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Assessing the Demand for Improved Cook Stoves among Low Income Households in Kenya: Case of Baringo and West Pokot Counties

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Abstract

In recent years, clean and improved cooking solutions have significantly evolved globally, generating an attractive market opportunity for enterprises engaging in the provision of innovative cooking appliances, fuels, and financing to speed uptake of the disseminated technologies. Improved Cook stoves (ICS) have been widely touted for their potential to deliver triple wing benefits of improved agricultural productivity, enhanced household health and time savings through reduced scrimmage in sourcing for biomass fuel, and sustainability through reduced local deforestation, further reducing black carbon emissions. Despite decades of promotion, diffusion of ICS has continued to remain slow. This project aimed at investigating the factors that hinder the uptake of ICS in some selected poor villages from Baringo and West Pokot Counties in Kenya, East Africa. Data was collected from 2918 households across 12 villages and analyzed statistically. On average, households spent approximately KES 2149 on fuel per month, covered 2.15 km and spent around 1.5 hours collecting/getting their primary cooking fuel. Majority of the consumers, 94% expressed willingness to pay (WTP) for an ideal cookstove (one that emits less smoke, saves fuel, safe during cooking, easy to light, and that could cook fast). A majority of the consumers (46.5%) preferred to acquire ICSs through equal monthly installments while 40.47% preferred to pay cash and the rest opted for the "pay-to-use" model and whenever cash was available. From the binary Probit model, consumers' WTP for the ICSs was positively influenced by age and level of education of the head of the family, size of the family, number of children under five years, distance to the source of fuel, and the desire to use and own an ICS. Policies that are aimed at maximizing cook stove effectiveness and uptake among the poor in the target counties and Kenya at large was recommended.

Keywords

Improved Cook Stoves, Descriptive Statistics, Inferential Statistics, Binary Probit, WTP

1. Introduction

The reliance on solid biomass for cooking is a deep-rooted practice for over a third of the world's population (approximately 2.8 billion people), especially in the Low and Middle Income Countries (Stanistreet et al., 2021; Maré & M'rithaa, 2021; Kahlenberg et al., 2021; Kyayesimira & Muheirwe, 2021). Combustion of the solid biomass fuels (wood, charcoal, dung, coal, and crop residues) leads to the emission of black carbon and other greenhouse gases accentuating climate change through forest degradation and deforestation (International Energy Agency (IEA), 2014). It also leads to high levels of indoor air pollution that immensely affects the health of users. Last but not least, the collection of such fuels is time consuming for women and children that are majorly involved in its collection further reducing the time that could have otherwise been invested in economic activities (agricultural activities and business) and education respectively (Boudewijns et al., 2020). As a consequence, the access to modern and sustainable energy for cooking, especially among poor rural households has evolved overtime and moved to the forefront of the discourse of international policy by enshrining access to clean energy in the Sustainable Development Goals (SDG 7) (Africa Energy Portal 2018; United Nations General Assembly (UNGA), 2019).

In Sub-Saharan Africa, bioenergy remains the dominant energy mix accounting for approximately 60% of the total energy use (IEA et al., 2019; World Bank, 2021). In Kenya, the predominant energy supply for over 86% of rural households is wood-based fuel (firewood and charcoal) (Njenga et al., 2017). Cooking with wood-based fuel is problematic not only because of the unsustainable harvesting and degradation of forests but also incomplete combustion of the wood fuel by the traditional cook stoves results in high levels of household air pollution which accounts for approximately 3.7 million annual deaths (Zhang et al., 2022). Furthermore, traditional cook stoves as reported by Ardrey et al. (2021), use solid fuels inefficiently, hence a burden to the collectors (often women and children) translating to an economic cost to the economy and education. Ardrey et al. (2021) further argue that spending more time collecting fuel reduces the time that women and children invest in productive economic activities and education respectively. Despite Kenya's commitment to the Vision 2030 development blueprint, a recent SDG7 progress report indicates that only 26% of Kenyan households use improved biomass stoves, while only 14% have access to clean cooking technologies like Liquefied Petroleum Gas, solar and electric cookers, implying that Kenya is among the top twenty most deficient countries in clean cooking energy access (Avila et al., 2017; Hsu et al., 2021).

To overcome these bottlenecks, Improved Cook stoves (ICS) are overarching technological advancement that must be adopted particularly by the rural households to effectively displace the conventional cooking stoves at a scale capable of achieving environmental, health, social, and economic goals. Due to the poor quality of combustion usually associated with inefficient traditional cook stoves and practices, household air pollution is ascribed to high premature deaths annually (Calzada & Sanz, 2018). Besides products of incomplete combustion are normally associated with high levels of black carbon that significantly contribute to climate change with traditional biomass cooking due to the black carbon contributing to approximately 34% - 45% of warming and up to 8% of the overall global warming. The situation in LMICs like Kenya has further been fueled by increasing populations that has continued to skyrocket firewood harvests to unsustainable rates that continue to threaten livelihoods of people who dwell in firewood depletion hotspots (IEA et al., 2019). Improved cookstoves as explained by Jan (2012), are efficient stoves that easy to light, emits less smoke, saves fuel, are safe during cooking, and cooks faster due to improved combustion of fuel used. ICSs have the ability to burn fuels efficiently resulting in lower air pollutant emissions, saving fuels, hence freeing up women and children, especially girls from unnecessarily longer cooking durations in addition to the health benefits associated with clean cooking (Shen et al., 2015; Ardrey et al., 2021; Mekonnen et al., 2022).

To confront these negative consequences of traditional cooking, a myriad of local, corporate and national driven programmes have been pursued to disseminate ICSs in Kenya. Despite the concerted efforts, progress has been slow with the efforts not successfully reaching scale. In effect, a range of explanations have been put forth for the lack of success of the previous improved cook stove programmes in Kenya. Firstly, critics have pointed out that ICSs (like Jiko Koa among others have generally remained unaffordable for poor households unless enormous subsidies are provided (Stanistreet et al., 2021; Gill-Wiehl, Ray & Kammen, 2021). Secondly, materials needed for the conventional stoves are freely available and requires minimal time to construct. Essentially, the slow progress in the uptake of designed ICS has been tied to the inability to tailor designs that are capable of suiting end-user customs and preferences of cooking culturally vital food types (Robinson et al., 2022; Clifford et al., 2022). Last but not least, ICS technologies often target to benefit women and girls who are primarily engaged in fuel collection and exposure to smoke, yet these categories have limited decision making power in low resource households (Maré &

M'rithaa, 2021; Kahlenberg et al., 2021; Kyayesimira & Muheirwe, 2021; Stanistreet et al., 2021).

It is on the foregoing that this study sought to understand the specific factors that hinder the uptake of ICS among the low-income communities. To achieve this, the project conducted a baseline survey to understand the current cooking information, cook stove use and patterns and household preferences for an ideal cook stove. To ensure affordability and sustainability of the project products (ICS), the project aimed at developing an inclusive and affordable business financing model premised on the income status of the rural poor households in the target community.

2. Methodology

2.1. Study Design

The study was conducted across the rural households in Baringo and West Pokot Counties in Kenya, East Africa through cross-sectional survey primarily focusing on household cooking habits types of cook stoves used, and factors informing the choice of cook stoves. The study team included researchers from the University of Nairobi, KALRO, Egerton University, Kibabii University and local staff from department of Environment. The survey was administered in 2020 and included questions about current household stove and fuel use patterns, beliefs about the health effects of biomass smoke exposure, and preferences regarding stove features and functionality.

Primary data was then collected by trained local enumerators who had no conflicting affiliation with local institutions using semi-structured questionnaires administered in ODK. The survey was conducted in a neutral manner but the questions on respiratory symptoms were well clarified. When asked about stove features, participants were presented with a list from which to select their preferences. Survey questions referenced a broad array of stove types, including the traditional three-stone, open fires, and ICS cooking technologies like enclosed stoves with outdoor venting chimneys, charcoal pots, among others. Survey questions about ICS specifically referenced the rocket stove, side-feed chamber style and the gasifier (or top lit updraft) style; participants were shown a composite set of images of these ICS designs when asked about ICS as a general stove category (**Figure 1**).

Figure 1. Composite image of various ICS shown to respondents when asked for their opinions.

Households from 18 villages from three sub counties in Baringo and 12 villages from two sub counties in West Pokot villages were surveyed. These villages were selected to ensure 10% of the households were surveyed in each of the selected sub county.

2.2. Data Handling and Analysis

Survey data was collected via ODK, transported to excel and exported to Stata for cleaning and analysis. Descriptive analyses were reported for participant responses. Demographic information was obtained; age, socioeconomic status, family size for meal preparation and stove location. Health symptoms reported by household head was also obtained. Measures of association were analyzed. General stove characteristics predicting ICS preference and willingness to pay for them, the issue of multiple predictors was addressed; proximity to biomass resources, reduced smoke production, increased cooking speed, ability to slow cook ("simmer"), health benefits, and reduced risk of burns to children.

For analyses of predictors of stove preference, focus was on determinants of households' willingness to pay for ICS technology leading to a more informed understanding of the make or break approach on the critical aspect of clean cooking among resource poor rural set. In all analyses, p-values < 0.05 were considered statistically significant. All statistical analyses were performed using Stata version 16 and excel.

3. Results and Discussion

This section presents and discusses the empirical findings of the project and is divided into two major parts. Part one presents the descriptive statistics for the socio-economic and institutional characteristics of the potential consumers based on their willingness to pay for improved cook stoves (ICSs). Section two presents the empirical findings of the bivariate Probit model on the critical factors that determine resource poor households' willingness to pay and uptake improved cooking technologies. The descriptive statistics showed that out of the 2918 households that were enumerated, 94% were willing to pay for improved cook stoves while only 6% were fully satisfied with their traditional cook stoves. More households in West Pokot (45.81%) were already using improved cook stoves compared to 30.59% in Baringo. Regarding willingness to pay, more households in Baringo (95.68%, n = 1639) expressed willingness to pay for ICSs as compared to their counterparts in West Pokot (91.62%, n = 1104).

3.1. Descriptive Statistics

3.1.1. Consumer and Consumer Characteristics

From the descriptive statistics, majority of decisions on cooking (83.52%) were made by women while only 6.27% were made by men while 6.34% were made jointly by men and women. In terms of willingness to pay, majority of the female decision makers (78.48%) were willing to pay for ICS while only 5.62% of the men as decision makers were willing to pay. From the inferential statistics, it was found that there was a statistical difference in willingness to pay for ICS between the major decisions makers at 5% level of significance. This could possibly be attributed to gender roles particularly on fuel collection and cooking. With women mostly involved in the kitchen, they are likely to see the increased need for ICS as compared to men.

There was no significant difference in the age of the household head and willingness to pay. This indicates that regardless of age, nearly all the household heads (94%) were willing to pay for ICSs as presented in Table 1. However, the proportion of willingness to pay based on age confirms to priori expectations as majority of the households headed by the young (69.22%) were willing to pay compared to 24.78% of the households that were headed by the relatively old household heads. This could be ascribed to the fact that young household heads are less risk averse, more innovative, and flexible in adapting to new ideas than older household heads who could be more conservative to new cooking technologies. However, due to experience and knowledge on the risks of traditional cooking it was expected that older household heads would be aware of the risks and hence be more willing to uptake ICS.

Table 1. Decision maker, age, education, health hazards, use of ICS, group membership (%).

Variable	Description	Willing to pay	Not willing to pay	Chi Square
Decision Maker on cooking	*Wife*	78.48	5.04	11.019**
	Husband	5.62	0.65	
	Jointly husband and wife	6.17	0.17	
	Other	3.74	0.14	
Age of the household head	*18 - 35*	34.44	2.26	0.645
	36 - 50	34.78	2.23	
	51 - 65	18.51	1.2	
	66+	6.27	0.31	
Education Level	*None*	13.74	2.43	85.402***
	Primary	36.19	1.85	
	Secondary	22.14	1.1	
	College	21.93	0.62	
Experienced Health hazards	*Experienced*	65.52	4.63	4.346**
	Did not experience	28.48	1.37	
Use of Improved cook stoves	*Used ICs*	34.06	2.78	7.138***
	Did not use Ics	59.94	3.22	
Group membership	*Member*	41.09	1.99	7.493***
	Non-member	52.91	4.01	

Note: *, ** and *** denote significant at 10%, 5% and 1% level respectively.

In terms of education level, majority (83.96%) of the consumers had accessed education. On willingness to pay and education level, the Chi Square results indicate that there was a significant statistical difference between the level of education and willingness to pay for ICS. From the proportion, it is clear that the level of education was positively associated with consumers' willingness to pay for ICS with majority of those not willing to pay lacking formal education while only 0.62% of those not willing to pay having attained tertiary education.

On experience with health hazards, the inferential statistics indicated a 5% level of statistical difference between households that experienced health hazards like nose and throat problems, coughing/pneumonia, red/itching eyes, asthma and burns and willingness to pay for ICS. About 66% of the households that had experienced health hazards related to cooking were willing to pay for ICS as compared to 28.48% who had not experienced any health hazard related to cooking. The increased desire by those with prior experience to health hazards could be informed by the need and desire to prevent further occurrences.

Concerning the association between willingness to pay for ICS and use of improved cook stoves, there was a significant statistical difference between households that previously used ICSs and those that had not used them at 1% level of significance. From the frequency, 59.94% of those willing to pay for ICSs had not used them previously compared to 34.06% of those that had used them previously. This could imply the need to reduce on the negative effects of unimproved cook stoves like high emissions, consumption of more fuel and unsafe cooking through burns among others.

On group membership, there was a significant statistical difference between group membership and willingness to pay for ICS at 1% level of significance. As presented in **Table 1**, majority of the households that were not affiliated with groups were more willing to pay for ICS than their counterparts with membership to social groups. This is contrary to priori expectation as groups often act as channels through which new technologies and information are transferred to end-users and platforms through which they could access financial assistance hence ameliorate adoption. However, this could be explained by the fact that members not affiliated to groups may not have been exposed to new cooking technologies and therefore, this was the source of enlightenment as compared to their counterparts in groups. As presented in **Figure 2**, approximately 42% and 44% of households in Baringo and West Pokot respectively were affiliated to social groups.

As presented in **Table 2**, there was a statistical difference in the mean number of family size and the consumers' willingness to pay for ICS at 1% level of significance. The results indicate that households which were willing to pay for ICS on average had more than 6 members as compared to 5 of those that that were not willing to pay for ICS. Higher willingness to pay may be due to increased usage of fuel and more family members affected by health hazards associated with cooking, hence families may have the desire to save on fuel.

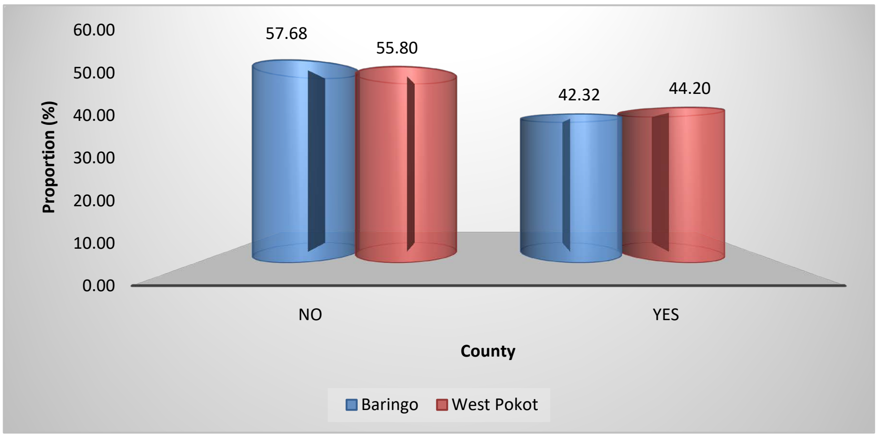

Figure 2. Participation in social groups.

Table 2. Mean household size, children under 5, income, distance to fuel, amount to be paid.

Variable	Willingness to pay	Mean	Std. Err.	t-Stat
Household Size	No	4.54	0.14	9.0268***
	Yes	6.45	0.05	
Children under 5 years	No	1.35	0.1	1.2419
	Yes	1.21	0.03	
Monthly Income	No	6264.77	824.22	3.6272***
	Yes	10564.86	294.76	
Distance to the fuel source	No	1.03	0.08	3.4499***
	Yes	1.56	0.04	
Future amount of ICSs	No	446	42.31	4.4123***
	Yes	1750.955	74.64	
Land size	No	4.81	0.57	1.4836
	Yes	6.19	0.22	

Note: *, ** and *** denote significant at 10%, 5% and 1% level respectively.

On average, the monthly income of the households in the two counties was around KES 10,306. As presented in Table 2 households that were not willing to pay for ICS on average made around KES 6265 while those that were willing to pay for ICS made around KES 10,565. The result t-statistics indicate that there was a statistical difference between monthly income and willingness to pay for ICS at 1% level of significance. Monthly income signifies the purchasing power of a household and therefore, a household with a higher income is in a position to purchasing the needed ICS as compared to those with low incomes.

The mean distance to the main source of fuel was 1.53 KM. The inferential statistics indicated that the distance to the source of fuel by households that were not willing to pay for ICS was 1.03 KM while for those that were willing to pay was 1.56 KM. The statistical difference between distance to the primary source of fuel and willingness to pay for ICS was significant at 1%. Distance reflects the opportunity cost of agricultural productivity and other livelihood enterprises. Willingness to pay for ICS was also statistical different between the amount that households were willing to pay for ICS at 1% level of significance with those willing to pay for the ICS willing to part around KES 1750.

3.1.2. Mode of Accessing Primary Source of Fuel

To understand the average cost of fuel, the project aimed to first understand the modes through which the target communities could access the primary fuel. It was found that the communities mostly accessed their primary fuels through collection, purchasing and combination of collection and purchasing. As presented in Figure 3, majority of the households (63.46% in Baringo and 64.65 in West Pokot) accessed their primary fuel through collection followed by collection and purchasing in Baringo at 17.22% and buying at 15.44% in West Pokot.

3.1.3. Cost of Fuel

On average, households in Baringo spent approximately KES 1978 on firewood in a month while those in West Pokot spent approximately KES 2150. On charcoal, households in Baringo and West Pokot spent around KES 672 and KES 892 respectively while on LPG households in Baringo and West Pokot spent approximately KES 1190 and KES 1188 respectively (Figure 4).

Improved Cook Stove Financing Model

For increased adoption and affordability of the ICS designed (Figure 5), the project sought to find a suitable model of payment that could be inclusive and convenient for the rural resource poor households in the two counties. Majority of the households in Baringo (54.47%) preferred to pay through equal monthly installments while those in West Pokot (49.21%) preferred to pay through cash on delivery. The second most preferred mode of payment for the ICS in Baringo was Cash on delivery (34.33%) while in West Pokot was Equal monthly installment (35.19%). This information is therefore, critical in informing the upscaling of ICS in the two Counties.

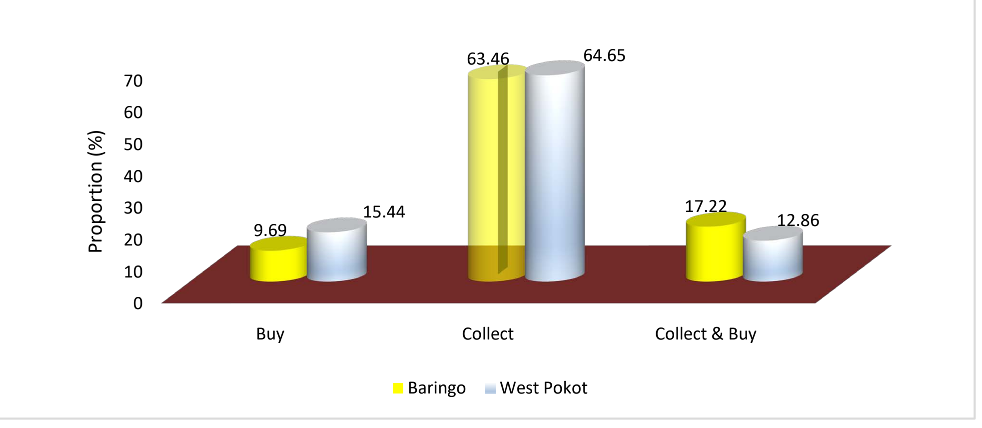

Figure 3. Mode of accessing primary fuel.

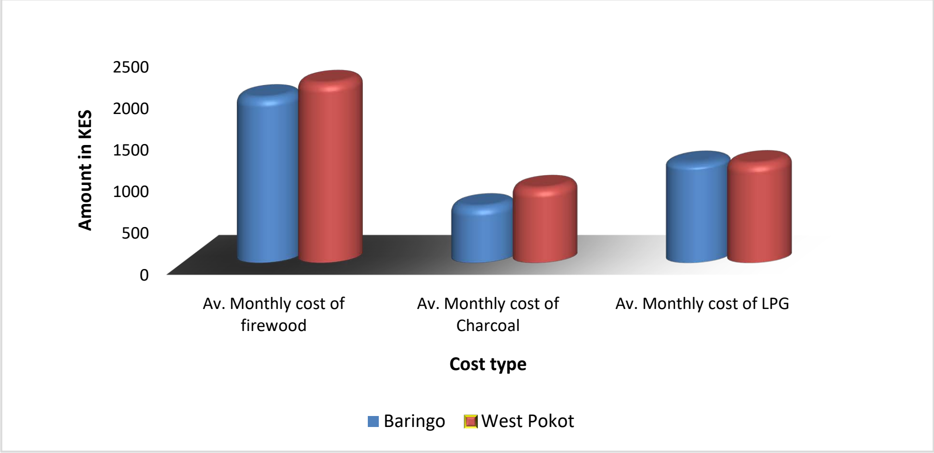

Figure 4. Monthly cost of fuel.

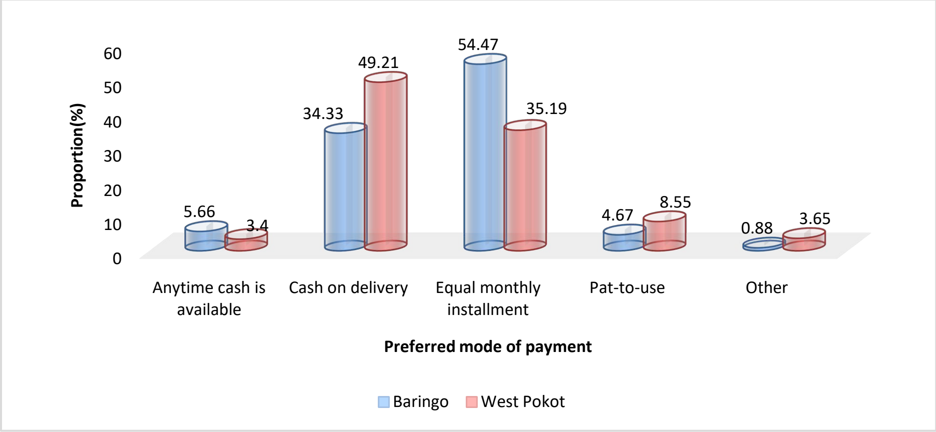

Figure 5. Preferred mode of payment.

3.1.4. Statistical Tests and Specification Diagnostics for Bivariate Probit Model

Since the study used cross-sectional data, there was need to ensure data compliance and consistency since this type of data is often associated with problems of heteroscedasticity and multicollinearity. Therefore, it was paramount to conduct preliminary tests and diagnostics, including the pair-wise correlation (pwcorr) and Variance Inflation Factor (VIF). Multi-collinearity is a state of moderate to high inter-associations among the predictor variables culminating into unreliability of the statistical inferences about a given dataset (Kavzogluet al., 2014; Vu et al., 2015; Heit et al., 2017). Variance Inflation Factor and pair-wise correlations were performed to test the presence of higher associations among the continuous and categorical explanatory variables respectively (Akinwande et al., 2015; Rahman et al., 2021). VIF is used to determine the precision of estimation in a regression model by expressing the level of interdependence among predictor variables that could otherwise reduce the precision of the model estimate (Kavzoglu et al., 2014).

By rule of thumb, VIF values above 5 in a regression indicate the presence of high association among the predictor variables of a regression model (Kavzoglu et al., 2014; Akinwande et al., 2015; Rahman et al., 2021). VIF values above 10 indicate poorly estimated regression coefficients. The VIF for Probit regression model used to determine the factors influencing household's willingness to pay for the ICS was 2.48, indicating that there was no strong association among all the continuous predictor variables in the Probit regression model premised on the rule of thumb as all the VIF values were less than 5 (Mutale et al., 2017).

Similarly, a pair-wise correlation was conducted for the categorical variables to test for multi-collinearity and the results as presented in **Table 3** indicated that the categorical variables were also not highly interdepended. By the rule of thumb, values above 0.7 in a pair-wise correlation indicate higher levels of correlation among the categorical variables used in predicting a regression (Vu et al., 2015; Heit et al., 2017). Premised on the test, the proposed explanatory variables exhibited values lower than the threshold 0.7, indicating absence of any problem involving two or more covariates used in the model. Therefore, all the potential predictor variables were retained for the execution of the Probit regression model to determine the specific factors that influenced household's willingness to pay for ICS.

Maximum likelihood method was used to estimate the Probit regression model. From the test results presented in **Table 3**, the model coefficients (cut1, cut2, cut3, and cut4) were −2.1280, −1.4427, 0.2143, and 2.1233. The log likelihood of the fitted model was −237.9466 implying that the model converged and predictors used in the regression were significantly different from zero. The number of observations as indicated by the Probit regression results were 1571 indicating the number of the households that gave their feedback regarding the possibility of willing to pay for the ICS. Furthermore, the log likelihood Chi-square (LR Chi^2 (21)) was 179.55 indicating that all the parameters were jointly significant at 1% therefore, the model had a good fit. The McFadden's Pseudo R-squared (Pseudo R^2) was 0.2739 indicating that the explanatory power of the model was stronger as it was above the statistical threshold value of 20% as asserted by Srisopaporn et al. (2015) further confirming that the willingness of the households to pay for the ICS were ascribed to the covariates considered in the model.

The results indicate that among the 14 hypothesized predictor variables used in the model, eight were found to significantly influence households WTP for the ICS. These included the age of the household head, education level, household size, children under the age of 5 years, geographic and environmental factors, distance to the source of fuel, future price of ICS, and previous use of ICS as shown in **Table 3**.

3.2. Econometric Analysis and Estimation of ICS Adoption Factors

In this section we discuss the relevant predictors of household's willingness to pay for the ICS through Probit estimation and the marginal effects (dy/dy) of each significant predictor used in the Probit model.

Table 3. Factors influencing willingness to Pay for ICS.

Variable	Coefficient	Std. Error	$p > \|z\|$	Marginal effects (dy/dx)
Gender	−0.0046	0.0043	0.2860	−0.058
Age of the household head	−0.1473*	0.0793	0.0630	−0.016
Education level	0.2375***	0.0804	0.0030	0.073
Household size	0.1955***	0.0304	0.0000	0.062
Children under 5 years	0.0410*	0.0221	0.0640	0.043
Disabled members	−0.0271	0.2271	0.9050	−0.241
Experienced Health hazards	0.1381	0.1508	0.3600	0.004
Location	−0.2765	0.1596	0.0830	−0.156
Land size	−0.0024	0.0118	0.8400	−0.038
Monthly income	2.0306	6.4806	0.7540	0.013
Distance to fuel source	0.2298***	0.0791	0.0040	0.096
Future price of ICs	−0.0006**	0.0001	0.0000	−0.024
Group membership	0.1235***	0.1333	0.3540	0.057
Previous use of ICs	−0.3254**	0.1322	0.0140	−0.018
Probit regression		No. of obs = 1571		
		LR Chi^2 (14) = 179.55		
		Prob > Chi^2 = 0.0000		
Log likelihood = −237.9466		Pseudo R^2 = 0.2739		

Note: ***, **, * significant at 1%, 5% and 10% probability respectively.

Influence of Household Characteristics

Gender; despite the effect of gender of the household head being statistically insignificant, it was found that female headed households had a lower likelihood of adopting ICS as their primary cooking stoves than their male counterparts. Participant observation pointed out although budget allocation was mostly a responsibility for the men, they did not directly undertake fuel procurement and cooking tasks. This could further be attributed to the low income status of the female-headed households as compared to the male-headed households across all the study areas (descriptive statistics). Therefore, education and awareness for clean cooking is inevitable since the negative outcomes of cooking with traditional cook stoves are not necessarily reflected in the decision-making of cooking in typical rural households.

The age of the household head had a positive and significant effect on the willingness of the households to pay for the ICS at 10% level of significance. This implies that households with relatively older household heads were more likely to pay for the ICS as compared to the younger household heads. This, as argued by Lavison (2013), could be explained by the fact that older household heads are more experienced and based on their past experiences are more likely to be aware of the costs (health, environment, and financial) associated with unimproved cook stoves and therefore, more willing to have ICS than younger household heads.

A unit increase in the level of education by the household head increases the likelihood of ICS adoption by 7.3% at 1% level of significance. This implies that household heads with higher education levels are more likely to pay for the ICS than their counterparts. This is because education enhances an individual's ability to acquire process and respond to new technologies. Education also shapes one's thoughts and perceptions making them rational and capable of analyzing the benefits associated with ICS and hence, adoption.

There was a positive and significant relationship between the size of the household and willingness to pay for improved cook stoves at 1% level of significance, implying that WTP for ICS increases with an increase in the size of the household members. From the marginal effects, it is clear that the probability for willingness to pay for ICS increases by 6.2% for each additional person to a household ($p < 0.001$). This alludes to the fact that fuel consumption is higher when there are more people in a household, hence the need for primary cook stoves that use fuel more efficiently. However, other studies argue that a larger household size implies additional labour for fuel collection especially in the rural areas and hence likely to have a negative effect on the willingness to pay for ICS.

The effect of children under the age of 5 years was statistically significant at 10% with a positive effect on willingness to pay for ICS as primary cook stoves implying that households that had more children under the age of 5 years were more likely to pay for ICS as compared to their counterparts with few or none. Assessing the marginal effects of children under 5 years on willingness to pay for ICS, it was inferred that the presence of an extra child under the age of 5 years increased the probability of a household paying for ICS by 4.3% ($p < 0.01$). This could partly be associated with the frequency of cooking and or warming of food for children under the age of 5 years, hence the need for primary cook stoves that are efficient on fuel consumption. Secondly, children under this age need closer attention and since most of the care is a responsibility of the women and girls who as evidenced in the descriptive statistics are the major fuel collectors (61% and 27.3% respectively), there is a need for such households to have primary cook stoves that use fuel efficiently.

Proximity of the household to biomass resources had a positive and significant relationship with the households' WTP for improved cook stoves. As evidenced by the marginal effects, the probability of households particularly those that rely on self-collected fuelwood paying for the ICS as their primary cook stoves increases by 9.6% with each additional kilometer walked to the forest/woodland from homesteads to collect fuel wood ($p < 0.01$). This could directly be linked to the amount of time and energy that could be saved hence free women and girls for other involvements, including agricultural activities and businesses especially SMEs. Therefore, such households will be more likely to pay for the ICS to save time and energy of collecting solid biomass and reinvest it in other productive economic activities.

However, the future price of ICS had a negative and statistically significant effect on the households' WTP for ICS as their primary cook stoves at 1% level of significance. This infersthat a unit increase in the price of ICS in the future is likely to reduce the willingness of households paying for ICS as primary cook stoves. The marginal effects from the probit model indicate that an increase the price of the ICS by 1 unit of currency in the future is likely to cause a 2.4% dip in the demand and willingness to pay for ICS as primary cook stoves. This could be explained by economic assumption on human behavior that all consumers are rational and will tend to go for substitutes or reduce their demand on products with relatively higher prices.

The results also indicated that social groups were a cardinal determinant of households' willingness to pay for ICS as primary cook stoves in the study areas. Households that were affiliated social groups had a significantly higher probability of paying for ICS as primary cook stoves by 5.7% compared to non-participating households ($p < 0.01$). This could primarily be ascribed to information exchange and social capital associated with group membership. Participant observation as evidenced by descriptive statistics revealed that women are mostly involved in local social groups referred to as "chamaas", merry-go round, table banking, among others. Through these arrangements, members are often able to pool money in modest amounts to support each other in rotational procurement of vital basic household assets like ICS. Social groups could also be an entry point into the target areas for training, creation of awareness and sustainability of the improved cook stove project.

4. Conclusion

This work focused on the use of inferential and empirical analysis as a methodology for understanding and predicting consumers' intentions to adopt ICS in Baringo and West Pokot Counties. The approach focused on the factors that motivate adoption of improved cooking solutions, sustained use of the adopted technology for impact evaluation. The results indicate that households spent heavily per month (KES 2149) and use more time (1.5 hours/day) on buying and collecting their primary cooking fuel respectively. The results further indicate that majority of the community members (94%) were willing to pay for an ideal cookstove that is efficient in cooking. The willingness of community members to pay for the ICS was influenced by age and level of education of the head of the family, size of the family, number of children under five years, distance to the source of fuel, and the desire to use and own an ICS. Finally, it was established that the target communities did not have the ability to procure the coking technologies on cash but preferred to acquire ICS through equal monthly installments while only a few preferred the "pay-to-use" model.

Therefore, the findings of this study are cardinal in twofold, first they inform the engineering design of the ideal cook stoves and secondly inform policy design through financing model, time spent, and gender mainstreaming for promoting sustained and consistent long-term adoption of improved cook stoves. From the perspective of engineering design, the study sheds comprehensive light on critical attributes of the ICS technology that need to be put under consideration to influence and convince the end users to use the new cooking solutions. Consequently, the cook calibration process is guided on the essential attributes and the extent to which they should influence cook stove design to ensure a user-centered design that captures all the preferred attributes for an ideal cook stove including; low emissions, low rate of fuel consumption, safe during cooking, easy to light and convenient for common meals.

From a policy design angle, the study would enable policy makers to craft policies that reflect the widespread beliefs, behavioral attributes, cultural tendencies, and supply side barriers that can ameliorate scale adoption of the ICS which will, in turn, positively impact public health hence individual productivity, curb climate change through reduced deforestation and less carbon emission, and save time spent on fuel collection for increased time in agricultural productivity and other livelihoods.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Africa Energy Portal (AEP) (2018). *Sub-Saharan Africa Power 2018*. https://africa-energy-portal.org/events/sub-saharan-africa-power-2018

Akinwande, M. O., Dikko, H. G., & Samson, A. (2015). Variance Inflation Factor: As a Condition for the Inclusion of Suppressor Variable(s) in Regression Analysis. *Open Journal of Statistics, 5,* 754-767. https://doi.org/10.4236/ojs.2015.57075

Ardrey, J., Jehan, K., Desmond, N., Kumbuyo, C., Mortimer, K., & Tolhurst, R. (2021). 'Cooking Is for Everyone?': Exploring the Complexity of Gendered Dynamics in a Cookstove Intervention Study in Rural Malawi. *Global Health Action, 14,* Article ID: 2006425. https://doi.org/10.1080/16549716.2021.2006425

Avila, N., Carvallo, J. P., Shaw, B., & Kammen, D. M. (2017). The Energy Challenge in Sub-Saharan Africa: A Guide for Advocatses and Policy Makers. In Pfeifer, K. (Ed.), *Generating Energy for Sustainable and Equitable Development, Part 1* (pp. 1-79). Oxfam Research Backgrounder Series. https://www.aler-renovaveis.org/contents/lerpublication/oxfam_rael_2017_jan_the-energy-challenge-in-sub-saharan-africa-a-guide-for-advocates-and-policy-makers-part-1.pdf

Boudewijns, E. A., Vermond, D., van der Kleij, R. M., Chavannes, N. H., van Schayck, O. C., Kirenga, B., & Brakema, E. A. (2020). Factors Critical to Implementation Success of Cleaner Cooking Interventions in Low-Income and Middle-Income Countries: Protocol for an Umbrella Review. *BMJ Open, 10,* Article ID: e041821. https://doi.org/10.1136/bmjopen-2020-041821

Calzada, J., & Sanz, A. (2018). Universal Access to Clean Cookstoves: Evaluation of a

Public Program in Peru. *Energy Policy, 118,* 559-572.
https://doi.org/10.1016/j.enpol.2018.03.066

Clifford, M. J., Robinson, B. L., Hewitt, J., & Jewitt, S. (2022). Cooking for Communities, Children and Cows: Lessons Learned from Institutional Cookstoves in Nepal. *Energy for Sustainable Development, 66,* 1-11. https://doi.org/10.1016/j.esd.2021.10.012

Gill-Wiehl, A., Ray, I., & Kammen, D. (2021). Is Clean Cooking Affordable? A Review. *Renewable and Sustainable Energy Reviews, 151,* Article ID: 111537.
https://doi.org/10.1016/j.rser.2021.111537

Heit, J. A., Armasu, S. M., McCauley, B. M., Kullo, I. J., Sicotte, H., Pathak, J., & Roden, D. M. (2017). Identification of Unique Venous Thromboembolism-Susceptibility Variants in African-Americans. *Thrombosis and Haemostasis, 117,* 758-768.
https://doi.org/10.1160/TH16-08-0652

Hsu, E., Forougi, N., Gan, M., Muchiri, E., Pope, D., & Puzzolo, E. (2021). Microfinance for Clean Cooking: What Lessons Can Be Learned for Scaling up LPG Adoption in Kenya through Managed Loans? *Energy Policy, 154,* Article ID: 112263.
https://doi.org/10.1016/j.enpol.2021.112263

IEA [International Energy Agency], IRENA [International Renewable Energy Agency], UNSD [United Nations Statistics Division], WB [World Bank], & WHO [World Health Organization] (2019). *Tracking SDG 7: The Energy Progress Report 2019*. World Bank.
https://worldbank.org/en/topic/energy/publication/tracking-sdg7-the-energy-progress-report-2019

International Energy Agency [IEA] (2014). *Africa Energy Outlook a Focus on Energy Prospects in Sub-Saharan Africa World Energy Outlook Special Report* (pp. 37-38). International Energy Agency / Organization for Economic Co-operation and Development.

Jan, I. (2012). What Makes People Adopt Improved Cookstoves? Empirical Evidence from Rural Northwest Pakistan. *Renewable and Sustainable Energy Reviews, 16,* 3200-3205. https://doi.org/10.1016/j.rser.2012.02.038

Kahlenberg, S. M., Bettinger, T., Masumbuko, H. K., Basyanirya, G. K., Guy, S. M., Katsongo, J. K. et al. (2021). A Case Study of Improved Cook Stoves in Primate Conservation from Democratic Republic of Congo. *American Journal of Primatology, 83,* e23218.
https://doi.org/10.1002/ajp.23218

Kavzoglu, T., Sahin, E. K., & Colkesen, I. (2014). Landslide Susceptibility Mapping Using GIS-Based Multi-Criteria Decision Analysis, Support Vector Machines, and Logistic Regression. *Landslides, 11,* 425-439. https://doi.org/10.1007/s10346-013-0391-7

Kyayesimira, J., & Muheirwe, F. (2021). Health Concerns and Use of Biomass Energy in households: Voices of Women from Rural Communities in Western Uganda. *Energy, Sustainability and Society, 11,* Article No. 42.
https://doi.org/10.1186/s13705-021-00316-2
https://link.springer.com/article/10.1186/s13705-021-00316-2

Lavison, R. (2013). *Factors Influencing the Adoption of Organic Fertilizers in Vegetable Production in Accra*. M.Sc. Thesis, University of Ghana.

Maré, M., & M'rithaa, M. K. (2021). *The Influence of Behaviour Centred Design Approaches on the Flame-Based Cookstove-Related Health and Wellbeing of Indigent South African Households*. Machakos University Press.

Mekonnen, A., Beyene, A., Bluffstone, R., Gebreegziabher, Z., Martinsson, P., Toman, M., & Vieider, F. (2022). Do Improved Biomass Cookstoves Reduce Fuelwood Consumption and Carbon Emissions? Evidence from a Field Experiment in Rural Ethiopia. *Eco-*

logical Economics, 198, Article ID: 107467.
https://doi.org/10.1016/j.ecolecon.2022.107467

Mutale, G., Kalinda, T., & Kuntashula, E. (2017). Factors Affecting the Joint Adoption of Herbicides and Conservation Tillage Technologies among Smallholder Farmers in Zambia. *Journal of Agricultural Science, 9,* 205-222.
https://doi.org/10.5539/jas.v9n12p205

Njenga, M., Mendum, R., Gitau., Iiyama, M., Jamnadass, R., & Watson, C. (2017). Trees on Farms Could Satisfy Household Firewood Needs. *Miti Magazine - The Tree Farmers Magazine for Africa, No. 33,* 20-23.

Rahman, M. M., Zimmer, M., Ahmed, I., Donato, D., Kanzaki, M., & Xu, M. (2021). Co-Benefits of Protecting Mangroves for Biodiversity Conservation and Carbon Storage. *Nature Communications, 12,* Article No. 3875.
https://doi.org/10.1038/s41467-021-24207-4

Robinson, B. L., Jewitt, S., Clifford, M. J., & Hewitt, J. (2022). Understanding the Current Market Enablers for Nepal's Biomass Cookstove Industry. *Development in Practice, 32,* 52-68. https://doi.org/10.1080/09614524.2021.1893659

Shen, G., Lin, W., Chen, Y., Yue, D., Liu, Z., & Yang, C. (2015). Factors Influencing the Adoption and Sustainable Use of Clean Fuels and Cookstoves in China—A Chinese Literature Review. *Renewable and Sustainable Energy Reviews, 51,* 741-750.
https://doi.org/10.1016/j.rser.2015.06.049

Srisopaporn, S., Jourdain, D., Perret, S. R., & Shivakoti, G. (2015). Adoption and Continued Participation in a Public Good Agricultural Practices Programme: The Case of Rice Farmers in the Central Plains of Thailand. *Technological Forecasting and Social Change, 96,* 242-253. https://doi.org/10.1016/j.techfore.2015.03.016

Stanistreet, D., Phillip, E., Kumar, N., Anderson de Cuevas, R., Davis, M., Langevin, J. et al. (2021). Which Biomass Stove(s) Capable of Reducing Household Air Pollution Are Available to the Poorest Communities Globally? *International Journal of Environmental Research and Public Health, 18,* Article No. 9226.
https://doi.org/10.3390/ijerph18179226

United Nations General Assembly (2019). *Transforming Our World: The 2030 Agenda for Sustainable Development.* United Nations General Assembly.

Vu, D. H., Muttaqi, K. M., & Agalgaonkar, A. P. (2015). A Variance Inflation Factor and Backward Elimination Based Robust Regression Model for Forecasting Monthly Electricity Demand Using Climatic Variables. *Applied Energy, 140,* 385-394.
https://doi.org/10.1016/j.apenergy.2014.12.011

World Bank (2021). *World Bank Sustainable Energy for All (SE4all) Database (2021).* World Bank.

Zhang, Y., Zhao, B., Jiang, Y., Xing, J., Sahu, S. K., Zheng, H. et al. (2022). Non-Negligible Contributions to Human Health from Increased Household Air Pollution Exposure during the COVID-19 Lockdown in China. *Environment International, 158,* Article No. 106918. https://doi.org/10.1016/j.envint.2021.106918