as anticipated by environmental management regulations (Mee, 2005). Taking Uganda as an example, a daily per capita utilisation of biomass estimated at 0.223 m^3 (Agea *et al.* 2010) implies that a biomass harvest of 7.8 million m^3 is recorded there every day, corresponding to thousands of hectares of forest cover.

In addressing the determinants of cooking energy choices among households in developing countries, several theoretical and conceptual frameworks based on micro-economic theory have been formulated (Muller and Yan, 2018). These concepts include the energy transition ladder (van der Horst and Hovorka, 2008), fuel stacking (Sclag and Zuzarte, 2008), urban household models (Muller and Yan, 2018), agricultural households models (Chen *et al.* 2006; Guta, 2012) and environment-Kuznets curves (Foster and Rowenzweig, 2003; Hoff, 2011). Determinants of cooking energy choices have been evaluated in Ghana (Amoah, 2019), Burkina Faso (Ouedraogo, 2006), Kenya (Yonemitsu *et al.* 2015; Pundo and Frasher, 2006), Uganda (Agea *et al.* 2010), Tanzania (Lusambo, 2016), Ethiopia (Geremew *et al.* 2014), Malawi (Brouwer *et al.* 1997), Cameroon (Nlom, and Karimov, 2015), China (Chen *et al.* 2006) and India (Dash *et al.* 2018), among others. From these studies, the determinants of cooking energy use could be categorised into income and price elasticity, household preferences, domestic constraints, production characteristics, and energy supply factors (Muller and Yan, 2018).

Despite the plethora of studies, information gaps exist in relation to incorporating agricultural crop production systems and bio-energy into household energy choice (Popp *et al.* 2014). Notably, this happens in a situation where bio-energy crops (Soto, et al. 2018) and tree planting for domestic energy subsistence (Agea *et al.* 2010; Egeru *et al.* 2014) have become agricultural activities. Desegregating cooking energy choice by meal types can provide further insights into households' energy demand (Muller and Yan, 2018). Another key unanswered question is the effectiveness of applying identical interventions across developing countries and various regions.

Most households in southern African (excepting Namibia, Botswana and South Africa) rely heavily on biomass cooking energy (Makonese *et al.,* 2018; UNEP, 2019), and so are considered to be energy-poor (Khandker *et al.* 2012). More than three-quarters of the population in energy-poor southern Africa countries rely on biomass cooking energy. Consistent patterns in cooking-energy sources across sub-Saharan Africa points to the compatibility of strategies across the region in order to meet SDG 7. This study's specific objectives were to assess the drivers of cooking energy choices for various essential meals made by households in western Kenya; to incorporate agricultural production factors into understanding cooking-energy choices; and to assess energy use homogeneity among various socio-economic and agro-ecological clusters.

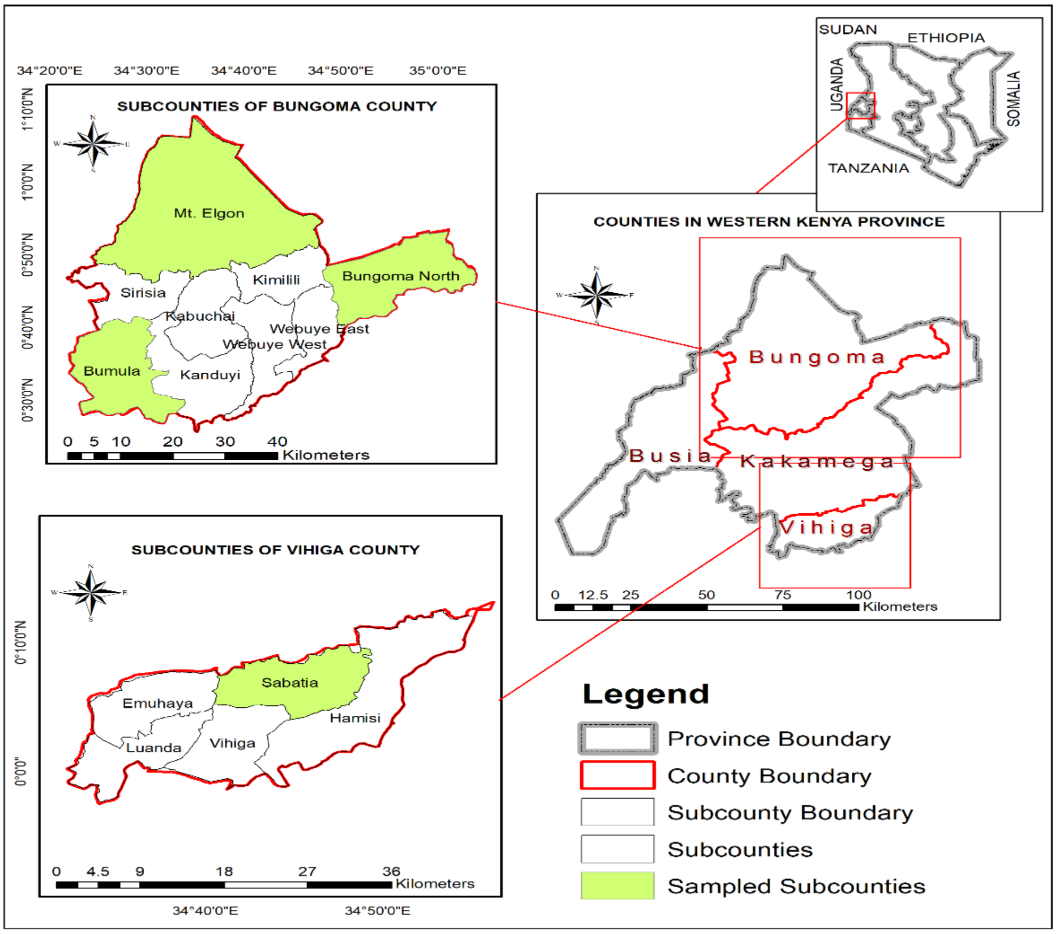


Figure 1: Map of sampled cluster sub-counties in western Kenya.

2. Material and methods

2.1 Description of the study area

Figure 1 shows the map of the study area and the sampled cluster of sub-counties in western Kenya. The area presents a sample of interest in a number of ways, including having the highest biomass energy deficit and challenges in biomass energy efficiency utilisation in Kenya (Kituyi *et. al.,* 2001). Despite the region being considered homogenous in terms of agriculture, biomass access, and farming system (Moebius-Clune *et al,* 2011), differences in agro-ecological zones and socio-economic characteristics are pertinent (Jaelzold *et al.* 2007). Table 1 shows sampled cluster sub-counties purposely selected to represent the heterogeneity in the region.

2.2 Data sources

A survey design was adopted for the study. A preset questionnaire was administered among the sampled 388 households, with each cluster having an equal number of respondents. The questionnaire was designed, and reviewed after a pilot test. It had modules that queried respondents on demographic, economic, general energy, and agricultural production information deemed necessary to predict household cooking energy choice among the rural community.

2.3 Sampling area

Factors that determined enumeration areas included the level of urbanisation, socio-economic characteristics, major economic activities, climatic factors, and access to sources of biomass (Jaetzold *et al*. 2007). A multi-stage sampling procedure involving purposive, stratified and random sampling was used to select respondents. The first step involved a purposive selection of the four clusters representing sub-counties and wards with distinct agro-ecological, climatic and socio-economic characteristics hypothesised to yield variant energy mix environments. The next two steps involved the stratified selection of sub-locations and villages. The final stage involved simple random sampling of households to be interviewed.

2.4 Theory and calculations

To estimate coefficients and for statistical specification on rural households for the discretely unordered cooking energy choices for various meals, a multinomial logit (MNL) model (Greene, 2012) was adopted. The model was chosen over the available alternatives because of its flexibility, computational efficiency and ability to allow simple behavioral interpretation of the parameters (McFadden et al. 1976). The MNL likelihood function does not require numerical integration and almost always converges to a global optimum (Dow and Endersby, 2004), making it stable. The MNL model assumes that if there are k categorical outcomes without loss of generality, the base outcome will be 1. The probability that the response for the jth observation is equal to the ith outcome is as shown in Equation 1.

$$p_{ij} = \Pr(y_j = i) = \begin{cases} \frac{1}{1+\sum_{m=2}^{k} \exp(x_j \beta_m)}, \text{if } i = 1 \\ \frac{\exp(x_j \beta_m)}{1+\sum_{m=2}^{k} \exp(x_j \beta_m)}, \text{if } i > 1 \end{cases} \quad (1)$$

where x_j is the row vector of observed values of the independent variables for the *jth* observation, and β_m is the coefficient vector for outcome m. The log pseudolikelihood is given in Equation 2.

$$\ln L = \sum_j w_j \sum_{i=1}^{k} I_i(y_j) \ln p_{ik} \quad (2)$$

where w_j is an optional weight; and

$$I_i(y_i) = \begin{cases} 1, \text{if } y_j = i \\ 0, \text{otherwise} \end{cases};$$

and y_i represents cooking choices of energy utilised for breakfast, lunch, and supper.

These energy choices include liquefied petroleum gas (LPG), sticks and firewood (see Table 2 for the distinction), crops wastes, and others (kerosene and charcoal) as described in Table 2. x_j is a matrix of explanatory variables, as described in Table 3. A pre-analysis correlation matrix test was undertaken to check for multicollinearity among explanatory variables. The outcome of the test showed the absence of multicollinearity among variables. A variance inflator factor post-analysis correlation test outcome confirmed multicollinearity low effects on the regression outputs.

3. Results and discussion

3.1 General descriptions of the smallholders

Table 4 shows the socio-economic characteristics of households sampled. Household heads were aged between 20 and 93 years, with an average of 49.8 years. On average, smallholding farming systems had been practised for about 21 years, a duration allowing households to have adopted particular energy consumption behaviours.

Households were observed to have, on average, 5.26 members, the majority (58%) of whom were adults. Farms owned by the households were small, averaging 2.42 acres (0.98 ha) per family. Most (68%) of the land was allocated to growing maize, the staple crop. The landholding and allocation showed households primarily involved in subsistence agriculture (Gatzweiler and von Braun, 2016). The subsistence farming practised was only able to secure, on average, 68% of household staple food demand. Despite the small land holding, farmers on average planted 127.4 trees. Weekly spending on firewood energy sources averaged KES 341 (USD 3.41) per household. Each household had about a fifth of its members at least once involved in sourcing firewood – fetched from as far as 12 km.

Table 1: Ecological characterisation of heterogeneous among the sampled cluster sub-counties in western Kenya.
Source: Jaetzold et al. (2007)

Characteristics	*Bumula*	*Bungoma North*	*Mt. Elgon*	*Sabatia*
Agro-ecological zone	LM3 (lower Midland)	UM4 (Upper Midland 4)	LH1 (Lower Highland & UM	UM1
Altitude (above sea level)	1200–1400m	1500–1900m	1950–3000 m	1500–1900 m
Annual mean temperature (°C)	22.4–21.6 °C	21.0–18.8 °C	18.0–7.0 °C	21.0–18.5 °C
Community and culinary behaviours	Luhya (Bukusu)	Luyha (Bukusu/Maragori)	Nilotics (Sabaot)	Luhya (Maragori)
Energy related industries	Tobacco curing, brick baking	Large farms and commercialised maize farming	Wet and cold weather necessitates warming of houses	Wet and cold weather necessitates warming of houses
Biomass information	Competing needs for biomass energy due to associated industries	High production of maize ensures availability of crop waste as energy option	Neighbouring a public forest reserve (Mt Elgon Forest)	A public forest reserve (Kakamega Forest) 15 to 20 km. Land size limits agricultural waste

Table 2: Description of dependent variables

Dependent variables/ energy	*Description of the variable*
LPG	Cleaner energy as per the transition ladder. The desired output for this research.
Others	Represents the transitional energy sources, i.e. charcoal and kerosene.
Firewood	Woody biomass energy sources which mostly entails substantial removal of biomass and deforestation. The diameter is above 3 cm for each side.
Sticks	Herbaceous biomass energy sources that include twigs from farm forestry, biomass die-backs and leaves (Geremew et al. 2014). Mostly collected by children and do not necessary results to deforestation. Either side of a stick is not hewed and is less than 3 cm in diameter.
Crop wastes	By-products of maize including stocks and cobs. A direct link between agriculture and energy.
	Meal types
Breakfast	The main morning meal.
Lunch	The main afternoon meal.
Supper	The main evening meal.

Table 3: Explanatory variables used in the MNL regression and the postulated effect of driving households to adopt modern energy sources.

Variable	*Description of the variable, literature relating it to cooking energy*	*Postulated effect on clean energy use*	*Observations (N)*	*Mean*
loghhage	(Log) of household head	-	376	3.858
sqrtfempr	The square root of the proportion of female in the household (Agea et al. 2010	-	380	0.641
sqrtepisofw	(Square root) Duration for firewood gathering (Egeru et al. 2014)	+	380	7.680
Sqrtinvesag	(Square root) the amount invested in agriculture in KES (Kandel et al. 2016)	+	377	122.04
sqrt2maiprd	Decreased levels of maize production achieved in 2017	+	375	5.333
Sqrtmaizeprd	(Square root) levels of agricultural production (i.e. maize yield) in 2017 (Kandel et al. 2016)	+	375	33.408
Sqrtfwcost	(Square root) Cost of firewood in KES (Brouwer et al. 1997; Geremew *et al. 2014*)	+	380	15.484
re1	Dummy, Mt. Elgon, a cluster (*see Table 1*)	-	380	0.263
re2	Dummy, North Bungoma, cluster (*see Table 1*)	+	380	0.271
re3	Dummy, Bumula, a cluster (*see Table 1*)	+	380	0.205
re4	Dummy, Sabatia, a cluster (*see Table 1*)	-	380	0.261
logexpcap	Log per capita weekly expenditure in KES (Lusambo, 2016)	+	378	3.815
swh_warmho~e	Dummy, Household consciousness of warming house	-	380	0.213
Improve_stove	Dummy, adoption of improved cooking stoves (Agea et al. 2010)	+	380	0.418
hhno	Number of houses being used by a household		380	1.947
solar	Dummy, adoption of solar energy (Dash et al. 2018)	+	380	0.516

Variable	*Description of the variable, literature relating it to cooking energy*	*Postulated effect on clean energy use*	*Observa-tions (N)*	*Mean*
livesente	Number of livestock enterprises (Démurger & Fournier, 2011)	-	380	1.887
farmergrp	Dummy, membership to farmer group networking	+	380	0.247
credit	Dummy, access to credit	+	380	0.229
agricont	The proportion of agriculture to total household income	_	380	77.537
Fcopdn	The proportion of own food/maize production meeting household demand (Kandel *et al.* 2016)	+	376	68.423
fw_1farm	Dummy, dependency of household on own farm (Kandel *et al.* 2016)	-	369	0.580
firepeople	Number of people gathering firewood (Brouwer et al. 1997)	-	380	1.345
hhhead_edu	Household head education in years (Lusambo, 2016; Bisu et al. 2016)	+	360	9.486
HH_A average_ed.	Adults average years of education (Lusambo, 2016)	+	380	8.138
Cumulative adults	Sum of all household member divided by 18 (adult) (Dash et al. 2018)	-	380	6.789
hsize	Total number of members in the household (Agea, et al. 2010)	-	380	5.261
Hhs	Dummy, gender household head (Male=1, Female=0 (Kiptot *et al.* 2013)	+	379	0.778
hhformal	Dummy, household head in formal employment	+	380	0.134
propadults	Percent of adults (18+ years) in household (Dash et al. 2018)	-	380	0.579
sqrtlandow	(Square root) land owned by household in acre (Dash et al., 2018)	+	380	1.358
sqrtfwdis	Square root, distance covered in firewood fetching (Jumbe and Angelsen, 2011; Brouwer *et al.* 1997)	+	377	0.561

Table 4: Socio-economic characteristics of sampled respondents for the four cluster sub-counties.

Socio-economic characteristics	*Average*	*Std dev.*	*Minimum*	*Maximum*
Household head age (years)	49.8	15.52	20	93
Household head farm experience (year)	20.84	15.11	1	75
Household size (numbers)	5.26	2.09	1	13
The proportion of adults (%)	57.8	25	20	100
Female proportion (%)	44	28	0	100
Land size (acre)	2.42	3.17	0.125	20
Maize acreage (acre)	1.65	5.57	0	100.5
Maize production in 2007 (kg)	2 194.6	11 99	0	225 97
Trees number	127.4	259	0	2 000
Food production (%)	68.4	31.1	0	100
Household head education (year)	9.48	3.8	0	16
Expenditure capita (KES)	55.25	40.6	6	476
Firewood duration per episode (minutes)	79.2	82	0	12
Firewood people (number)	1.3	0.96	0	6
Firewood fetching distance (kg)	0.55	1.0	0	12
Weekly estimated firewood cost (KES)	341.2	310.8	0	1 400

Note: KES 100 = USD 1

Figure 2 shows the categorical socio-economic characteristics associated with the households, including female-headed households, adoption of solar energy and improved cooking stoves, access to credit, and consciousness of warming the house environment as the choice of cooking energy was made. The rate of solar energy and improved cooking stove adoptions was high, considering the low investment in promoting sustainable energy sources in the country.

3.2 Heterogeneity in socio-economic and biomass energy characteristics among cluster sub-counties

Table 5 shows the outcome of comparing sample differences (ANOVA test for unequal variance) for the household's socio-economic characteristics in various cluster sub-counties. Significant *($p<0.05$)* heterogeneity was observed on demographic factors among few sub-counties or across the sub-counties. The observed heterogeneity implied differences beyond the agro-ecological, postulated biomass energy demand, and supply characteristics were to affect drivers of cooking energy choice among sub-counties. Older household heads and with more farming experience were reported in Sabatia than the other sub-counties. Sabatia's demographic patterns were associated with the settlement duration (de Sherbinin *et al*, 2008) and historically high population pressure (Jaetzold *et al.* 2007) influencing migration. The higher education levels observed in Bungoma North were attributable to its enhanced formal employment rate. The education and employment pattern among the sub-counties affect labour for sourcing biomass energy (Murphy *et al.* 2018).

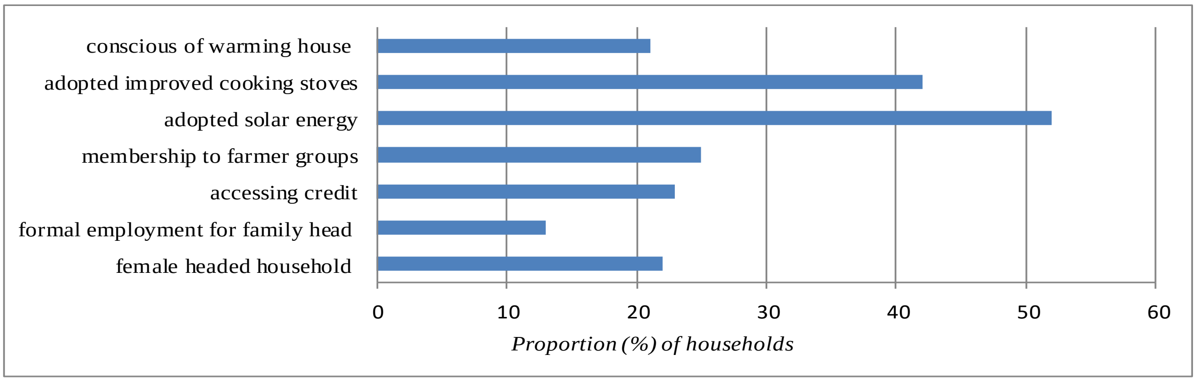


Figure 2: Socio-economic characteristics associated with the sampled households.

Table 5: Households' socio-economic characteristics and energy information by cluster sub-counties

Household characteristics	*Overall*	*Bumula*	*Mt Elgon*	*Sabatia*	*Bungoma North*	*P-values*
Female headed households (%)	28	19	29a	24	17a	*P<0.05*
Household head age (years)	49.8	47.1a	44.4bd	56.2abc	50.9cd	*P< 0.05*
Experience farming (years)	20.8	17.3a	17.1b	28.8abc	19.1c	*P< 0.05*
Formal employment (%)	13	13	8a	11b	19ab	*P< 0.05*
Adult equivalent	3.6	3.3	3.8	3.5	3.6	*n/s*
Adult total (> 18 years)	2.8	2.5ab	2.8a	2.7	2.9b	*P< 0.05*
Children (7-18)	1.7	1.8	2.1ab	1.5a	1.5b	*P< 0.01*
Children below 7	1.2	1.7ab	1.4ce	0.6acd	1.0bde	*P< 0.05*
Household size	5.26	5.6a	5.8bd	4.6abc	5.1cd	*P< 0.05*
Adults proportion	58%	48.9ab	54.8c	65bc	61a	*P < 0.01*
Female proportion	44	41a	44.7b	49abc	42c	*P< 0.05*
Household head education (years)	9.48	9.4a	9.1b	8.7c	10.8abc	*P< 0.05*

Note: Identical letter across a row denotes significance differences among those particular sub-counties.

Table 6: Economic and energy consumption characteristics of households in various sub-counties

Household characteristics	*Overall*	*Bumula*	*Mt. Elgon*	*Sabatia*	*Bungoma North*	*P-values*
A firewood episode duration (minutes)	79.2	54.7ab	110acd	78.8bd	71c	*P < 0.05*
Firewood-fetching household members	1.3	1.6a	1.2a	1.3	1.4	*P < 0.05*
Weekly firewood gathering duration (minutes)	273	243a	391ab	292	200ab	*P < 0.05*
Average firewood distance (km)	0.56	0.31a	1.2abc	0.44b	0.28c	*P < 0.01*
Own farm firewood gathering (%)	56	73ab	35acd	56bd	70c	*P < 0.05*
Solar adoption (%)	52	58a	51bd	30abc	70cd	*P < 0.01*
Improved cooking stoves (%)	49	53a	22abd	40bc	56cd	*P < 0.05*
Weekly household expenditure (KES)	1872	2422ab	1805ac	1889d	1508bcd	*P < 0.05*
Per capita daily expenditure (KES)	55	63.8a	49.5b	64.7bc	45ac	*P < 0.05*
Sufficiency in maize production	73	82ab	71ace	55bcd	86de	*P < 0.01*
Credit access (%)	23	33a	14a	20	26	*P < 0.01*
Number of houses owned by a household	2.0	1.9a	2.03b	1.7bc	2.2ac	*P < 0.01*
Conscious of warming house	21	15a	25c	31abd	13bcd	*P < 0.05*

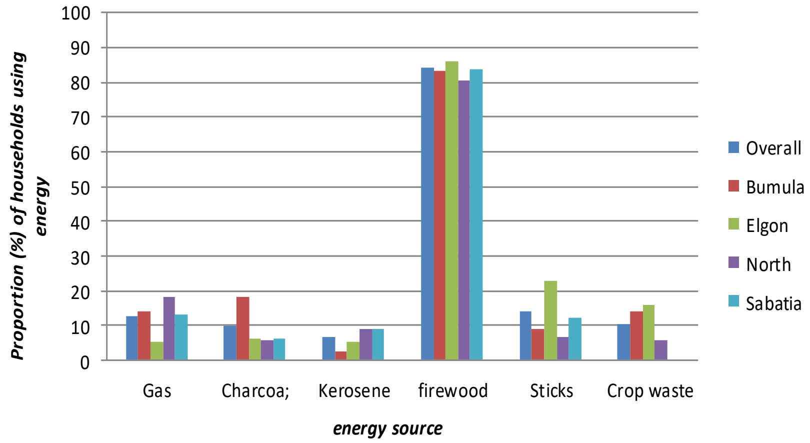
Notes: 1. KES 100 = USD.
2. Identical letter across a row denotes significance differences among those particular sub-counties.

A comparison of sample differences (ANOVA test for unequal variance) for the household's energy associated factors among the sub-counties is shown in Table 6. Firewood gathering was observed to take between four and seven hours weekly for each household. Households in Mt Elgon were observed to significantly ($P< 0.05$) employ more biomass cooking energy sourcing efforts than others in terms of distances covered to fetch firewood and duration per episode. The numbers of household members involved in firewood gathering in Bumula were significantly more than in Mt Elgon. Comparing cooking energy security and drivers of biomass reliance among the sub-counties was complex, for a number of reasons. First, while firewood fetching efforts, as evidenced by duration per episode, time taken weekly, and distance covered, demonstrates Mt Elgon facing challenges in accessing firewood. The lower opportunity cost associated with accessing firewood from the forest reserve could explain the observed fuel sourcing behaviour there. Forest reserves are associated with sufficiency (Kandel *et al,* 2016), quality and diversity of firewood (Egeru *et al,* 2014; Agea *et al,* 2010). Availability of labour is another factor that could drive households to assign more effort to energy sourcing.

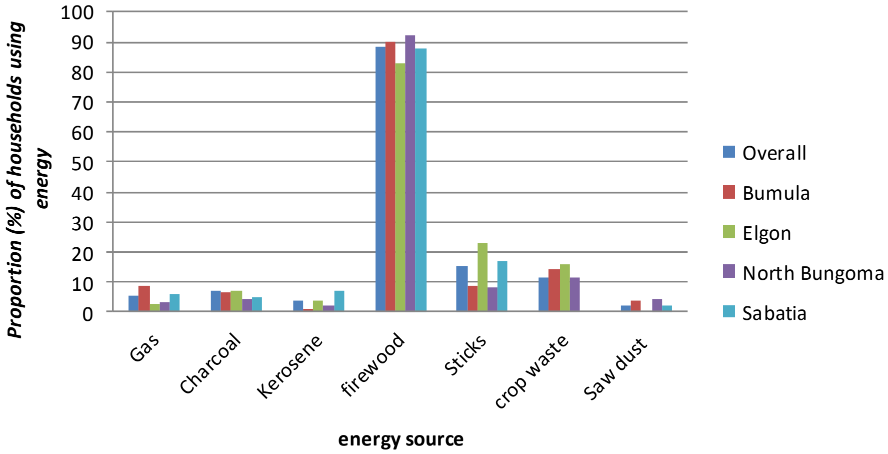
Inaccessibility of a public forest for firewood gathering had driven households to rely more on their own farm products through tree planting or use of agricultural waste, or to adopt cleaner, modern energy sources. Households in all the other sampled sub-counties significantly relied on their farm for firewood compared with only 35% in Mt Elgon. The diminished free access to the forest for firewood collection appears to have driven households to adopt improved cooking stoves associated with energy saving (Murphy *et al*. 2018). A significantly higher proportion in adopting improved energy cooking stoves was reported in sub-counties other than Mt Elgon. Firewood fetched from own farm was supplemented by collection from road reserves and by purchases from the market (Murphy *et al.* 2018), especially during harsh weather. Consciousness of warming the house's environment when choosing the cooking energy source reported mainly in Mt Elgon and Sabatia, was attributable to the higher altitude and resultant low temperatures (Jaetzold *et al*. 2007).

3.3 Cooking energy sourcing by essential meals for various cluster sub-counties

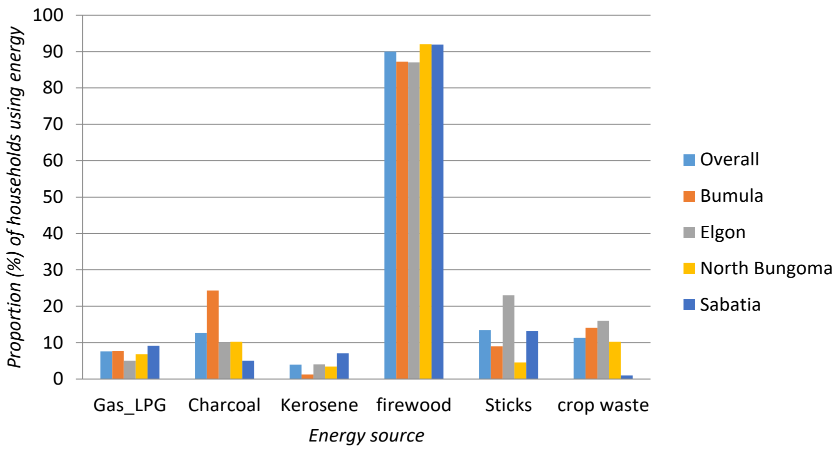
Households were observed to use various multiple energy sources in cooking breakfast, lunch and supper. In Figure 3 (a), (b) and (c), the proportions of households using the various cooking energy choices for respective meals and in the sampled sub-counties are shown. Firewood was the most preferred cooking energy choice, with more than three-quarters of respondents adopting it across meals and sub-counties. Other cooking energy sources utilised in cooking, although to a far lesser extent, include sticks, agricultural waste, transitional sources (charcoal and kerosene) and LPG. The outcome of this study portrays energy stacking (Muller and Yan, 2018) across the essential meals prepared by the household. The energy stacking concept states that, as household incomes rise, the households expand their energy use options by adopting other sources while they continue using the traditional sources (Sclag and Zuzarte, 2008). The observation on energy stacking is consistent with other research findings (van der Kroon *et al.* 2014; Jumbe and Angelsen, 2011).



(a) Breakfast



(b) Lunch



(c) Supper

Figure 3: Proportion of households using various cooking energy sources for key meal preparations among sub-counties.

A slight increase in the use of cleaner energy, mostly LPG, was observed in breakfast preparation compared with the other meals. The proportion of households using LPG for breakfast preparation doubled (13%) compared with those using it for cooking lunch in the entire region, and by 500% in Bumula. The usage of charcoal was slightly higher for supper preparation than for other meals. A few households across sub-counties had adopted the use of sawdust as an energy source for lunch cooking. The observed shift in the choice of cooking energy based on the essential meal was associated with the types of food prepared and the cooking methods (Pathare and Roskilly, 2011). Shifting in using an energy type to make different meals indicated a desire to optimise cooking time and the disparity in value attached to various meals (Akinoso and Oladeji, 2017) by households. As household members wish to disperse for various daily chores, including school, formal employment, and off- and on-farm commitments, the usage of LPG increases as an energy source for breakfast preparation. Setting up firewood and charcoal stoves takes longer and reduces their choice for breakfast preparation. Nevertheless, the initial investment in LPG energy, economic welfare, and accessibility to refilling points may have hindered more households from adopting this cleaner energy source.

3.4 Cooking durations for various meals

Figure 4 shows the time households took to make the three essential meals. On average, households in Sabatia took half an hour to prepare breakfast and twice as long (64 minutes) to prepare lunch. Lunch and supper took almost the same time to prepare in Sabatia, unlike the other sub-counties, where substantial time differences were reported. Households in Sabatia used the shortest duration for preparing lunch and the longest for cooking supper. On average, the total time taken to prepare the three meals ranged between 159 (Bumula) and 215 minutes (Mt Elgon).

Considering the close cultural proximity between households in Bungoma North and Bumula sub-counties to those of Sabatia, differences in durations of cooking and culinary behaviours (Geremew *et al.* 2014) were mostly associated with food and energy availability.

3.5 Determinants of cooking energy choices

Multinomial regression results outcome are shown in Tables 7, 8 and 9 for breakfast, lunch, and supper respectively. The statistical regression outcomes, including the number of observations, the likelihood ratio (LR), chi2; Prob >chi2, Pseudo R^2 and log-likelihood, are shown in respective tables.
Consistent with the energy ladder theory (Nlom and Karimov, 2015) and the energy poverty-income poverty interlinks (Khandker *et al.* 2012), factors associated with household income – including access to credit (credit), involvement in formal employment (hhformal), per capita expenditure (logexpcap), and proportion of adults in a household (propadults) – were significant in influencing the shift from firewood to LPG for breakfast preparation (Table 7). The 'cooking energy ladder' concept states that households shift from traditional cooking energy sources to modern, sophisticated fuels as their economic status improves (van der Horst and Hovorka, 2008). The cooking energy stepwise pattern (ladder) as a household's financial status improves, starts from animal dung, crop wastes/firewood and charcoal, moving up to kerosene, LPG and then electricity. The observed interlinks between income factors and shifts to cleaner energy provide incentives for testing the environmental Kuznets theorem (Al-Mulali *et al.* 2016), especially with the availability of time series data. The

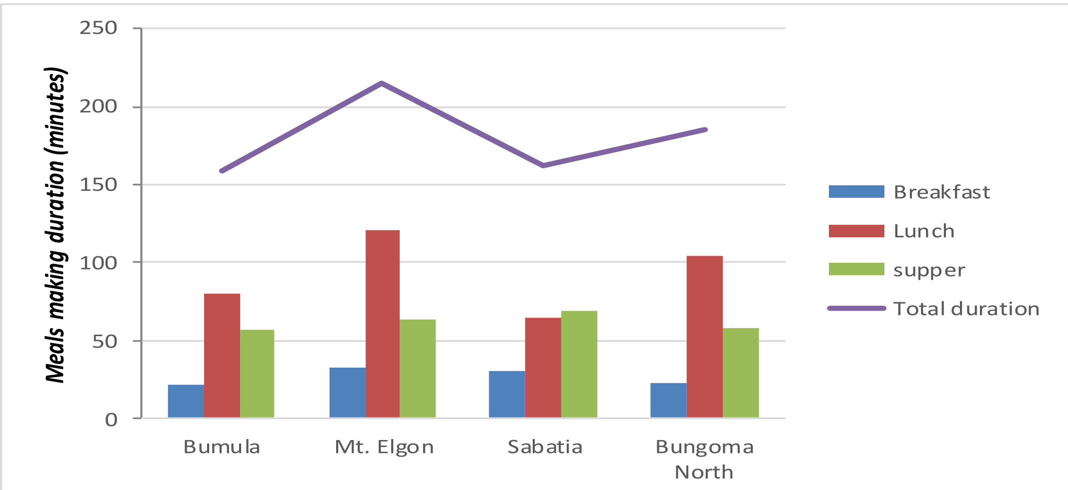


Figure 4: Average daily households' duration of cooking meals in minutes for the cluster sub-counties.

Table 7: Multinomial regression for outcome for drivers of breakfast cooking energy choice

Breakfast energy	*LPG*		*Sticks*		*Agricultural*		*Others*	
	Coefficient	*Std. error*	*Coefficient*	*Std error*	*Coefficient*	*Std error*	*Coefficient*	*Std error*
loghhage	0.591	2.706	-2.289	1.542	-1.444	1.392	-0.886	1.555
sqrtfempr	-1.142	3.016	-1.176	1.752	-0.739	1.993	-3.334**	1.59
sqrtepisofw	0.028	0.092	0.003	0.061	0.046	0.060	0.013	0.062
sqrtinvesag	0.005	0.007	-0.001	0.006	-0.004	0.005	-0.005	0.006
sqrt2maiprd	0.454	0.740	0.248	0.311	1.255	0.445	0.385	0.603
sqrtmaizeprd	-0.054	0.081	-0.008	0.023	-0.047	0.021	-0.037	0.056
sqrtfwcost	-0.031	0.041	0.091***	0.034	0.038	0.029	-0.002	0.031
Elgon	-1.9097	1.744	0.679	0.862	16.836	969.866	0.842	0.956
Bungoma North	-2.102	1.360	0.621	0.852	16.903	969.865	1.028	0.863
Bumula	-1.438	1.307	-1.797	1.284	17.013	969.865	0.919	0.930
sqrtfwdis	-0.715	1.269	0.27	0.647	-2.907	0.895***	0.240	0.633
logexpcap	1.893**	0.828	0.098	0.544	0.759	0.452*	0.241	0.465
improvjiko	1.237	1.006	-0.554	0.616	-0.763	0.616	0.604	0.552
swh_warmhouse	-0.261	0.934	0.351	0.615	1.487	0.6245**	-0.175	0.68
hhno	-0.280	0.549	-0.836***	0.363	0.099	0.296	-0.151	0.366
solar	1.381	1.0045	-0.036	0.558	-0.013	0.546	0.259	0.564
livesente	0.236	0.574	0.301	0.33	-0.278	0.315	0.058	0.298
farmergrp	1.218	1.489	-1.952*	1.126	-1.181	0.976	-3.391***	1.194
credit	-3.771**	1.854	1.754*	1.178	1.036	0.966	1.672**	1.152
fcopdn	0.039	0.024	-0.009**	0.012	-0.026	0.015*	-0.009**	0.013
agricont	-0.020	0.017	-0.010	0.009	0.005	0.011	0.002	0.010
fw_1farm	-0.475	1.008	1.935***	0.632	0.448	0.637	0.385	0.589
firepeople	-1.238	0.864	-0.195	0.340	-0.141	0.262	-0.541	0.427
hhhead_edu	0.114	0.147	-0.090	0.103	0.003	0.099	0.156	0.105
HH average_ed	-0.169	0.227	0.011	0.129	-0.0373	0.113	-0.406***	0.130
hsize	-0.803*	0.496	-0.369	0.268	0.180	0.234	-0.294	0.299
hhs	1.849	1.586	-.0334	0.719	-0.9016	0.672	-0.083	0.8313
hhformal	2.271**	1.035	0.771	0.979	-0.57	0.902	0.952	0.799
adults_equiv2	0.513	0.386	0.397	0.260	0.273	0.235	0.253	0.262
propadults	-7.039**	3.368	-2.120	1.899	1.225	1.618	1.214	1.947
Sqrttree	0.144	0.1596	-0.311*	0.178	-0.074	0.119	-0.097	0.145
sqrtlandow	1.029	0.789	-1.029*	0.610	-0.245	0.4184	0.002	0.538
_cons	-11.512	12.997	8.048	6.217	-20.645	969.883	2.743	6.832

No of observations 336 — Prob > chi2 = 0.0000

LR chi2 (128) 259.06 — Pseudo R^2 = 0.3471

Log likelihood =-243.64

NB: Sabatia is base sub-county

*** Significance at 1%; ** Significance at 5%; * Significance at 10%

environmental Kuznets theorem relates community economic development and environmental welfare. It postulates that initial economic growth leads to deterioration in the environment; however, after a certain level of economic growth, a society begins improving its relationship with the environment and reducing its levels of environmental degradation.

The probability of households shifting from firewood to LPG in breakfast preparation was significantly ($P < 0.05$) influenced by access to credit, involvement in formal employment, per capita expenditure, and the proportion of adults. The household head's involvement in formal employment positively influenced the probability of shifting from firewood to LPG. Formal employment is associated with extra income that could be invested in both the LPG and its associated equipment, including gas cylinder and burners. Formal employment also boosts the perception of an individual affiliation to a high ranking in a rural society, enhancing preference for clean energy (Muller and Yan, 2018). The desire for a household to spend a short time in preparation, and ensuring the formally employed partake of breakfast at home together with their family, also underlines the adoption of LPG.

Access to credit negatively affected the probability of household shifting to clean energy an observation that was contrary to expectation since credit has been reported to enhanced welfare (Rehfuess *et al,* 2006). Borrowing could be quite risky, and associated with extreme deficiency in finances, so that credit was restricted to more basic needs than investing in the energy transition. The proportion of adults in a household negatively, and significantly, affected the shift from firewood to LPG. A high proportion of adults pointed to access to labour that could be harnessed for both sourcing firewood fuel and preparing meals. Per capita income presented by expenditure, positively and significantly influenced the shift from firewood to LPG. This observation was consistent with other studies including Baiyegunhi and Hassan (2014) and Nlom and Karimov (2015).

The probability of households shifting from firewood to sticks in breakfast preparation was significantly ($P < 0.01$) influenced by the number of houses owned (hhno), reliance on their farm for firewood collection (fw-1farm), and the cost of firewood (sqrtfwcost). At $P < 0.05$, the ability to meet food demand by own production (fcopdn) was indirectly related to a shift from firewood to sticks. Membership of farmers' groups (farmerprp), credit access, number of trees planted (sqrttree), and the amount of land owned by the households (sqrtlandow) were weakly significant ($P< 0.1$) in influencing the probability of a shift from firewood to sticks. Considering the probable factors and the direction of shifts to sticks utilisation, the energy source is inferior. With firewood being used by a large proportion of households and being a base of analysis, the shift to sticks with a rise in firewood price attests to the inferiority of sticks. Poor households may only have one hut, however, as access to income increases their ability to construct more houses was enhanced. Households without the networking opportunity provided by membership of farmers' groups were likely to utilise sticks instead of firewood. Holding small farms and having few or no trees planted was associated with poverty.

Table 8: Multinomial regression for outcome for drivers of lunch cooking energy choice

Lunch energy	*Sticks*		*Agricultural wastes*		*Others*	
	Coefficient	*Std error*	*Coefficient*	*Std error*	*Coefficient*	*Std error*
loghhage	-0.757	0.978	0.197	0.928	-0.122	0.812
sqrtfempr	-0.072	1.795	1.161	1.946	1.375	1.256
sqrtepisofw	-0.039	0.063	0.054	0.058	0.010	0.051
sqrtinvesag	-0.001	0.005	-0.002	0.004	-0.008	0.005
sqrt2maiprd	-0.025	0.288	1.411	0.442	-0.101	0.281
sqrtmaizeprd	0.011	0.022	-0.043	0.022	0.017	0.021
sqrtfwcost	0.066**	0.030	-1.351*	0.692	-0.038*	0.025
Elgon	0.917	0.854	15.231	538.56	0.772	0.727
Bungoma north	0.761	0.801	15.553	538.56	-0.483	0.695
Bumula	-15.764	703.02	15.607	538.56	-0.986	0.794
sqrtfwdis	0.803	0.622	-2.459	0.842	-0.155	0.551
logexpcap	0.673	0.558	0.313	0.416	-0.213	0.399
Improve_stove	-0.873	0.636	-0.303	0.561	0.470	0.478

swh_warmhouse	-0.182	0.633	1.063***	0.575	-0.132	0.556
hhno	-0.786**	0.347	0.028	0.275	-0.072	0.289
solar	0.622	0.563	-0.024	0.525	0.897	0.508
farmergrp	-1.047*	0.940	-1.029	0.891	-0.304	0.508
credit	1.362**	1.027	0.967	0.889	0.716	0.804
fcopdn	-0.025***	0.012	-0.026	0.014	-0.013	0.010
agricontri	-0.0224**	0.010	0.0175	0.0112	-0.0061	0.0079
fw_1farm	2.454***	0.687	0.639	0.619	-0.386	0.533
firepeople	-0.028	0.340	-0.080	0.240	-0.040	0.325
hhhead_edu	-0.099	0.096	0.021	0.091	0.084	0.094
HH_A average_ed.	-0.041	0.132	-0.153*	0.116	-0.167	0.107
hsize	-0.037	0.298	0.413	0.299	0.540	0.256
Adult_ equiv2.	0.251	0.436	-0.039	0.391	-1.215**	0.381
hhs	0.421	0.688	-0.869	0.640	0.035	0.589
Hh formal	1.903	0.887	-0.536	0.782	1.625**	0.623
sqrttree	0.030	0.041	-0.015	0.033	0.015	0.031
propadults	-0.794	1.865	3.586*	1.900	3.930*	1.764
sqrtlandow	-0.822	0.606	-0.647	0.434	0.561	0.400
_cons	-2.730	6.355	-25.242	538.58	-0.975	3.802

NB: Sabatia is base sub-county

The LR chi2 (96) = 202.08 Pseudo R2 = 0.302

Prob >chi2 = 0.00 log likelihood = -233.83

*** Significance at 1%; ** Significance at 5%; * Significance at 10%

The probability of households shifting from firewood to agricultural crop wastes was significantly influenced by the wish to warm the house (*p< 0.01*), the distance covered to fetch firewood (sqrtdis), and per capita expenditure (*p< 0.05)*. At a significant level (p < 0.01), the probability of households shifting from firewood to other sources of breakfast cooking energy was correlated with households' members' average education (HHaverage-ed) and membership of a farmers' group. Other factors influencing shifts to transition energy sources (p<0.05) include credit and the proportion of females (sqrtfempr). Both firewood and stick collection from farmlands and/or forests have been largely associated with women (Agea *et al.* 2010). Therefore, it was expected that, if the female proportion reduces, the shift from gathered biomass to other sources is enhanced.

The number of households utilising LPG for both lunch and supper were few, hindering the energy source from being analysed separately. The few households using LPG were considered as among 'other'. Factors influencing households to shift from firewood to sticks, agricultural wastes and other transitional energy for breakfast were similar to those associated with lunch (Table 8) and supper (Table 9). Notable differences were observed among determinants of energy sources for various meals in terms of a few factors and levels of significance. For example, in the case of lunch *agricontri* and *sqrtfw* cost were significant for shifting to sticks and 'other' respectively in contrast to breakfast. Enhanced levels of significance were observed in *fcopdn* and *credit* for lunch compared to breakfast. Except for *hhno*, which showed significance in influencing the shift from firewood to sticks in case of breakfast and not supper, all other factors had similar effects. Determinants of energy shifts to 'other' in the case of supper included *improve_stove*, *fw_1farm* and *firepeople,* unlike for breakfast.

Results of average marginal effects for firewood and its probabilities of use for various meals are shown in Appendix 1. Households were observed to have 90%, 91% and 96% probabilities of choosing firewood as the energy for cooking breakfast, lunch, and supper, respectively. The likelihood of adopting modern energy (LPG) was only 0.3% for breakfast.

4. Conclusion

Consistent with other studies across the sub-Saharan Africa, including southern Africa, firewood was found to be the most utilised source of cooking

Table 9: Multinomial regression for outcome for drivers of supper cooking energy choice

	Sticks		*Crops wastes*		*Others*	
	Coefficient	*Std error*	*Coefficient*	*Std error*	*Coefficient.*	*Std error*
loghhage	-1.132	1.567	-0.844	1.291	-1.640	1.510
sqrtfempr	1.364	1.438	-0.177	1.742	-0.621	1.481
sqrtepisofw	-0.084	0.079	-0.005	0.058	0.072	0.061
sqrtinvesag	-0.001	0.007	0.000	0.005	-0.002	0.005
sqrt2maiprd	-0.337	0.372	-0.167	0.385	-0.235	0.355
sqrtmaizeprd	0.039	0.042	0.030	0.032	-0.011	0.040
sqrtfwcost	0.073**	0.0353	0.003	0.026	-0.076	0.031**
Elgon	0.681	0.869	17.821	1463.88	0.685	0.890
Bungoma North	-0.576	0.934	17.909	1463.88	0.248	0.815
Bumula	-17.264	1661.5	17.378	1463.88	0.838	0.812
sqrtfwdis	1.164	0.644*	-1.54**	0.709	-0.074	0.594
logexpcap	0.531	0.594	0.716*	0.432	0.085	0.404
improve_stove	-1.164	0.772	-0.530	0.577	1.441**	0.56
swh_warmhouse	-0.446	0.733	2.071***	0.544	0.308	0.556
hhno	-0.558	0.366	-0.102	0.292	0.075	0.332
solar	-0.070	0.603	-0.154	0.506	-0.315	0.556
livesente	-0.108	0.363	0.028	0.294	0.035	0.305
farmergrp	-1.299	1.124	-0.837	0.886	-0.471	0.942
credit	1.993	1.196*	0.329	0.828	-0.548	1.021
fcopdn	-0.020	0.010*	0.004	0.008	0.001	0.009
agricont	-0.015	0.010	0.018	0.011	0.007	0.009
fw_1farm	2.357***	0.753	0.255	0.584	-1.436**	0.613
firepeople	0.201	0.369	0.023	0.255	-0.973*	0.524
hhhead_edu	-0.091	0.107	0.059	0.088	0.109	0.107
HH average_ed	-0.187	0.136	-0.103	0.104	-0.095	0.123
hsize	0.009	0.263	0.252	0.218	0.085	0.285
hhs	0.282	0.742	-0.581	0.612	-0.101	0.754
hhformal	1.482	1.074	-0.544	0.849	0.920	0.693
adults_equiv2	0.106	0.251	0.150	0.218	0.061	0.242
propadults	0.147	1.886	0.886	1.542	0.289	1.953
sqrttree	-0.174	0.200	0.089	0.124	0.025	0.119
sqrtlandow	-0.675	0.754	-0.151	0.387	0.729	0.450
_cons	2.436	6.389	-22.061	1463.88	4.012	6.662

NB: Sabatia is base sub-county

LR chi2 (96) =205.71 Pseudo R^2 = 0.337

Prob >chi2 =0.00 log likelihood = -202.78

*** Significance at 1%; ** Significance at 5%; * Significance at 10%

energy. The higher level of the sampled household reliance on firewood was, however, attributed to the sampled area being rural. High levels of heterogeneity were observed among sub-counties in demographic and traditional biomass usage characteristics, requiring caution as to policy analysis variable choices. Sticks were observed to be inferior energy sources, where the shift from firewood to them was influenced by price and the household's disposable income positions (poverty).

Desegregation of cooking energy utilisation by the meals type (breakfast, lunch and supper) has revealed household energy choices. Each of the meals represents varying requirements of time, energy choice mix, and number of optional sources of energy. Adopting clean energy sources was more associated with breakfast than the other meals. Nevertheless, consistency was observed both in the significant factors and the direction of influence on choices for cooking energy used for various meal types. Across all types, reliance on own farm for firewood significantly influenced shifting to sticks. The choice of crop waste as a cooking energy source was influenced by the desire to warm houses, across the meal types.

Despite western Kenya having sub-counties showing salient contrasts in agro-ecological, socio-economic and energy access environments, no significant differences were observed in drivers of cooking energy choice between them. The region's sub-counties' farming community could therefore be considered as homogenous in energy demand and supply behaviour. However, significant differences in choice of cooking energy were observed, as influenced by welfare characteristics including formal employment, reliance of own farm for biomass energy, average pool of household years of education, per capita income, credit use, and the proportions of females and adults in the household. The only agricultural production factor that influenced energy choice was the proportion of food covered by household own production. Both the levels of maize production and increased levels of maize production failed to return a significant influence on cooking energy choice. The cost of firewood and the distance covered to fetch firewood were fuel-sourcing factors influencing choice of energy.

This study has also confirmed various concepts associated with choice of cooking energy, including the transition ladder, energy stacking, and the environment-Kuznets (Démurger and Fournier, 2011). The incorporation of agricultural production variables has attested to a relationship between energy choice and agricultural production as explained through the agricultural households' models (Chen *et al.* 2006).

Author contributions

F.M. Mwaura: Designed the study, collected and analysed data, and drafted the manuscript as a part of a PhD thesis.
M. Ngigi: Supervised the first author in undertaking research, data analysis and developing the manuscript.
G. Obare: Supervised the first author in undertaking research, data analysis and developing the manuscript.

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Appendix 1. Marginal effects on drivers of cooking energy choice for various meals

	Breakfast energy choice		*Lunch energy choice*		*Supper energy choice*	
	Pr (LPG_gas = 0.3 %) Firewood = 90%		*Pr (Firewood =91%)*		*Pr (Firewood= 96%)*	
Variable	*dy/dx*	*Std error*	*dy/dx*	*Std error*	*dy/dx*	*Std error*
loghhage	0.001	0.008	0.061	0.529	-0.140	0.647
sqrtfempr	0.000	0.009	0.021	0.593	-0.013	0.598
sqrtepisofw	0.000	0.000	-0.002	0.038	-0.001	0.014
sqrtinvesag	0.000	0.000	0.000	0.000	0.001	0.002
sqrt2maiprd	0.001	0.002	0.009	0.149	0.018	0.066
sqrtmaizeprd	0.000	0.000	0.000	0.021	-0.002	0.007
sqrtfwcost	0.000	0.000	0.003	0.031	0.003	0.024
Elgon *	-0.004	0.005	-0.966	1.339	-0.923	1.004
Bungoma North*	-0.004	0.005	-0.962	1.362	-0.892	1.189
Bumula*	-0.004	0.004	-0.931	0.540	-0.860	0.512
sqrtfwdis	-0.003	0.005	0.003	0.835	0.006	0.556
logexpcap	0.005	0.006	-0.005	0.381	-0.002	0.284
improve_stove*	0.004	0.005	-0.059	0.581	-0.038	0.310
swh_warmhouse*	-0.002	0.003	-0.016	1.850	0.017	0.915
hhno	0.000	0.002	-0.002	0.240	0.008	0.213
Solar*	0.005	0.006	0.012	0.064	-0.060	0.097
livesente	0.000	0.002	-0.001	0.049	0.010	0.042

	Breakfast energy choice		*Lunch energy choice*		*Supper energy choice*	
	Pr (LPG_gas = 0.3 %) Firewood = 90%		*Pr (Firewood =91%)*		*Pr (Firewood= 96%)*	
Variable	*dy/dx*	*Std error*	*dy/dx*	*Std error*	*dy/dx*	*Std error*
Farmergrp*	0.015	0.019	0.017	0.510	0.041	0.417
Credit*	-0.009	0.009	0.012	1.687	-0.145	1.289
fcopdn	0.000	0.000	0.000	0.009	0.001	0.007
agricont	0.000	0.000	0.000	0.010	0.001	0.009
fw_1farm*	-0.001	0.003	0.057	1.069	-0.004	0.836
firepeople	-0.003	0.004	0.035	0.123	0.004	0.029
hhhead_edu	0.000	0.001	-0.004	0.047	0.002	0.028
HH average_ed	0.000	0.001	0.004	0.086	0.006	0.071
hsize	-0.003	0.003	-0.003	0.109	-0.021	0.091
hhs *	0.004	0.004	0.004	0.323	-0.017	0.288
hhformal *	0.016	0.018	-0.049	1.059	-0.214	0.364
adults_equiv2	0.002	0.002	-0.003	0.077	0.037	0.129
propadults	-0.021	0.022	-0.012	0.390	-0.235	0.961
sqrttree	0.004	0.006	-0.001	0.0055	-0.001	0.065
sqrtlandow	0.003	0.004	-0.025	0.317	-0.041	0.333

(*) dy/dx is for discrete change of dummy variable 0 to 1