Discrete Choice Modelling study

Rwanda

Working paper

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Energy 4 Impact

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Executive Summary

This report was commissioned by Loughborough University, the lead implementing partner on the Modern Energy Cooking Services (MECS) programme.

This report presents the findings and learnings from a discrete choice modelling (DCM) study conducted to explore the preferences of potential users in Rwanda for electric cooking products/services, through gathering data on user preferences regarding various aspects of the design and functionality of cooking devices, and existing expenditures on cooking fuels, cooking practices and the quality of electricity supply. The study uses choice models to predict the probability of choosing a cooking product based on specific characteristics or parameters.

300 interviews with households (HHs) representatives have been conducted in Kigali city and Bugesera district within a 3-week period. In addition to questions on cooking practices, the quality of electricity supplied, and expenditure on cooking fuels, survey questions asked respondents to make choices between two discrete products' options with different design parameters. Choice models were set up using choice cards, based on the key parameters identified, each of which having a limited number of levels. The respondent would choose one of the two cards presented.

The DCM key findings have been summarized into overview of the survey sample, electricity connection and supply, overview of cooking behaviours, cooking fuels consumption and cost, beliefs and perceptions, experience with technology, and discrete choice modelling results.

Overview of the survey sample

The survey sample predominantly consisted of female (77%) and youth (55%) respondents. Half of all respondents were educated to higher than secondary level. Half of the interviewed HHs were in urban areas, 33% in peri-urban whilst 17% were in rural areas. The majority of the HHs (68%) had fewer than 5 people, whilst more than 10 people per HH were only found in 1% of the interviewed HHs.

The study has shown that, for either urban or rural HHs, around 85% of the main cooks were female.

Electricity connection and supply

Except for 3 HHs which were not connected to any source and 1 HH using a solar home system, all other urban and peri urban HHs were connected to the national grid. Selected rural HHs were connected to the ARC Power's solar mini grid in Bugesera district. Electric appliances ownership was highest in urban HHs, with the exception of radios and mobile phones which were comparably owned in most urban and rural HHs.

87% of grid connected HHs reported 2 or fewer power outages a month, lasting less than 30 minutes each in 90% of the cases. Higher power outage occurrences have been reported on the solar mini grid, going up to 5 times a month (43% HHs) and each time lasting more than 30 minutes.

Overview of cooking behaviours

Charcoal was the most popular main fuel, used in 46% of HHs, followed by LPG (39%), then firewood (13%). Furthermore, when considering settlements locations, LPG was the mostly used main fuel in urban HHs (75% of the LPG-using HHs) and rarely used in rural HHs (3% of the LPG-users). Charcoal was the popular main fuel in peri urban HHs, whilst firewood dominated in rural HHs (80%) and rarely existent as a main fuel, in urban HHs. eCooking, however, was hardly used as a main fuel at 1% in all HHs. Nevertheless, when considering supplementary usage, it was reported as being used in 22% of HHs, practically all urban HHs. More than half of the HHs that used eCooking used it for only few selected dishes. It was used regularly in very few HHs.

Most of urban HHs (90%) cooked 3 meals a day, whilst rural HHs generally prepared 2 meals per day. Nevertheless, approx. 30%of rural HHs also prepare 3 meals a day.

Cooking fuels consumption and cost

The main cooking fuels (LPG, charcoal, and firewood) seem to be purchased monthly. 78% of LPG-users and 58% of charcoal users purchase them once a month, whilst 78% of firewood users purchase it twice a month. Home-delivery services for cooking fuel has taken off, with 90% of LPG-users and 58% of charcoal users getting them delivered at their homes. Firewood lags behind as only 17% users get it home delivered. Considering HHs where they are used as main fuels, the HHs' mean LPG monthly cost was found at USD18.3, that of charcoal at USD11.4, whilst firewood was at USD10.

Beliefs and perceptions

Experience from users indicates that each main fuel was found expensive by its users. On the other hand, non-users' opinions on cooking fuels indicates that charcoal was found expensive by majority of its non-users (67%), whilst only 27% of LPG and 20% of firewood non-users found them expensive. Encouragingly enough, less than half (40%) of eCooking non-users found it expensive.

The survey indicates there is awareness around respiratory health problems associated with cooking fuels' smokes as 62% of the respondents, including the majority of firewood (70%) and charcoal users (66%) reported smoke from cooking fuels as a big problem for their family.

73% of the respondents believed that many people would switch to modern fuels (LPG or electricity) if their cooking cost was the same as the current expenditure on charcoal or firewood. This, coupled to the fact that electricity was reported convenient to cook with by 52% of its non-users, might favour the adoption of eCooking should the promotional campaign take off. Although most users of each fuel reported it convenient to cook with, only 15% of firewood non-users qualified it as convenient, whilst half reported both LPG and charcoal convenient to cook with.

Experience with technology

A contrast in ownership (45%) and often watching (15%) television observed in rural HHs can be explained by the intended reduction in electricity bill. Internet access was observed in urban HHs (80%), whilst only for 10% of rural HHs, which can partly be explained by its low penetration in rural areas. This impacts on different levels including access to financial services. For instance, only 30% of the rural respondents had ever used a mobile banking application, in contrast with 85% of urban respondents. Nevertheless, other non-internet-required form of financial services such as mobile money was almost universal (90%) even in rural area.

Discrete choice modelling results

People seemed to prefer low-cost cooking appliances, pots which provides them the possibility to use the lid or not whenever they see fit, showed preference to appliances with multiple hobs (the more hobs the better), preferred appliances that can both boil and fry, and appliance that cook fast. They also stressed the importance of avoiding appliances that emit smoke like the ones from wood fire, the ability to move the cooking appliance in and out of the kitchen, the capacity to cook for many people, ability to last long, and they expressed that they are happier supplementing their appliance with another stove. Additionally, people preferred weather-independent appliances, easy to clean, ability to pay half upfront with the rest paid in instalments and would like to be having a TV as an addition to the cooking appliances.

Further analysis showed that respondents' gender, households' size, and technology proficiency did not have any effect on the choice of appliance's characteristics. Type of settlement and type of main cooking fuel, however, were found to have an influence on the preference choice of appliance's cost, number of hobs, wood-like smoke emissions, its portability, use of supplementary appliance, capacity in terms of number of people it cooks for, its availability in terms of weather dependence, and its ease of cleaning. In addition to these above-mentioned choice preferences, the domestic status had influence on appliance's financing mechanisms. The respondents' age, on the other hand, seemed to influence the choice of appliance's cost, number of hobs, wood-like smoke emissions, use of supplementary appliance, capacity in terms of number of people it cooks for, its availability in terms of weather dependence, and its ease of cleaning.

Table of Contents

List of figures

List of tables

1. Introduction

Background of the study

Energy 4 Impact (E4I) was contracted through Loughborough University, the lead implementing partner for the five-year Modern Energy Cooking Services (MECS) programme, to be the in-country partner for Rwanda. The programme aims to accelerate the global transition from traditional biomass-based cooking to modern-energy cooking solutions. The discrete choice modelling study is one of the research pieces E4I will do in Rwanda to understand consumer environments and to gather new insights into consumers' wishes and cultural cooking practices in Rwandan HHs.

The DCM study serves as a market research quantitative tool that provides a more realistic picture of customer preference in cooking technologies to better inform design, pricing, and marketing of eCooking appliances. It enables product or service providers to predict the probability that a target market or customers will choose a product or service based on specific characteristics or parameters, defined in this study as, cooking processes (e.g., speed of cooking), stove design (e.g., smoke emissions), and functionality (e.g., lights, mobile phone charging, TV, ability to clean, financing plans).

This DCM report is based on primary data collected by E4I in April 2022. E4I carried out interviews with 300 respondents across six different clusters within Kigali city and Bugesera district. This report analyses empirical evidence on preferences of cooking appliances' characteristics, electricity use, cooking energy (quantity and choices), cooking perceptions, as well as respondents' feedback on the experience with technology and intra-household decision making.

The cooking landscape in Rwanda

In Rwanda, there is still a huge reliance on traditional fuels for cooking. In rural areas, firewood accounts for 93% of the fuel used for cooking. Even in urban areas, firewood represents 26.3% of cooking fuel, with charcoal being the most common (65% of the total cooking fuel used). With firewood and charcoal as the prevalent cooking fuels, the use of traditional cooking technologies is also common in Rwanda. Traditional stoves are the most commonly used (53%) by HHs, followed by charcoal or open fire stoves (with 16%) (NISR, 2018).

As a result, access to clean cooking acts as a significant bottleneck when it comes to improving the health and well-being of Rwandan HHs. The Government of Rwanda (GoR), through its Rwanda Energy

Policy, recognises both the environmental and health threats presented by the overexploitation of biomass – in particular, firewood and charcoal. HH air pollution (HAP) from solid fuel use is the fourth-leading risk factor for morbidity and mortality in Rwanda, and respiratory infection is the leading cause of loss of life (IHME, 2021). It is estimated that annually, more than 7,383 premature deaths in Rwanda are attributable to HAP, with total welfare losses of U$ 674 million per year (World Bank and IHME, 2016). On average, 76% of HHs spend at least seven hours per week acquiring fuel, either by collecting or purchasing it and preparing the fuel for their stoves, with a disproportionate burden on HHs using firewood (World Bank, 2020). Women and girls also disproportionately bear the burden of fuel collection and cooking-related activities. As a result, women and children are more susceptible to HAP and associated adverse health effects, and chores relating to cooking take a considerable amount of their time, which otherwise could be used for other productive activities such as education or employment (World Bank, 2020).

eCooking in Rwanda

According to the Rwandan Government's Biomass Energy Strategy, electricity is an alternative source of energy for cooking, particularly for the hospitality sector and high-income segments of the population. Progress in electricity generation and electricity access in recent years has meant that Rwanda experiences significant surpluses of energy during off-peak hours, while power supply and demand become more closely matched in peak evening hours. This, in addition to the challenge of low electricity demand across the country, indicates that using electricity for cooking through "smart" electricity tariffs around meal hours might help to absorb the excess baseload electricity in the daytime, and help reduce the dependence on biomass at the same time. The inclusion of eCooking appliances within the recent clean cooking results-based-finance window by the Development Bank of Rwanda (BRD) (BRD, 2021a) has been seen as a positive development.

All around Kigali city, there are several shops selling eCooking appliances. However, there is a lack of after-sales service and little awareness of their benefits, which has hampered their adoption. Encouragingly, there is growing interest from private companies such as Electrocook and BURN Manufacturing in selling and, in the long term, manufacturing EPCs in Rwanda, which would reduce considerably most of the barriers to adoption of eCooking.

Aims of the study

The aim of this study is to explore the preferences of potential users in Rwanda for electric cooking products/services.

In particular, the specific objective is to gather data on:

- User preferences regarding various aspects of the design and functionality of cooking devices.
- Existing expenditures on cooking fuels, cooking practices and the quality of electricity supply.

Methodology

Study set up

To ensure that data was captured as accurately as possible and the smooth implementation of the study, the recruited enumerators had good knowledge of the neighbourhood and HH characteristics, as they were coming from the assigned clusters. Specifically, enumerators had the following characteristics:

- University graduates or in the university
- Familiar with the HHs in their locality
- Committed to be available the whole period of the study
- Computer literate and familiar with common languages spoken in Rwanda such as English, Kinyarwanda and French
- Familiar with the cooking processes of most common Rwandan dishes

Enumerators received a 2-day training on the study overview, objectives, and methodology particularly on choice cards method designed to make a discrete option between 2 distinct choices. The training also included data recording using Kobo toolbox. The KoboCollect digital survey tool was used to collect and record data. However, choice cards were printed out on paper to allow for a better graphics' visualization.

Study area

The study was carried out in 6 sectors from 4 districts located in 2 provinces (Table 1). These sectors were chosen to capture urban, peri-urban, and rural character of households (Figure 1).

Table 1: Discrete Choice Modelling study location

Province	District	Sector	Urbanization class	# of households
Kigali city	Kicukiro	Kanombe	Peri-urban	50
		Gahanga		50
		Gikondo	Urban	50
	Nyarugenge	Nyamirambo		50
	Gasabo	Kimironko		50
Eastern province	Bugesera	Mayange	Rural	50

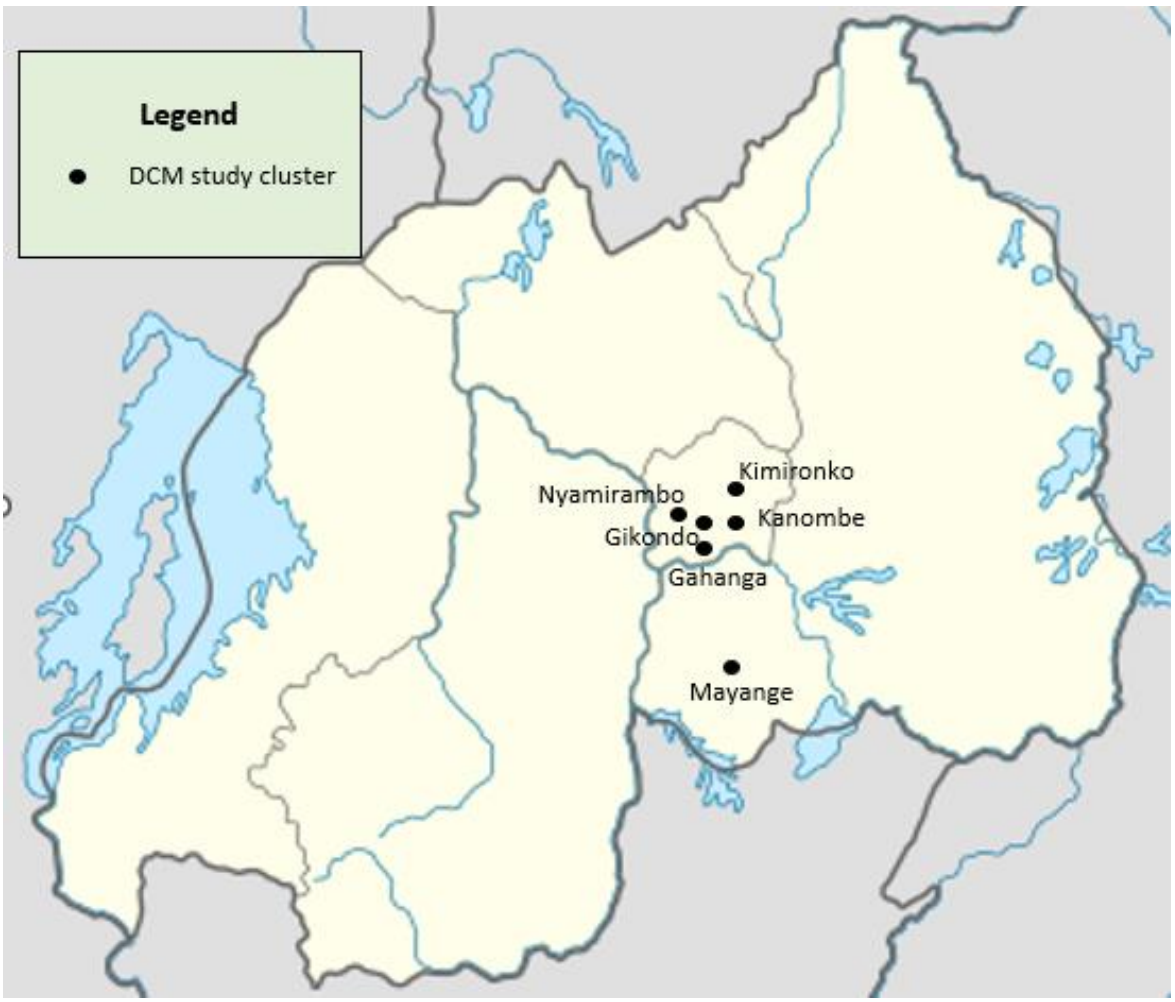


Figure 1: DCM study clusters' location within Rwanda

Study structure

The DCM methodology adopted in MECS programme countries investigates consumer cooking preferences using three main parameters:

- Cooking processes: cooking capability (boiling, frying), speed (power), use of lid, number of hobs
- Stove: capacity (number of people), smoke emissions, portability and looks
- Additional functionality: lights, mobile phone charging, TV, financing options, ability to clean.

This, paired with information on cooking practices, provided some useful insights into key parameters to consider when designing eCooking appliances.

The discrete choice experiments enable understanding of user priorities pertaining to selected products and with which the consumer need not be so familiar. Survey questions asked respondents to make choices between two discrete options (hypothetical technical solutions, or products) with different design parameters. The respondent chose one of the two cards presented. Discrete choice models predict the probability that an individual will choose an option, based on the levels of each parameter given in the option. Essentially it asked, "Would you like product A with these types of characteristics or would you like product B which has a different set of characteristics?". Choice models were set up using choice cards, based on the key parameters identified, each of which has a limited number of levels, as the Table 2 below indicates.

Table 2: Parameters and levels used in choice models

Parameters	**# of levels**	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Cooking processes					
Type of cooking	2	boil only	boil & fry		
Power (speed of cooking)	3	slow	normal	fast	
Use of lid	3	no lid	pot with lid	sealed pot	
Number of hobs	3	single hob	2 hobs	4 hobs	
Stove					
Capacity (people)	3	cooks for 4 people	cooks for 7 people	cooks for 10 people	
Capacity (devices)	3	always need to use with another stove	sometimes need to use with another stove	you can do all your cooking on it	
smoke emissions	3	No smoke	gives same smoke as charcoal stove	gives same smoke as firewood stove	

Parameters	# of levels	Level 1	Level 2	Level 3	Level 4
Portability	2	cannot be moved (too heavy)	can be carried in/out of the house		
Durability	2	3 years	5 years		
Functionality					
Devices	4	2 hobs	2 hobs + 3 LED lights	3 hobs + charge mobile phone	4 hobs + television
Availability	2	only works on sunny days	works on sunny and rainy days		
Financing	3	pay as you go (monthly)	half upfront and the rest in instalments	pay cash in totality	
Cleaning	2	awkward to clean	easy to clean		

There would be 54 possible combinations of design parameters for the cooking processes, 108 for the stove features, and 48 for the additional functionality's experiment. Since these choices would be too much for the respondent, fractional orthogonal design using SPSS (Scott, Batchelor, & Jones, 2019) was used to reduce the number of choices to 16 choice cards per design domain. Orthogonal design ensures that all possible combinations are adequately covered, and that the stats package can unpack the responses down to the values assigned to the individual parameters (Scott, Batchelor, & Jones, 2019). A constant comparator approach (De Bekker-Grob, M., & K., 2012) was used, in which one of the 16 choice cards was used as a reference, and the 15 resulting pairs presented respondents with a choice between this comparator and each of the other choice cards (Example of the card in Figure 2). The respondent had to choose one of the two cards presented. The constant comparator card was selected on the basis that the mix of levels represented a mid-level of attractiveness, so one would expect the number of times the comparator was chosen and rejected to be roughly balanced. Furthermore, we divided the 15 choice pairs into two for 2 sets of respondents who answered half the questions each (Questionnaire A and Questionnaire B) and then later we analysed as a whole.

Parameter	Choice A	Choice B
Monthly cost	Rwf 20,000/month	Rwf 10,000/month
Number of people	10 people	4 people
Need to use another stove	need another stove to cook	can be cooked on alone
Smoke people breathe	smoke like charcoal	smoke like charcoal
Weight of the stove	portable	portable
Stove duration	3 years	5 years

Figure 2: Example of a choice card used during the DCM survey in Rwanda

The analysis used binary logistic regression to fit predictive models to the data as each dependent variable was a dichotomous categorical variable. All the parameters were entered into the model, which calculated regression coefficients for each, along with p values indicating whether the parameter was significant in the model.

HHs were later disaggregated into 7 different groups (variables), including gender, type of settlement, type of main cooking fuel, HHs' size, age of the respondent, domestic status, and technological proficiency. A domestic status index has been calculated from 4 variables including the type of floor construction of the HH, the HH's main source of drinking water, TV and refrigerator ownership. The technological proficiency index, on the other hand, was calculated from 4 variables including the type of phone owned, how often it is used, how often the internet is used, and the use of mobile money. The Chi-Square Test of Independence was used to determine whether there is a relationship between these groups/variables and the selected preferred appliances' characteristics (whether the variables are independent or related). Both the modelling and the Chi-square test were done using SPSS.
As highlighted in the second objective, the study also gathered valuable data on cooking practices (e.g., the mix of fuels used and the timing of meals), the quality of electricity supplied, and data on

expenditure on cooking fuels. The latter is especially useful as it represents disposable income that can be substituted by modern energy cooking services.

Study stages

The DCM study was carried out in three main stages:

- **A pre-survey stage** to set up tools needed for the data capture and analysis, recruit, and train enumerators, identify suitable locations to carry out the survey, and develop a sampling methodology. This stage lasted for 2 weeks.
- **A survey stage** when the DCM study was carried out and lasted for 3 weeks. 300 respondents were interviewed.
- **An analysis and reporting stage** estimated at 6 weeks, whereby data analysis is conducted, and findings shared through a final report for publication.

Analysis

Overview of respondents' characteristics

1.1.1. Personal characteristics

The survey sample consisted of 300 interviews and respondents were predominantly female, 77%, compared to male (23%) (Figure 3). HHs were randomly selected with some system to it. In fact, enumerators would make sure to put a 5-HH interval between 2 consecutive HHs, where possible, to ensure a high degree of representativeness and provide a sample's even distribution. The target interviewee was the HH's head, if not present, any other adult or a group of HH's members.

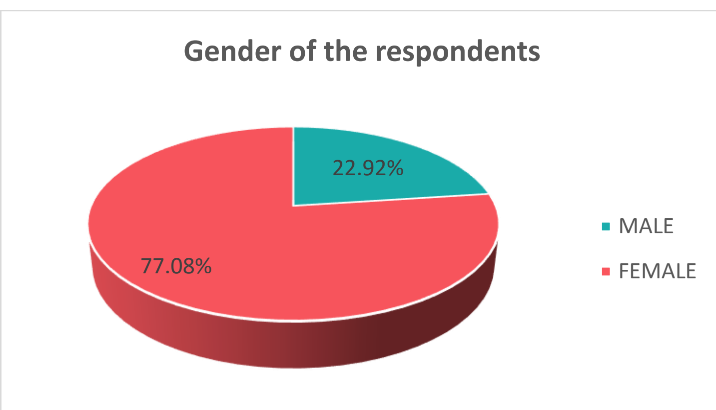


Figure 3: Gender distribution of respondents

The sample was also dominated by the youth, 55.5% (Figure 4), and half the respondents (49%) were found to be educated on higher than secondary level (Figure 5). Normally, when there is a well-educated person in a HH, he/she is the one confident enough to respond to questions. In addition, some HHs with only less-educated members shyly prefer not to be interviewed, leaving the sample dominated by well-educated respondents.

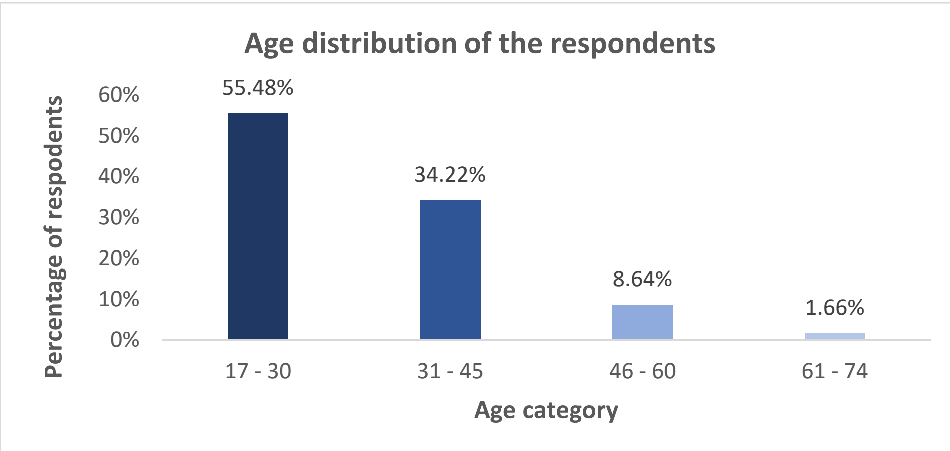


Figure 4: Age distribution of the respondents

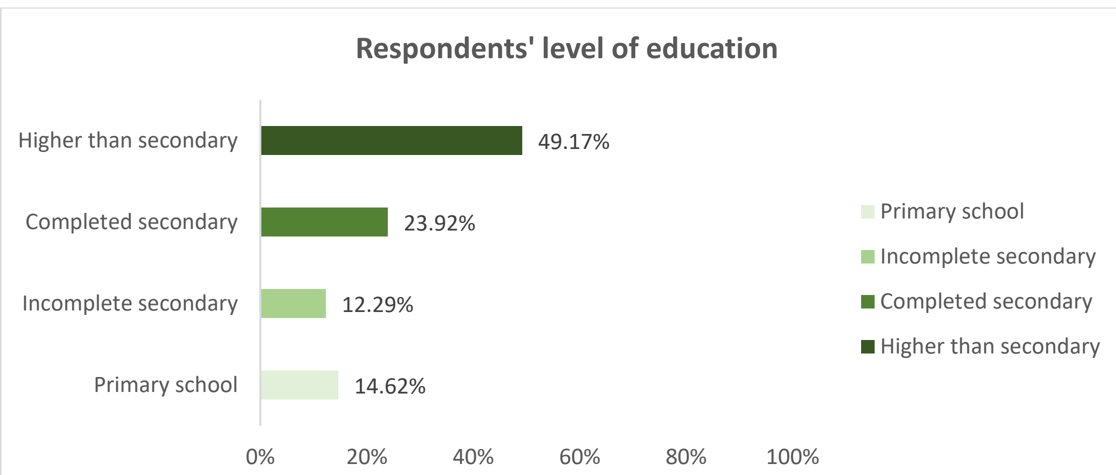


Figure 5: Respondents' level of education

1.1.2. Households' characteristics

The majority of the HHs (68%) houses less than 5 people per each, whilst more than 10 people per HH are only found in 1% of the interviewed HHs (Figure 7).

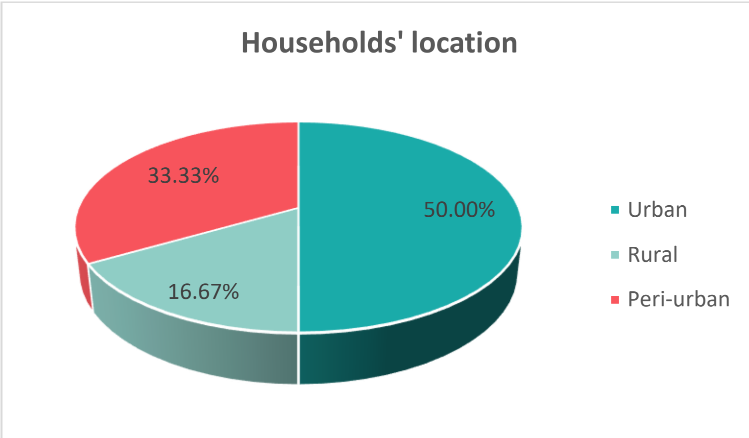


Figure 6: Households' location

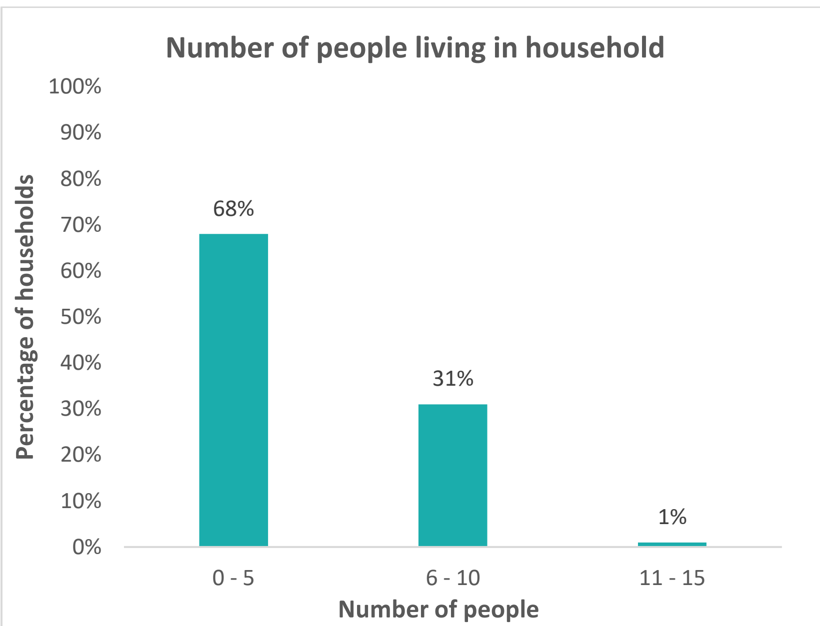


Figure 7: Number of people living in households

Figure 8 indicates that urban HHs are more likely to employ house cooks (54% of cases) as opposed to rural HHs which most often (84%) relied to HHs' members for cooking. In fact, Rwandan HHs, mostly urban, employ house cookers, thus the observed high cases of house cooks are in line with the typical situation in Kigali city, in general, and actually that percentage may in reality be much higher if we only consider neighbourhoods we sampled our respondents from. When considering only the HHs' members part, Figure 9 shows that around 85% of the cooks are female for either urban or rural HHs.

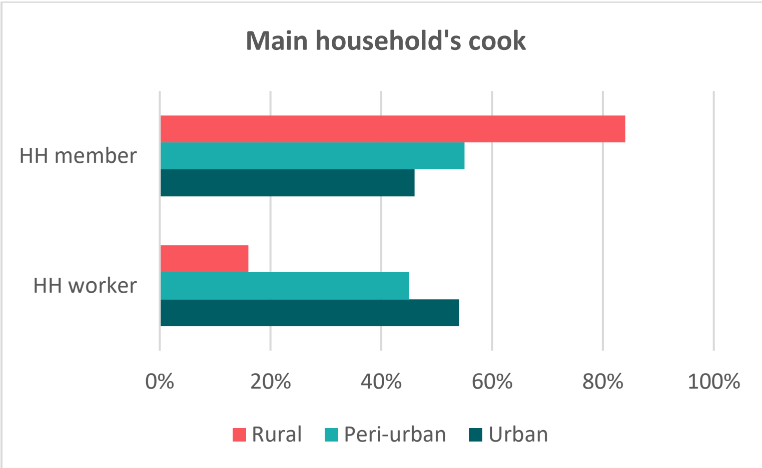


Figure 8: Overview of households' main cooks

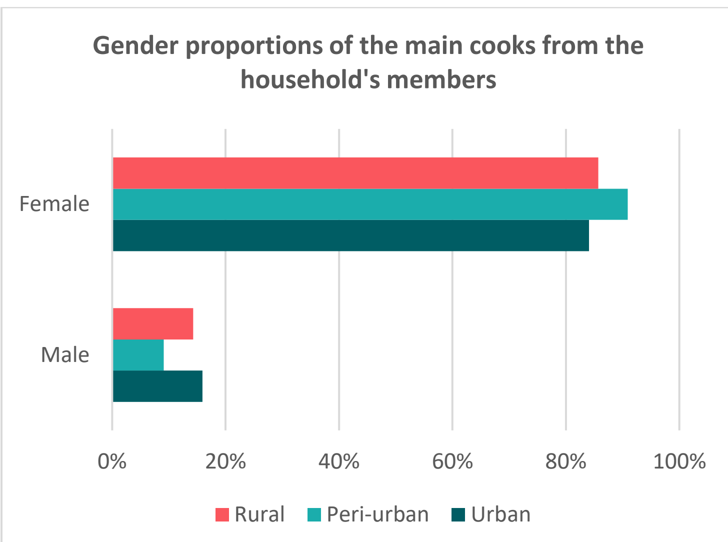


Figure 9: Gender proportions of the main cooks from the households' members

The survey showed that urban HHs drink mainly bottled water (90%). Public standpipe dominates as a source of drinking water for peri urban HHs at 52%, followed by bottled water at 28% and utility water piped into the yard at 19%. Rural HHs mostly drink water from public standpipe (92%), although a small number uses bottled water and rainwater at 4% each (Figure 10).

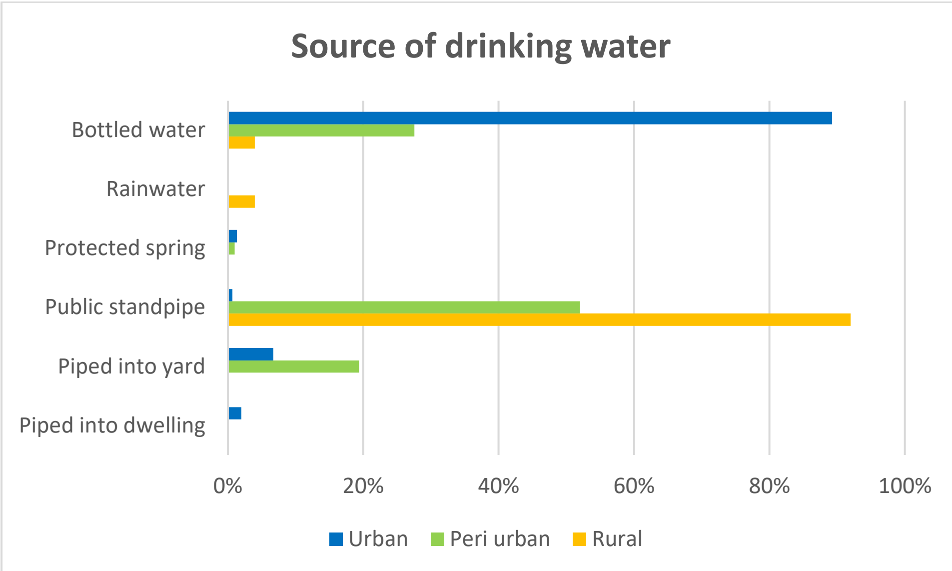


Figure 10: Sources of households' drinking water

Characteristics of households’ electricity supply

1.1.3. Sources of electricity for households

Almost all HHs in urban (99%) and peri-urban (97%) areas are connected to the national grid, except for 3 HHs which aren’t connected to any other source and 1 HH which uses solar lantern. Rural HHs were selected from the zone of intervention of ARC Power Ltd, thus all connected to solar mini grid (Figure 11).

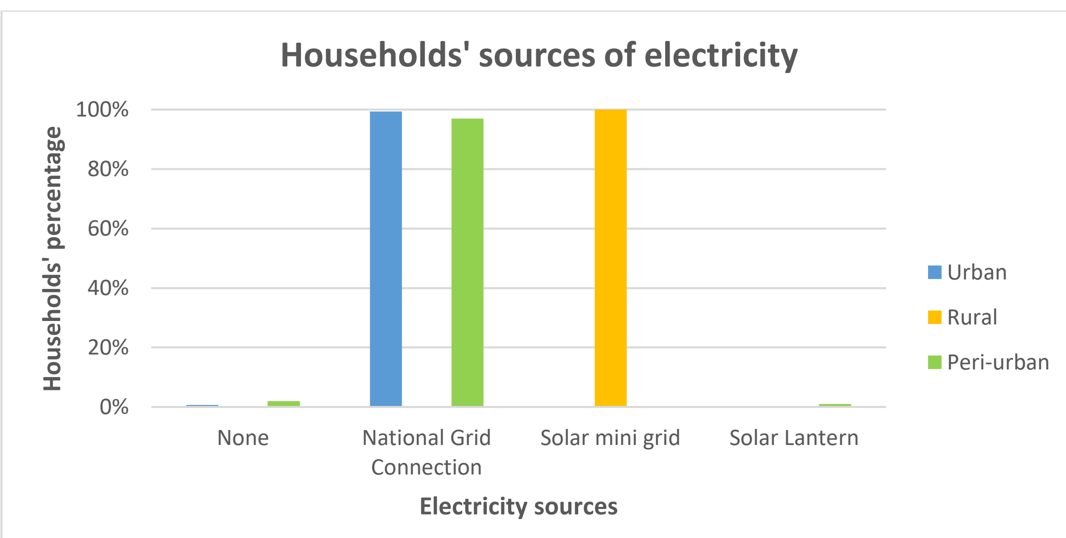


Figure 11: Households' sources of electricity per urbanization type

1.1.4. Electric appliances owned by households

Figure 12 shows that mobile phones and radio are owned by almost all HHs in urban, peri-urban, and rural areas, although a slight advantage radio ownership for rural HHs can be seen. A significant decrease in television posts ownership can be noted from urban (97%), peri-urban (83%), to rural HHs (46%). Other electric appliances such as refrigerator and iron were not found in any rural HHs, and in limited occurrences even in peri-urban, whilst they were found at around 63% in urban HHs.

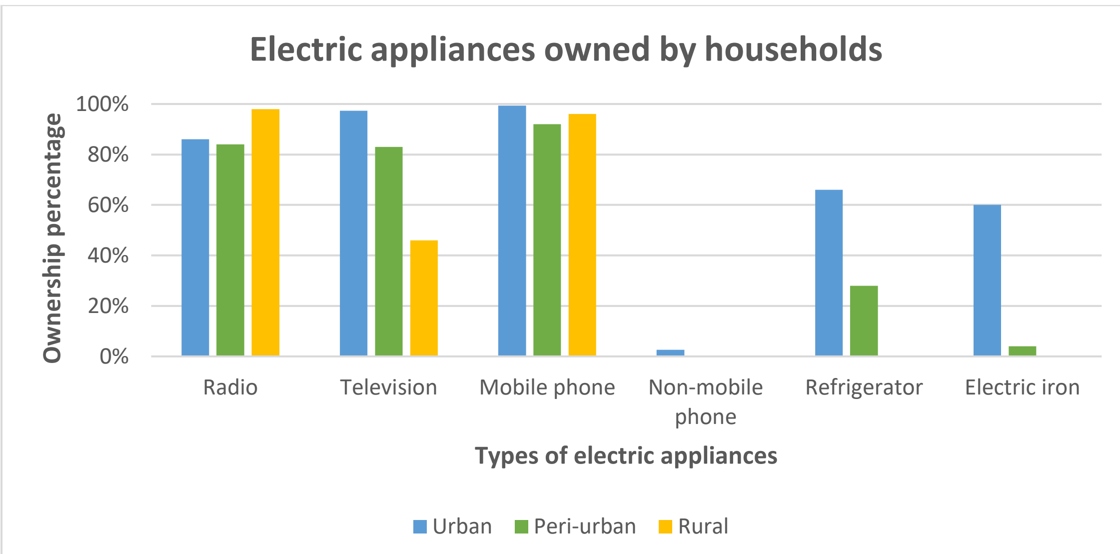
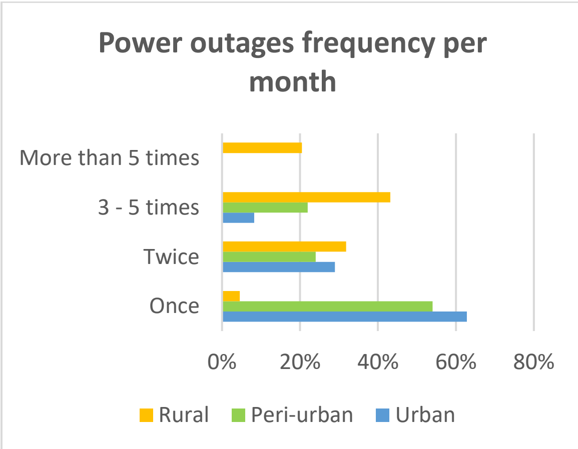


Figure 12: Some of the electric appliances owned by the interviewed households

1.1.5. Power outage characteristics

Power outages occurrence, analyzed on a monthly basis, were reported by around 70% of grid connected HHs and 90% of solar mini grid connected HHs. Figure 13 shows that the grid connected, both urban and peri urban HHs, reported power outage occurrence of once a month in around 60% HHs and twice a month in 27% of HHs. The rural HHs connected to the solar mini grid reported higher power outages frequencies, 3 to 5 times a month reported by 43% HHs, and 20% HHs reported frequencies of more than 5 times a month. Again, with similar trends, Figure 13 shows that power outages usually last less than 30 minutes in 90% of times, for the grid connected HHs, whereas around that same figure, 90%, of solar mini grid connected HHs reported a power outage duration of more than 30 minutes.



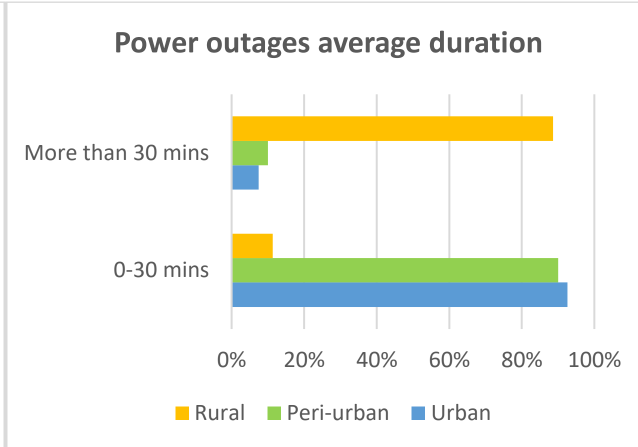


Figure 13: Average frequency of power outages

Figure 14: Average duration of power outages

Characteristics of households' cooking behaviour

1.1.6. Cooking fuel preference

Charcoal was reported as the most popular main fuel (46% of HHs), followed by LPG (39% of HHs), then firewood (13%), whilst electricity was the main fuel in only 1% of HHs. When considering HHs' locations, Figure 15 shows that LPG was the most popular main fuel in urban HHs (75% of the LPG-using HHs), rarely used in rural HHs (3% of the LPG-users), whilst charcoal was the popular main fuel in peri urban HHs. Firewood, as it's often the case, dominated in rural HHs (80%), whilst non-existing, as a main fuel, in urban HHs.

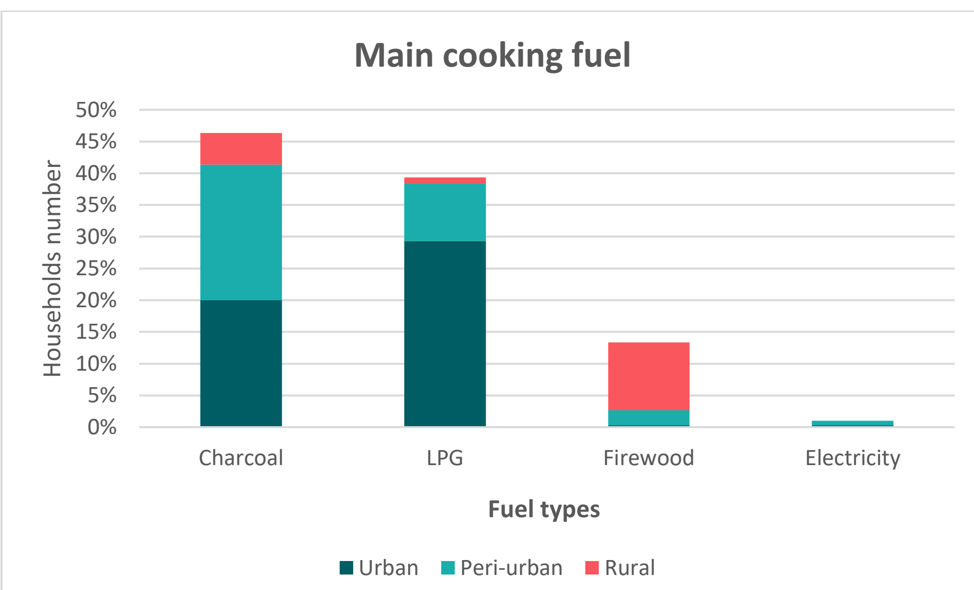


Figure 15: Main cooking fuel of households

When considering any use (not only as a main fuel), eCooking was reported used in 19% of HHs (**Error! Reference source not found.**) from 1% HHs as a main fuel. The majority found in urban HHs and more than half of the HHs that use eCooking used it for cooking only certain dishes (Figure 17). Only 7 HHs used eCooking regularly. Back to Figure 16, we can see that charcoal is the most stacked fuel, used in overall in 76% HHs from 46% HHs using it as a main fuel. LPG follows, used in 56% HHs from 39% as a main fuel, whilst firewood is used in 21% HHs from 13% as a main fuel.

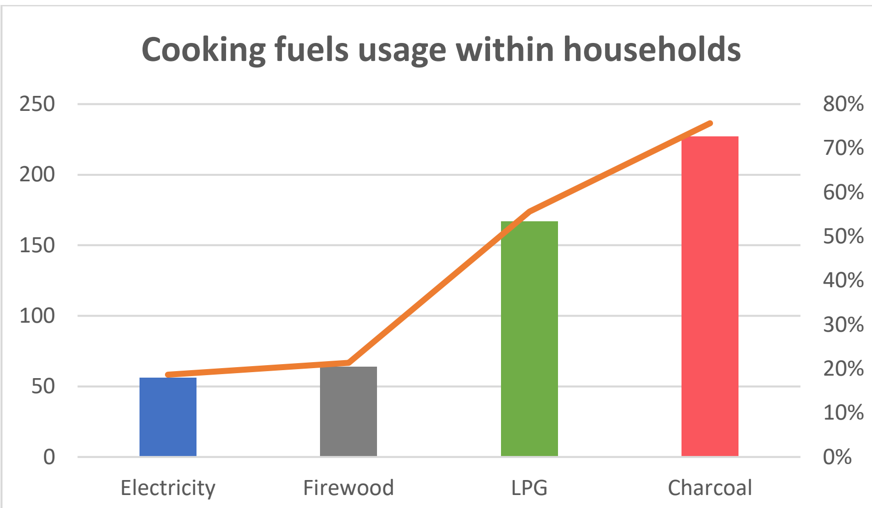


Figure 16: Cooking fuels usage within households

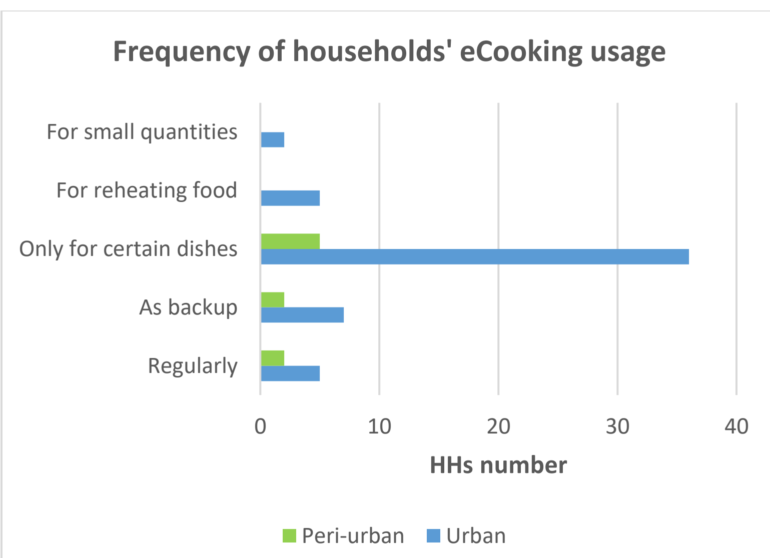


Figure 17: Frequency of eCooking usage

1.1.7. Meals' preparation

All respondents reported that they prepare dinner every day, and Figure 18 indicates that the majority (above 90%) prepare lunch every day whether they are urban, peri urban, or rural HHs.

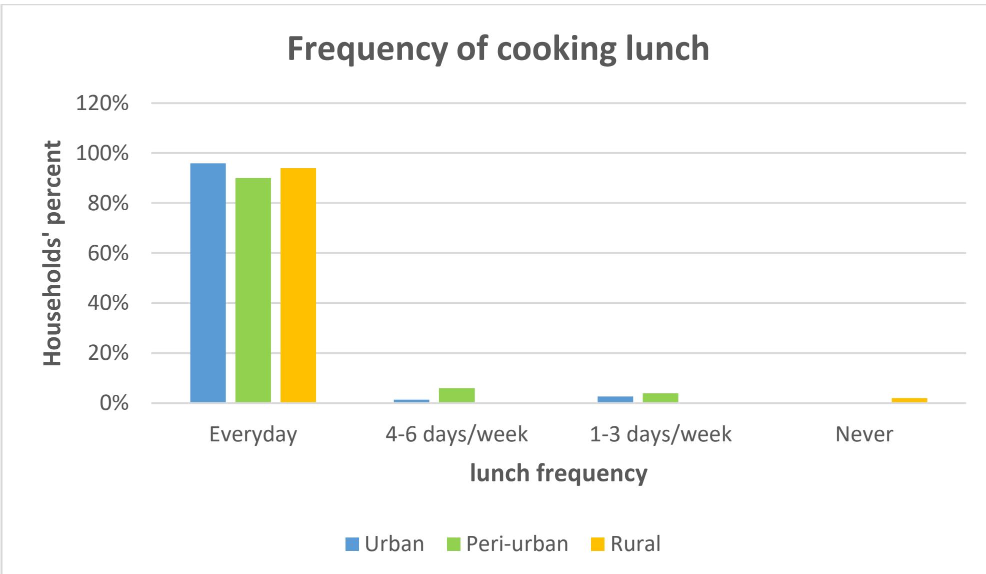


Figure 18: Frequency of cooking lunch

However, when it comes to breakfast, the pattern changes. Breakfast was cooked every day in 87% of urban HHs and 72% of peri urban HHs, whilst in rural HHs they were only 34% (Figure 19). In fact, 22% of rural HHs reported to never cook breakfast, whilst they were 12% in peri urban and 4% in urban HHs.

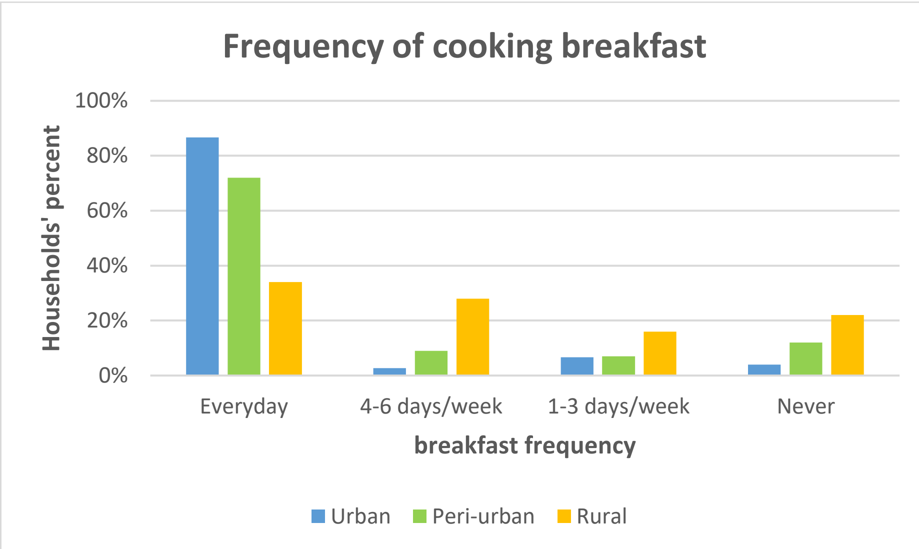


Figure 19: Frequency of cooking breakfast

Rural HHs spend relatively less time on cooking compared to urban and peri urban HHs (Figure 20). Although small, in addition to the lower number of meals prepared per day, this difference can be explained by the fact that often times urban and peri urban HHs employ house workers (Figure 8) whose primary role is cooking, whereas rural HHs don't benefit that privilege due to limited income. In fact, rural adult female (mostly mothers), despite being involved in daily income-generating activities, they are also responsible for all HH's chores including cooking. To accommodate all those tasks, time spent for each, cooking included, is reduced.

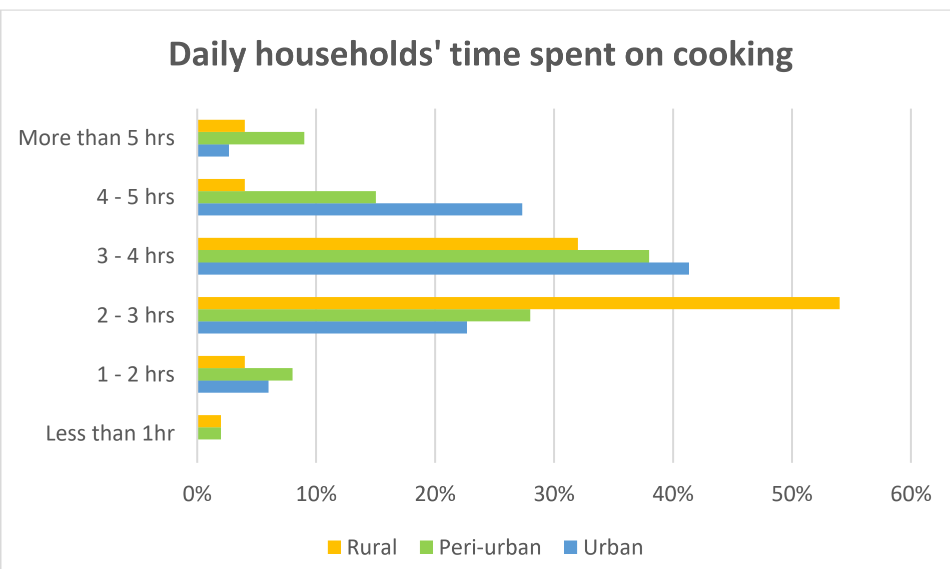


Figure 20: Time spent on cooking in a day by households

1.1.8. Cooking fuel consumption and cost

A. LPG

The survey indicates that various LPG cylinder sizes are in use with the 12-kg cylinder being the popular one, used in 67% of LPG-users, followed by 6-kg cylinder, 20%. The heavy weight cylinder (20 kg) seems less preferred as it was found in only 3% of HHs (Figure 21). Access to LPG seems not to be an issue as around 90% of users get it delivered to their homes, Figure 22, and as shown by Figure 23, it seems all size of cylinders, in use, are delivered on higher than 85% frequency. Furthermore, it seems even more convenient for LPG users as the refilling frequency is relatively low. In fact, LPG-users mostly (78%) refill once a month, and 11% refill twice in 3 months. Only 7% of users refill twice a month (Figure 24). The HHs' mean LPG monthly cost was found to be USD18.3, with 40% of LPG-users spending between USD17 and USD21 a month (Figure 25).

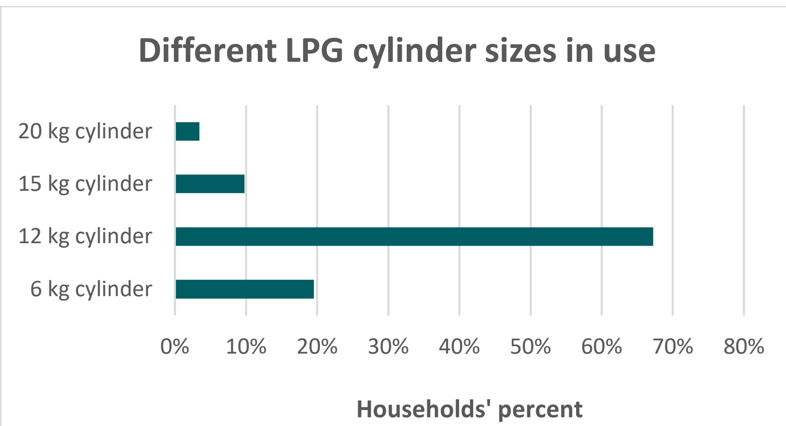


Figure 21: Different LPG cylinder sizes used by interviewed households

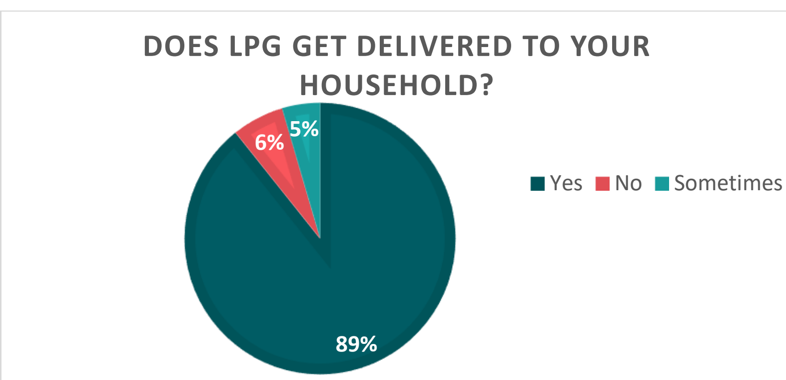


Figure 22: Access to LPG home-delivery service

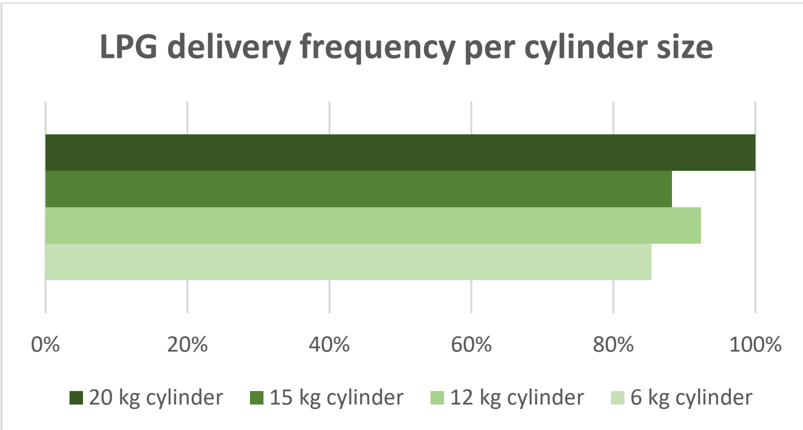


Figure 23: LPG delivery frequency per cylinder size

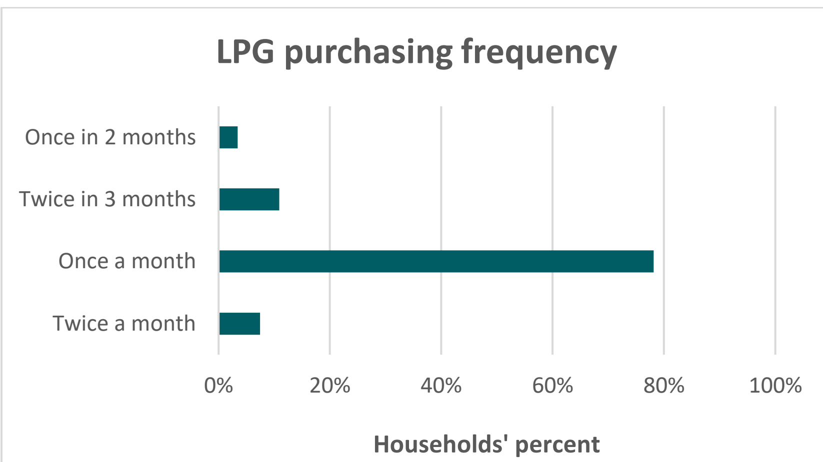


Figure 24: LPG monthly refilling frequencies

N	174.0
Mean	18.3
Median	18.1
Mode	17.6
St. Dev.	6.7
25th Percentile	14.5
75th Percentile	21.6

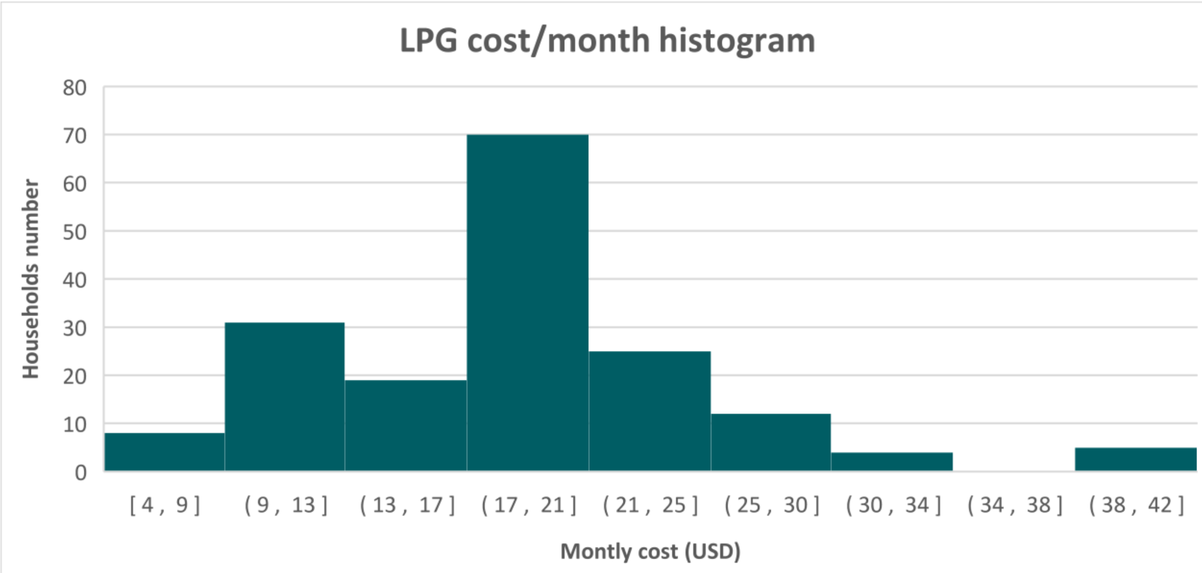


Figure 25: Histogram of the LPG cost per month for interviewed households

B. Charcoal

Purchasing charcoal, which could either be in a large sack (roughly 35 Kg), a bucket (roughly 1 Kg), or just by weighing precise amount of Kgs, seems to be, in most cases (58%), once a month, whilst only 20% of users purchase it twice a month (Figure 26), which makes it convenient in terms of time saving. In addition, the rise of marketing strategy such as home-delivery services for charcoal (58% of users), occurring in urban and peri urban areas and mostly when purchasing large sacks, makes its use more convenient (Figure 27). The mean charcoal monthly cost was found at USD11.4, with 30% of charcoal-users spending between USD12 and USD15 a month (Figure 28).

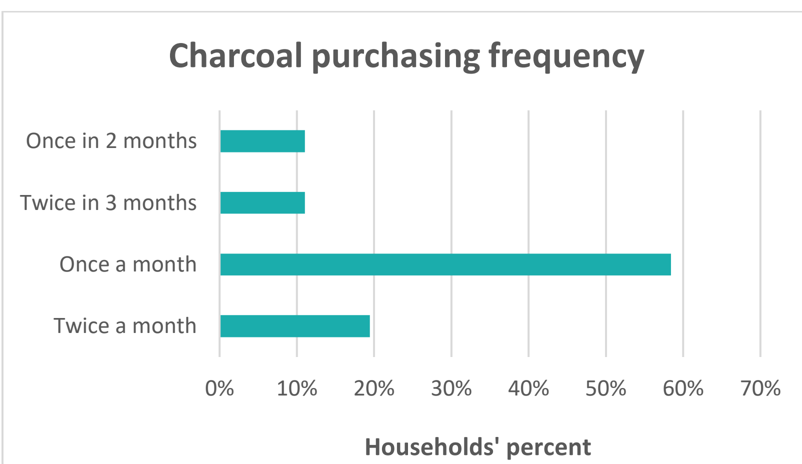


Figure 26: Charcoal monthly purchasing frequencies

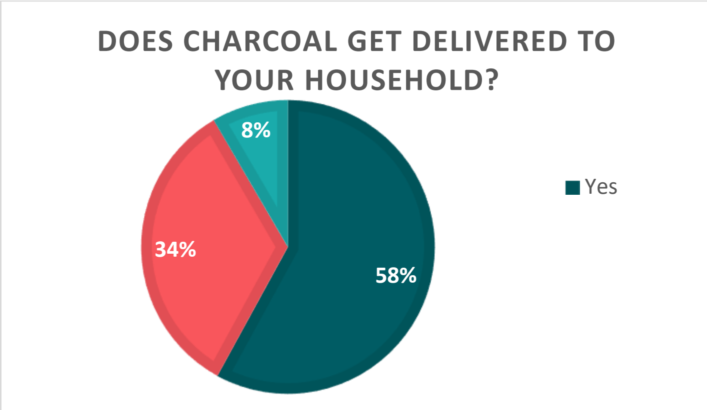


Figure 27: Access to charcoal home-delivering services

N	225.0
Mean	11.4
Median	11.4
Mode	11.4
St. Dev.	5.0
25th Percentile	8.7
75th Percentile	12.7

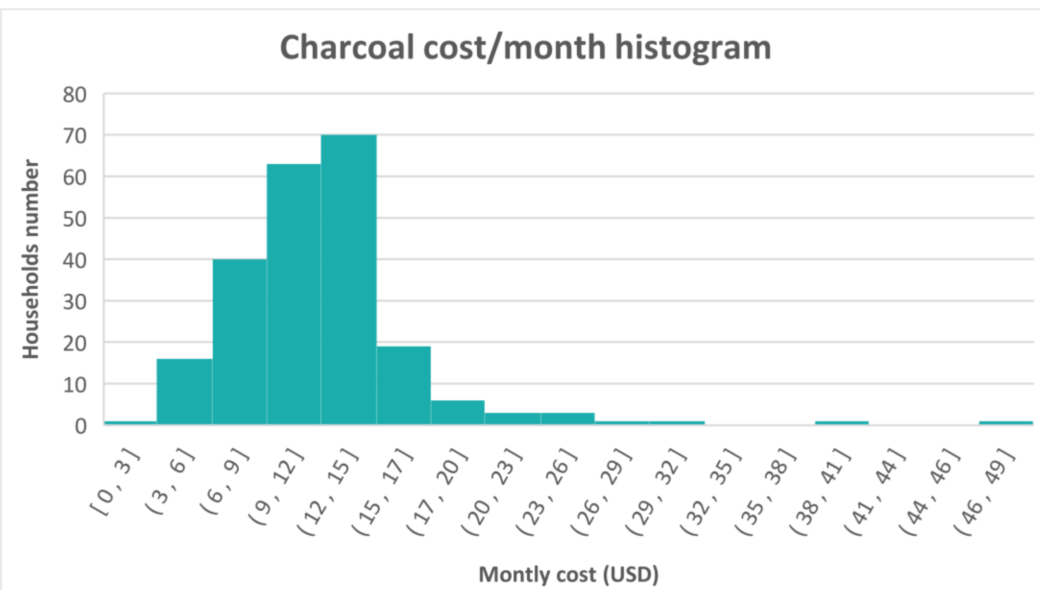


Figure 28: Histogram of charcoal monthly cost for interviewed households

C. Firewood

The survey suggests that firewood is commonly (74%) purchased twice a month, and once a month in some cases (22%) (Figure 29). Although this would not mean cause for concern, when additional inconveniences such as health problem associated with wood fire smokes discussed in Perceptions around cooking fuels chapter below, pile on its weak marketing strategy in terms of home-delivery services (Figure 30), firewood lose attractiveness. The mean firewood monthly cost was found to be the lowest at USD10, with 70% of wood-users spending between USD6 and USD15 a month (Figure 31).

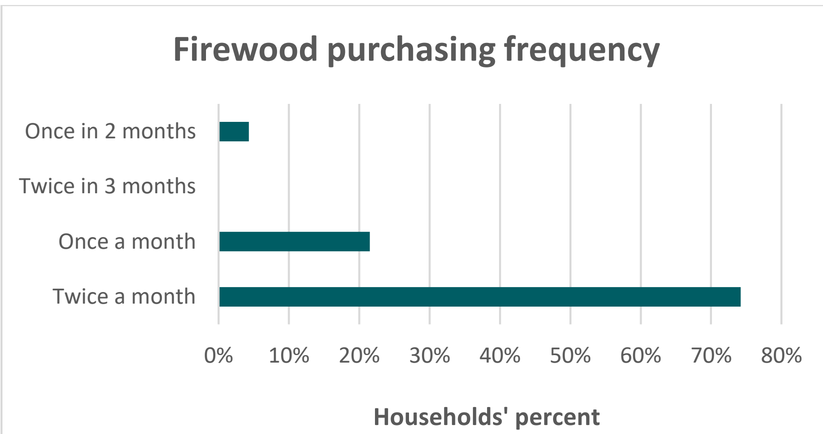


Figure 29: Firewood monthly purchasing frequencies

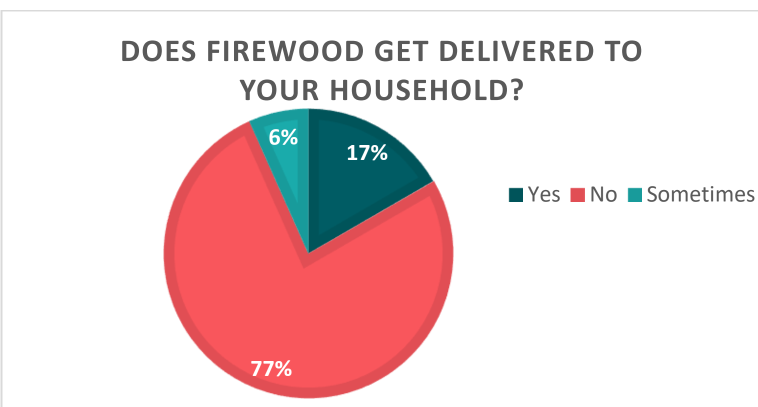


Figure 30: Access to firewood home-delivery services

N	56
Mean	10
Median	10
Mode	10
St. Dev.	5
25th Percentile	7
75th Percentile	14

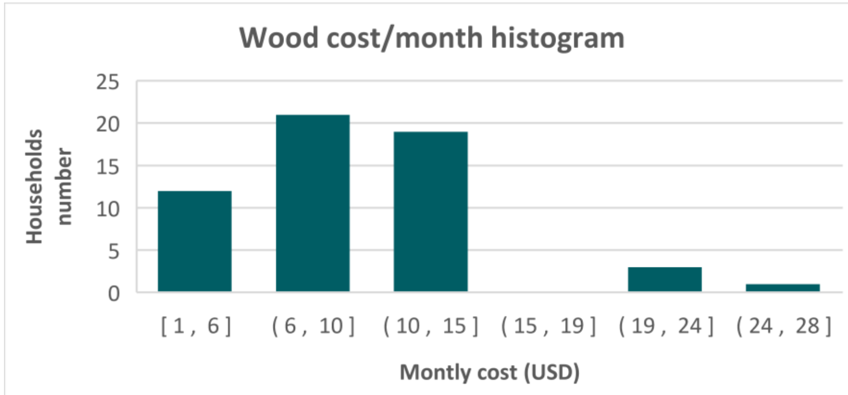


Figure 31: Histogram of firewood monthly cost for interviewed households

D. Overall cooking fuel cost

The mean cooking fuel monthly cost was found at USD22, with 65% of HHs spending between USD11 and USD27 a month (Figure 32). Again, this mean monthly fuel cost, higher than any single fuel's mean, suggests that fuel stacking is commonly practiced.

N	290
Mean	22
Median	22
Mode	22
St. Dev.	11
25th Percentile	13
75th Percentile	27

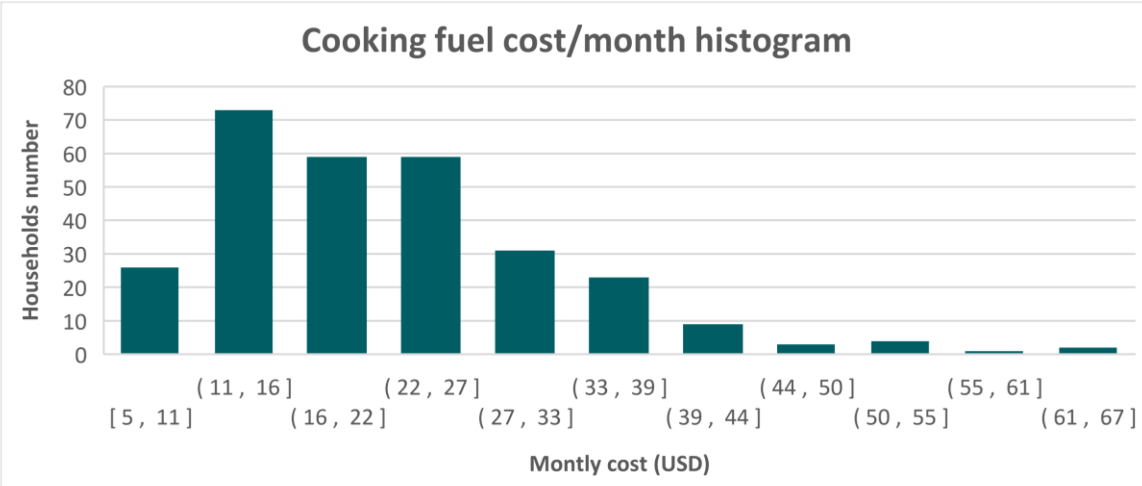


Figure 32: Overall cooking fuel cost per month

Table 3 suggests that at energy unit level, modern fuels are more expensive (electricity at USD0.062, followed by LPG at USD0.034) compared to biomass cooking fuel (charcoal at USD0.014 and wood the least expensive at USD0.011). Nevertheless, it is important to note that the Cooking Diary study (Ntivunwa, 2022) conducted in Kigali showed that charcoal required 8 times electricity's energy and double that of LPG to cook a meal of one person. In fact, the energy cost required to cook a meal per person were estimated at USD0.048 for electricity, USD0.069 for charcoal, and USD0.074 for LPG.

Table 3: Quantifying unit cost of energy for various fuel types used in Kigali

Fuel	Calorific value (MJ/Kg) or (MJ/Kw)	Standard cost in Kigali (USD)	Corresponding standard quantities (Kg)	Unit cost (USD/Kg) or (USD/Kw)	Energy unit cost (USD/MJ)
Wood	15.5	1.176	7	0.168	0.011
Charcoal	29	0.392	1	0.392	0.014
LPG	46.1	18.627	12	1.552	0.034
Electricity	3.6	0.225	1	0.225	0.062

Beliefs and attitudes

1.1.9. Perceptions around cooking fuels

Figure 33 and Figure 34 highlight experience and opinions, respectively, on the perspective of cooking fuels' cost. In fact, experience, here, means cost's perceptions views from users on their main cooking fuel, whilst opinions mean cost's perceptions views from non-users. Experience says that each main fuel was found expensive by its users (Figure 33). On the other hand, charcoal is found expensive by majority of its non-users (67%), whilst only 27% of LPG and 20% of firewood non-users found them expensive. Encouragingly enough, less than half (40%) of eCooking non-users found it expensive (Figure 34). Note that electricity users were too few for this experience analysis.

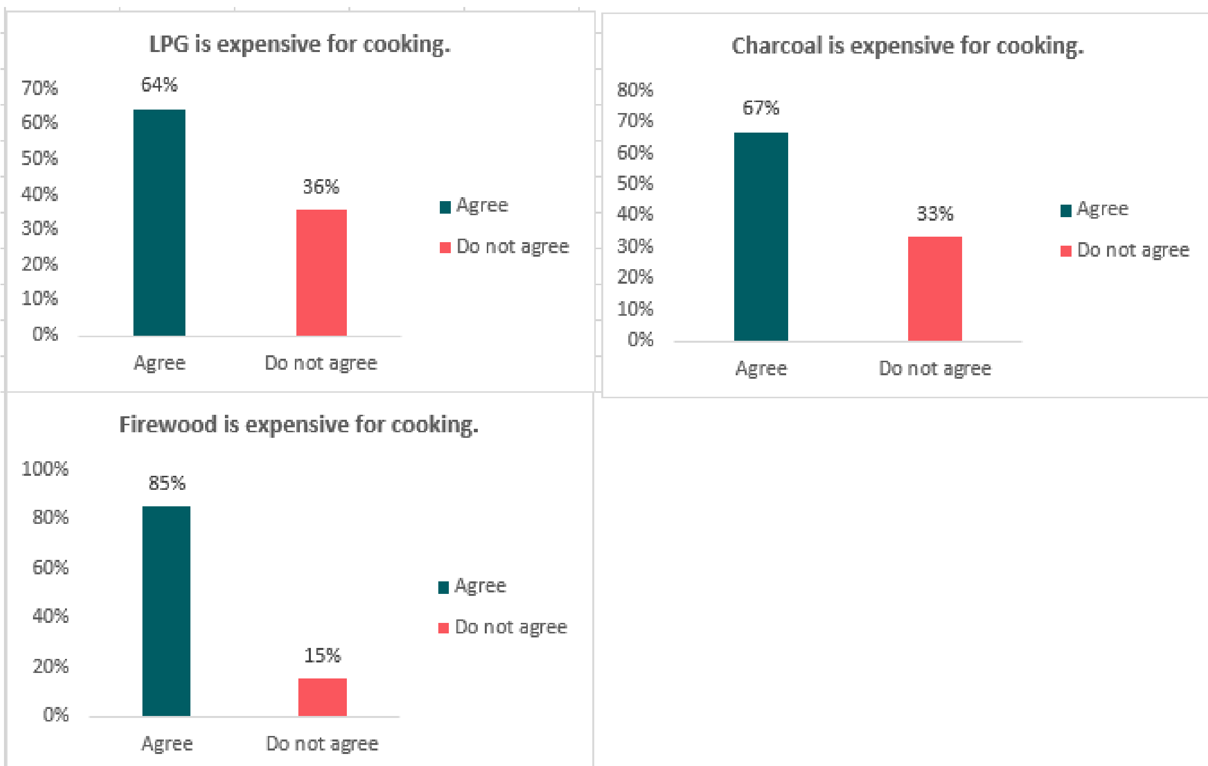


Figure 33: Perception of main cooking fuels 'cost by their respective users

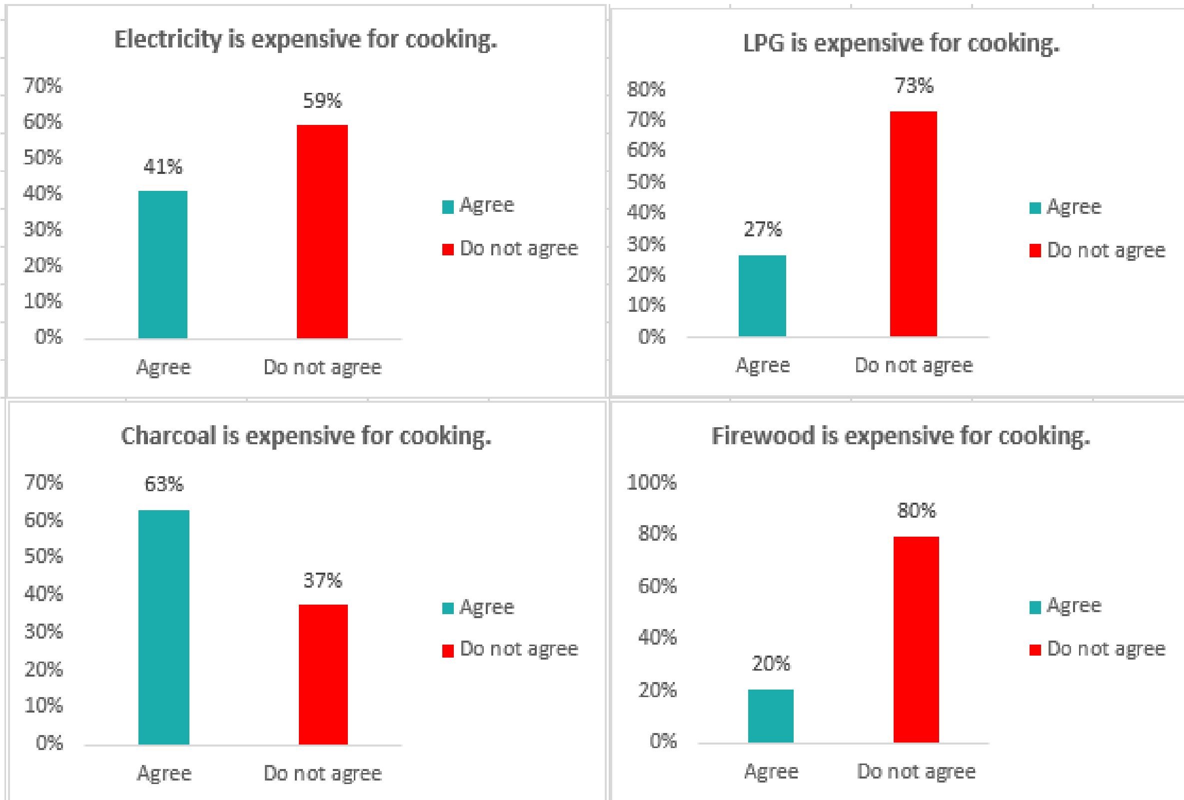


Figure 34: Perception of main cooking fuels' cost by their non-users

Interesting to note is that the majority of firewood (70%) and charcoal users (66%), and around half of LPG users (55%) reported smoke from cooking fuels as a big health problem for their family (Figure 35), which suggests there is already an awareness around the established fact of respiratory health hazards associated with smoke from cooking fuels.

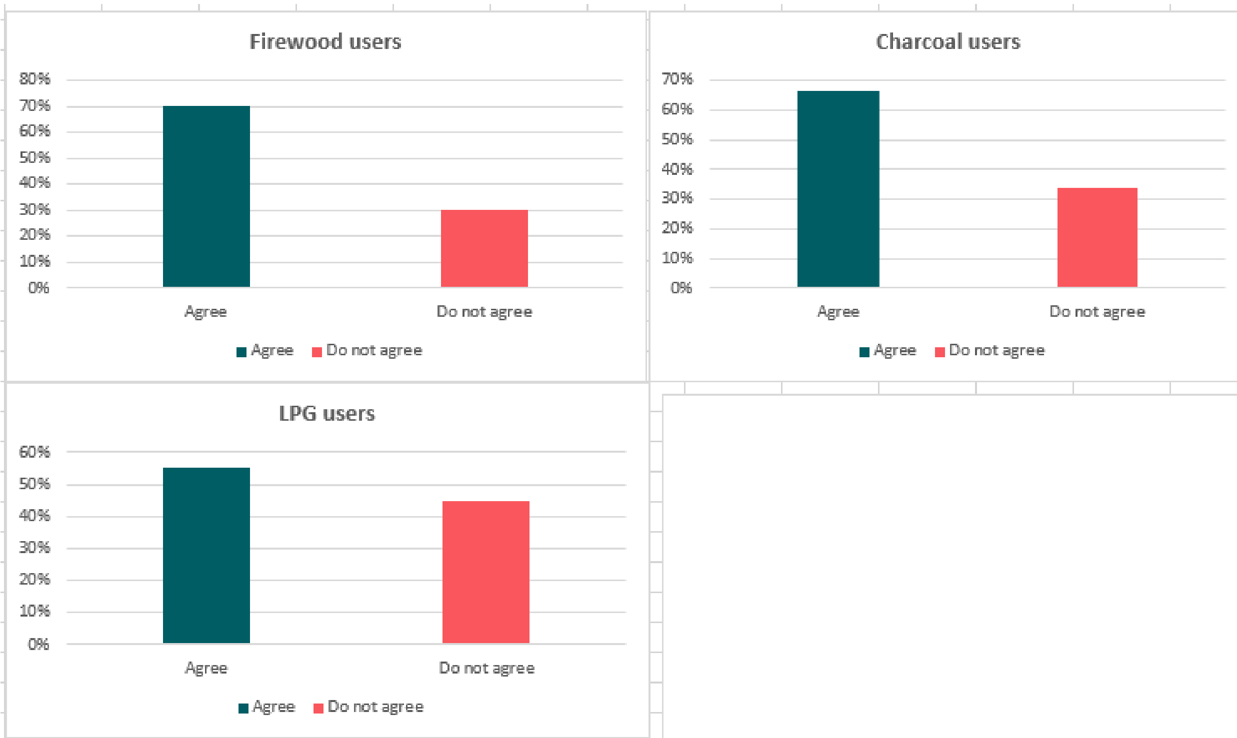


Figure 35: Is smoke from cooking fuels a health problem to your family?

Conveniency's perceptions from users on their main cooking fuel (experience) highlighted by Figure 36 indicates that most users of each fuel found it convenient to cook on, with almost all LPG users (98%) and even 60% of firewood users. When looking at the opinions of fuels non-users, however, only 15% qualified firewood as convenient to cook on, whilst half found both LPG and charcoal convenient. Noteworthy, is the fact that 52% of eCooking non-users qualified it as convenient for cooking (Figure 37).

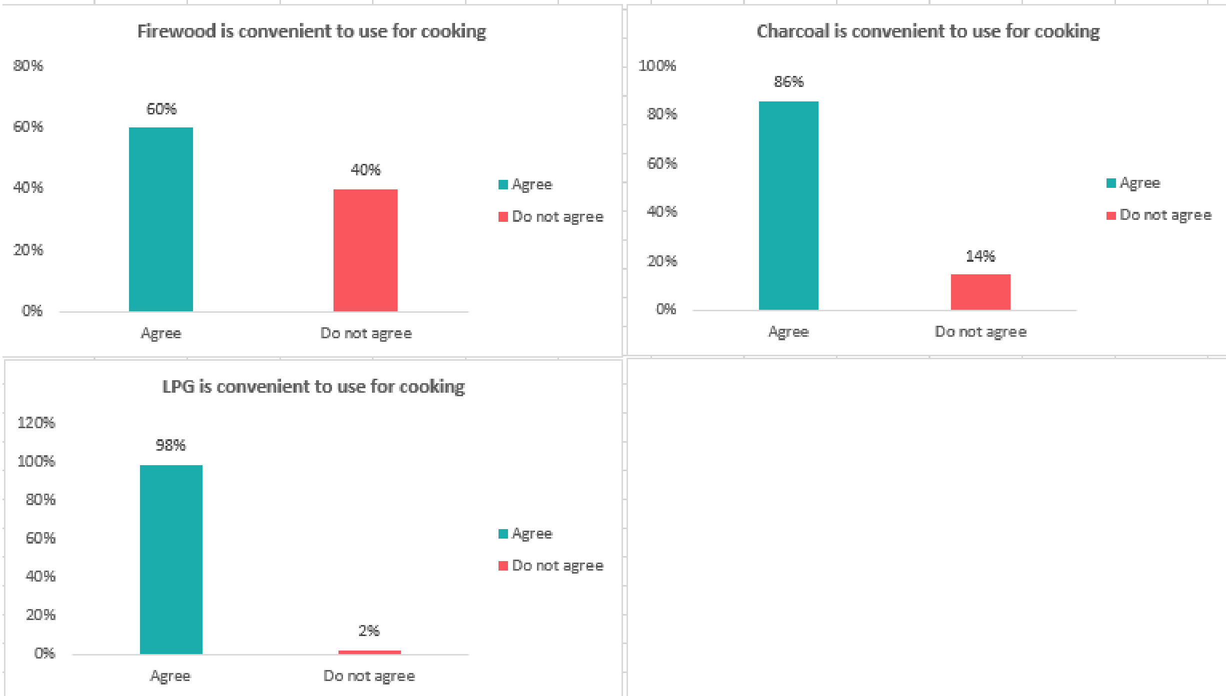


Figure 36: Perceptions around cooking conveniency of different main fuels by their respective users

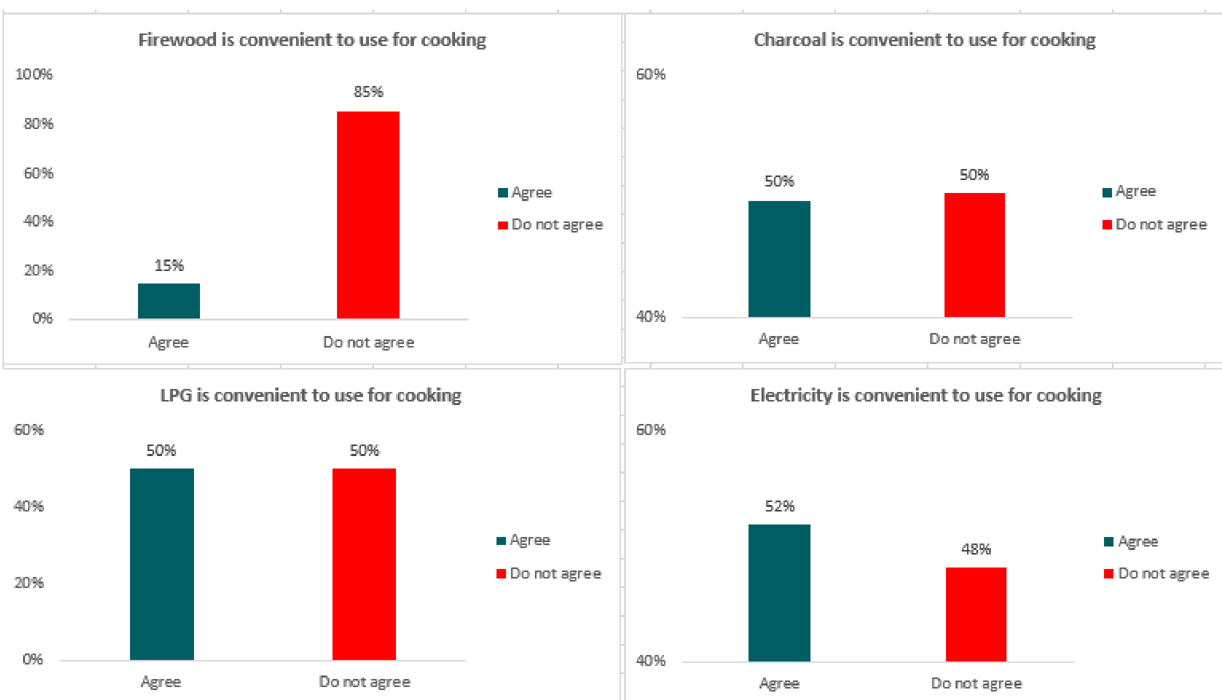


Figure 37:Perceptions around cooking conveniency of different main fuels by their non-users

In fact, 73% of the respondents believed that many people would switch to modern fuels (LPG or electricity) if their cooking cost was the same as the current expenditure on charcoal or firewood (Figure 38).

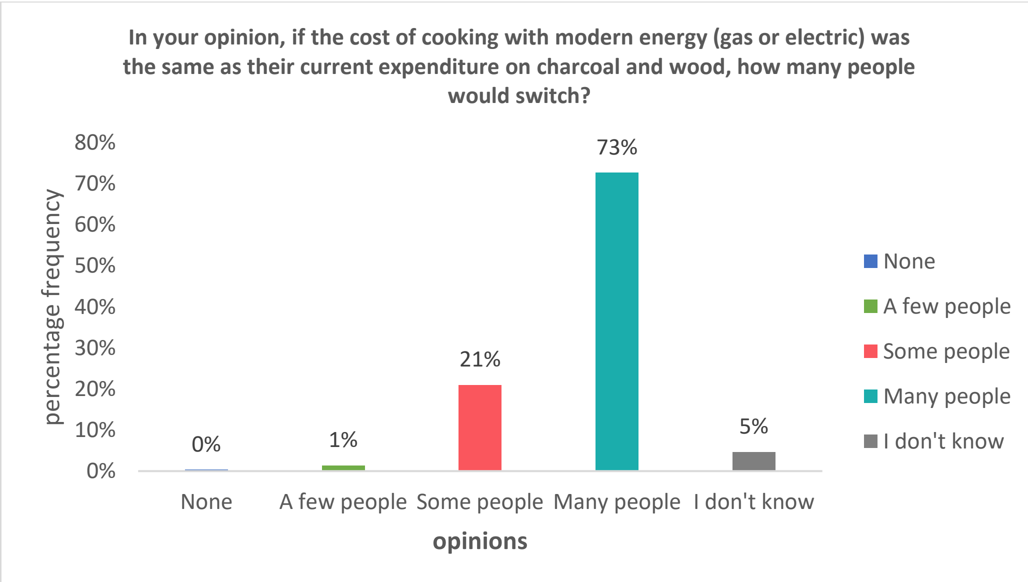
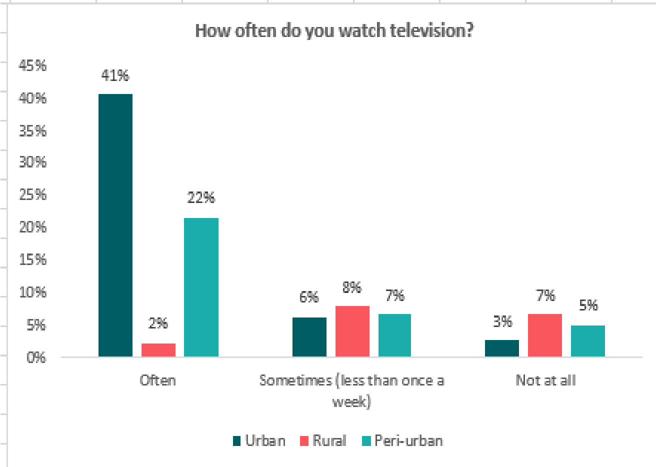


Figure 38: Respondents' opinions on cooking fuel switch probability depending on their prices

1.1.10. Experience with technology

Most respondents, 73%, reported watching television often, whilst 61% reported listening often to the radio (Figure 39). Breaking down these proportions based on the respondents' location, it seems only 15% of rural HHs often watch television, whilst it is 82% for urban HHs. The trend changes when it comes to listening to the radio with 78% of rural HHs often listening to it whilst the number becomes 57% for urban HHS. This trend is in line with the HHs' ownership character discussed in sub-chapter 1.1.4 above, with urban HHs characterized by high TV ownership compared to rural ones, whilst rural HHs' radio ownership is higher than that of urban HHs.



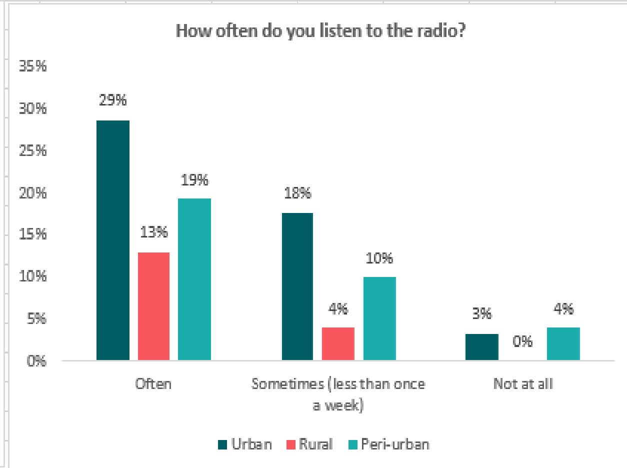


Figure 39: Frequencies of following television and radio based on households' location

Almost all respondents (98%) reported using mobile money as a form of financial transaction service. This access to financial service goes further with around 60% of the respondents have at least once used a mobile banking application. However, when considering HHs' location, it is found that only a quarter of rural HHs ever used a mobile banking application (Figure 40). This can partly be explained by the low internet penetration in rural areas, in line with findings that only around 10% of rural HHs often use internet in contrast to 80% of urban HHS, as highlighted by Figure 41.

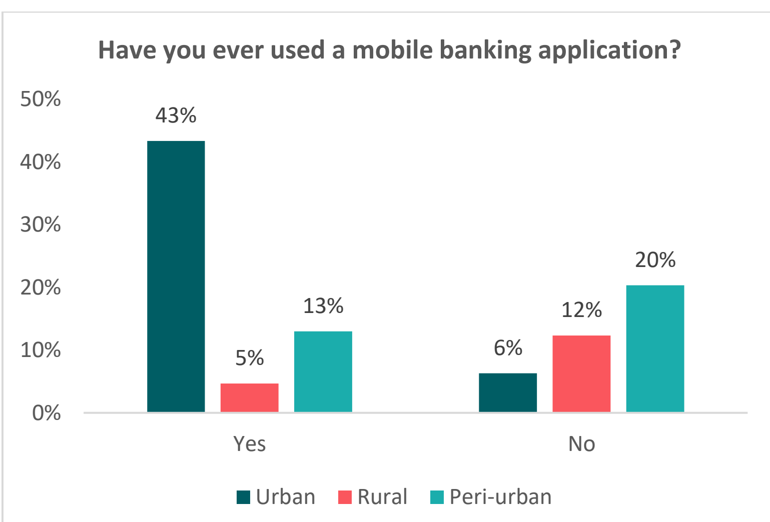


Figure 40: Mobile banking usage per households' location

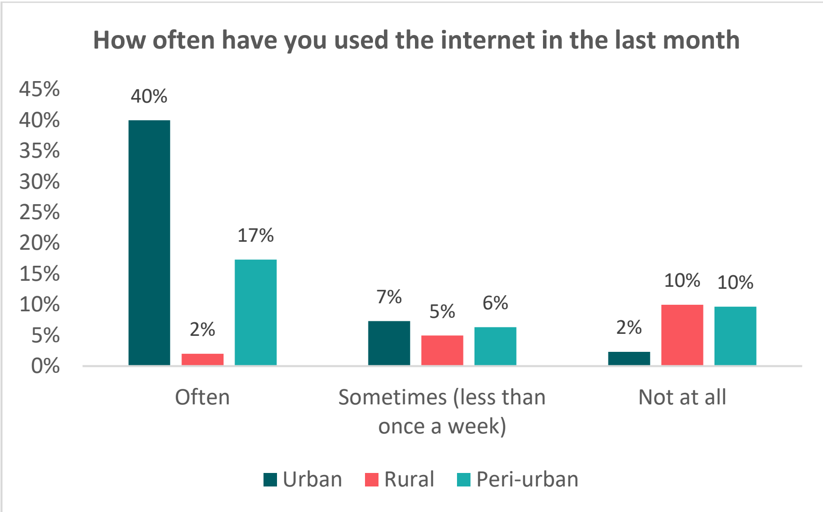


Figure 41: Frequency of internet usage per households' location

1.1.11. Households' decision making

In general, Figure 42 shows that there's a high (around 60%) collaboration between male and female heads within the HHs when it comes to making decisions on purchasing of household equipment. Nevertheless, a significant number of respondents (35%) expects female head of the HH to make decision regarding purchasing of cooking devices compared to only 13% when it comes to other purchases such as a solar panel for the house.

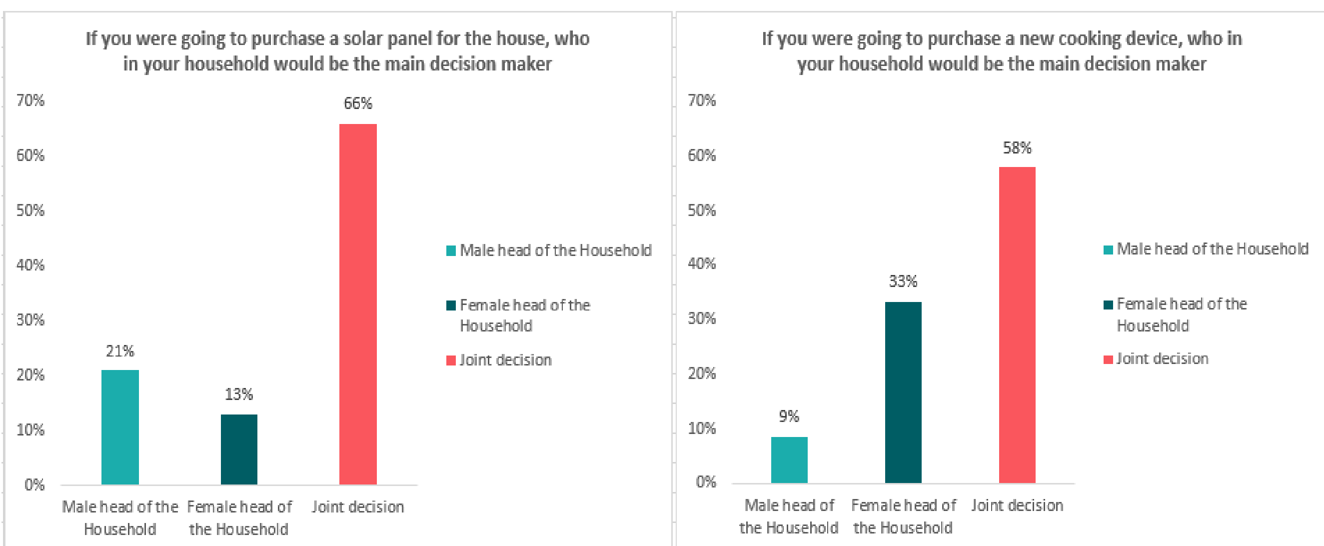


Figure 42: Households' decision making

Discrete choice modelling results

Three sets of choices representing different aspects of cooking device design were asked to respondents

- Cooking processes: type of cooking (boiling and frying), power (speed of cooking), use of lid, and number of hobs
- Stove: capacity in terms of number of people it cooks for, capacity in terms of need for supplementary stove, smoke emissions relative to charcoal or wood fire, portability, and durability
- Additional functionality: devices topped up (lights, mobile phone charging, TV), availability in terms of weather impact (sunny and rainy time), financing options, ability to clean.

1.1.12. Cooking processes

Table 4 highlights different variables and their corresponding binary options selected to define cooking processes.

Table 4: Cooking processes variables and their corresponding options

Variable	Options	
CPboil	0	can only boil
	1	can boil and fry
CPspeed_normal	0	slow cooking
	1	normal cooking
CPspeed_fast	0	slow cooking
	1	Fast cooking
CPpot_lid	0	pot with no lid
	1	pot with lid
CPpot_sealed	0	pot with no lid
	1	sealed pot (cannot stir)
CPhob_2	0	1 hob
	1	2 hobs
CPhob_4	0	1 hob
	1	4 hobs
CPcost	0	20,000 and below
	1	30,000

A logistic regression was carried out to assess the influence of type of cooking, cooking speed, use of lid, number of hobs, and cost of appliance on the choice of the cooking appliance. The overall model was significant when compared to null model (χ^2 (8) =1159.278, p<0.001). The model explained 30.2% of variability in the choice of parameters and correctly predicted 73.4% of the choices.

Results, Table 5, show that cooking processes characteristics that appear to be most important to consumers are:

- Cost: people seem more likely to choose low-cost appliances
- Pots with lid: people seem to prefer cooking on pots which provides them the possibility to use the lid or not whenever they see fit. In fact, this is a practice which is often found in many HHs and goes along well with wet frying which is a popular cooking process in Rwanda. It also enables cooks to prepare dishes when unsure of required cooking time.
- Multiple hobs: people showed preference to appliances with multiple hobs, and in fact, it seemed the more hobs the better. There was more preference for 4 hobs than 2 hobs, although the latter was also preferred to 1 hob.
- Ability to boil and fry: appliances that can both boil and fry were found very important to respondents.
- Fast cooking: people were more likely to choose appliance that can cook fast

Table 5: Binary logistic regression output: cooking processes

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	CPboil(1)	.970	.098	97.589	1	<.001	2.638	2.176	3.197
	CPspeed_normal(1)	.243	.129	3.540	1	.060	1.275	.990	1.642
	CPspeed_fast(1)	.713	.130	29.890	1	<.001	2.041	1.580	2.635
	CPpot_lid(1)	1.135	.142	64.304	1	<.001	3.112	2.358	4.107
	CPpot_sealed(1)	-.276	.127	4.697	1	.030	.759	.591	.974
	CPhob_2(1)	.780	.110	50.292	1	<.001	2.181	1.758	2.705
	CPhob_4(1)	1.040	.130	63.829	1	<.001	2.828	2.192	3.650
	CPcost(1)	-1.517	.134	128.208	1	<.001	.219	.169	.285
	Constant	-1.969	.138	203.260	1	<.001	.140		

a. Variable(s) entered on step 1: CPboil, CPspeed_normal, CPspeed_fast, CPpot_lid, CPpot_sealed, CPhob_2, CPhob_4, CPcost.

The willingness to pay, Table 6, which is the maximum amount of money that a customer is willing to pay for a product or service, can be derived from the ratio of the coefficients of each parameter to that of the cost parameter (Hanley, Mourato, & Wright, 2001).

$$WTP = \frac{\beta_x}{\beta_c}$$

Where:

β_x: coefficient of any parameter

β_c: coefficient of cost parameter

Table 6: Willingness to pay for preferred parameters - cooking processes

Parameter	**WTP (USD)**
Pots with lid	0.73
Multiple hobs (4)	0.67
Boil and fry	0.63
Cooking fast	0.46

1.1.13. Stove features

Table 7 indicates different variables and their corresponding binary options selected to define stove features.

Table 7: Stove features and their corresponding options

Variable	Options
STpeople_7	0 4 people 1 7 people
STpeople_10	0 4 people 1 10 people
STsupplement_sometimes	0 always need to use with another stove 1 sometimes need to use with another stove
STsupplement_all	0 always need to use with another stove 1 can do all cooking on it
STsmoke_charcoal	0 no smoke 1 smoke like charcoal
STsmoke_wood	0 no smoke 1 smoke like firewood
STweight	0 portable 1 too heavy to move
STduration	0 3 years 1 5 years
STcost	0 20,000 and below 1 30000

A logistic regression was carried out to assess the influence of number of people an appliance cooks for, its capacity to cook different dishes, its emitted smokes, its portability, its duration, and cost of appliance on the choice of the cooking appliance. The overall model was significant when compared to null model (χ^2 (9) =872.180, p<0.001). The model explained 23.4% of variability in the choice of parameters and correctly predicted 69.0% of the choices.

Results, Table 8, show that stove features characteristics that appear to be most important to consumers are:

- Smoke emissions like wood fire: people expressed the importance of avoiding appliances that emit smokes like the ones from wood fire. However, the analysis wasn't conclusive regarding charcoal emissions.
- Cost: people seem more likely to choose low-cost appliances
- Portable appliances: the ability to move the cooking appliance in and out of the kitchen was also found important to respondents.
- Supplemented by another stove: people expressed that they are happier supplementing their appliance with another stove, which might be a reflection for their existing stacking practices.
- Appliance that lasts long: people seem to prefer appliance that last long, 5 years compared to 3 years in this case study.
- Appliance that cooks for many people: interestingly, results show that respondents prefer appliance that can cook for up to 7 people rather than 4, but regarding the preference to cook for 10 people, the results were not conclusive.

Table 8: Binary logistic regression output: stove features

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	STpeople_7(1)	.346	.112	9.516	1	.002	1.413	1.134	1.761
	STpeople_10(1)	.108	.115	.891	1	.345	1.115	.890	1.396
	STsupplement_sometime (1)	-.518	.123	17.730	1	<.001	.596	.468	.758
	STsupplement_all(1)	-.386	.127	9.298	1	.002	.680	.530	.871
	STsmoke_charcoal(1)	.144	.103	1.955	1	.162	1.155	.944	1.415
	STsmoke_wood(1)	-1.309	.107	148.634	1	<.001	.270	.219	.333
	STweight(1)	-.780	.093	70.730	1	<.001	.459	.382	.550
	STduration(1)	.418	.094	19.767	1	<.001	1.519	1.263	1.826
	STcost(1)	-.935	.133	49.602	1	<.001	.393	.303	.509
	Constant	.456	.127	12.949	1	<.001	1.578		

a. Variable(s) entered on step 1: STpeople_7, STpeople_10, STsupplement_sometime, STsupplement_all, STsmoke_charcoal, STsmoke_wood, STweight, STduration, STcost.

Table 9: Willingness to pay for preferred parameters - stove features

Parameter	WTP (USD)
Wood-like smoke	-1.37
Portability	-0.82
Supplementary appliance	-0.54
Duration	0.44
Cook for many people	0.36

1.1.14. Additional functionalities

Table 10 indicates different variables and their corresponding binary options selected to define additional functionalities.

Table 10: Additional functionalities and their corresponding options

Variable	Options	
Fnhobs_led	0	2 hobs
	1	2 hobs + 3 LED lights
FNhobs_charge	0	2 hobs
	1	2 hobs + charge mobile phone
FNhobs_tv	0	2 hobs
	1	2 hobs + TV
FNavailability	0	only works on sunny days
	1	works on sunny and rainy days
FNfinancing_go	0	half upfront and the rest in instalments
	1	pay as you go (monthly)
FNfinancing_cash	0	half upfront and the rest in instalments
	1	pay cash in totality
FNcleaning	0	awkward to clean
	1	easy to clean
FNcost	0	15,000 and below
	1	25,000

A logistic regression was carried out to assess the influence of topping up different devices (lights, mobile phone charging, TV) on the appliance, its availability in terms of sunny and rainy days, financing options, its ability to clean, and its appliance cost on the choice of the cooking appliance. The overall model was significant when compared to null model (χ^2 (8) =371.352, p<0.001). The model explained 10.5% of variability in the choice of parameters and correctly predicted 59.8% of the choices.

Results, Table 11, show that additional functionalities characteristics that appear to be most important to consumers are:

- Sunny and rainy days: respondents seem to prefer appliance which aren't affected by the weather, thus can cook any time of the day, whether it's raining or it's sunny.
- Ease to clean: people give importance to appliances that can be cleaned easily
- Financing: people expressed that they would prefer to pay half upfront with the rest being paid in instalments instead of full cash payment or monthly payments in form of Pay As You Go.
- Cost: people were more likely to choose low-cost appliances
- Additional features: people expressed the importance of having a TV in addition to cooking appliances, however, other features such as lights and charge station were not conclusive.

Table 11: Binary logistic regression output: additional functionalities

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Fnhobs_led(1)	.183	.120	2.318	1	.128	1.201	.949	1.521
	FNhobs_charge(1)	.343	.129	7.047	1	.008	1.409	1.094	1.816
	FNhobs_tv(1)	.505	.127	15.856	1	<.001	1.658	1.293	2.126
	FNavailability(1)	1.225	.096	164.160	1	<.001	3.405	2.823	4.107
	FNfinancing_go(1)	-.716	.111	41.390	1	<.001	.489	.393	.608
	FNfinancing_cash(1)	-.356	.107	11.100	1	<.001	.701	.568	.864
	FNcleaning(1)	.767	.088	76.444	1	<.001	2.154	1.814	2.559
	FNcost(1)	-.508	.106	23.053	1	<.001	.602	.489	.741
	Constant	-.479	.136	12.435	1	<.001	.620		

a. Variable(s) entered on step 1: Fnhobs_led, FNhobs_charge, FNhobs_tv, FNavailability, FNfinancing_go, FNfinancing_cash, FNcleaning, FNcost.

Table 12: Willingness to pay for preferred parameters - Additional functionalities

Parameter	WTP (USD)
Availability	2.36
Cleaning	1.48
Financing	-1.38
Additional TV	0.97

1.1.15. Disaggregating respondents into groups

Respondents and their respective HHs have been expressed into 7 different variables to explore differences in preferences and impact of each group on the choice of appliance characteristics. Those variables were:

- Gender
- Type of settlement
- Type of main cooking fuel
- Household's size
- Age of the respondent
- Domestic status
- Technology proficiency

The analysis investigated the relationship between these variables and the modelling parameters that were selected important (preferred) by respondents: cooking processes (cost of appliance, use of the lid, number of hobs, and type of cooking), stove features (smoke emissions like wood fire, portability, usage of supplementary appliance, cooking for a large number, and duration), additional functionalities (effect of weather and time, ease to clean, financing, and additional feature in terms of a TV). The analysis used a 95% confidence level.

A. Gender

Table 13 suggests that gender had no effect on any of the selected preferred appliance's characteristics, as there was not enough evidence to suggest relationship with any variables (p-value >0.05 for each). This means both female and male users would have the same preferences on these variables.

Table 13: Effect of gender on preferred appliance's characteristics

Variable		Options	Female	Male	Pearson Chi-square Value	df	Asymptotic Significance (2-sided)
CPcost	0	Rwf 20,000 and below	3016	897	.371a	1	0.542
	1	Rwf 30,000	458	145			
CPboil	0	can only boil	928	276	.021a	1	0.885
	1	can boil and fry	2546	766			
CPpot_lid	0	pot with no lid	1392	414	.038a	1	0.845
	1	pot with lid	2082	628			
CPhob_4	0	1 hob	3004	911	.636a	1	0.425
	1	4 hobs	470	131			
STsmoke_wood	0	no smoke	2421	742	.883a	1	0.347
	1	smoke like firewood	1053	300			
STweight	0	portable	2552	759	.157a	1	0.692
	1	too heavy to move	922	283			
STsupplement_sometimes	0	sometimes need to use with another stove	3004	911	.636a	1	0.425
	1	can do all cooking on it	470	131			
STpeople_7	0	4 people	3016	897	.371a	1	0.542
	1	7 people	458	145			
STduration	0	3 years	2546	766	.021a	1	0.885
	1	5 years	928	276			
FNavailability	0	only works on sunny days	2653	811	.961a	1	0.327
	1	works on sunny and rainy days	821	231			
FNcleaning	0	awkward to clean	934	269	.469a	1	0.493
	1	easy to clean	2540	773			
FNfinancing_go	0	half upfront and the rest in instalments	1386	421	.086a	1	0.77
	1	pay as you go (monthly)	2088	621			
FNhobs_tv	0	2 hobs	3010	904	.009a	1	0.925
	1	2 hobs + TV	464	138			

a. 0 cells (0%) have expected count less than 5

B. Type of settlement

Table 14 indicates that the HH's location influences the choice of appliance cost (X^2 = 28.1, p-value <0.001), number of hobs (X^2 = 48.1, p-value <0.001), wood-like smoke emissions (X^2 = 66.7, p-value <0.001), portability of the appliance (X^2 = 11.8, p-value =0.003), usage of supplementary appliance (X^2 = 48.13, p-value <0.001), capacity of the appliance in terms of number of people it cooks for (X^2 = 28.1, p-value <0.001), its availability in terms of weather impact (X^2 = 72.7, p-value <0.001), and how easy it is to clean it (X^2 = 35.5, p-value <0.001). In fact, it seems that rural HHs are less interested in appliance with many hobs, less bothered by wood-like smoke emissions, portability of the appliance, and impact of weather on the appliance as opposed to urban ones. Rural HHs are, however, more interested in low-cost appliances, in using a supplementary appliance, in appliances that can cook for many people and easy to clean in contrast with the urban HHs. For the remaining characteristics (variables), it seems that the HH's location does not have any effect (p-value >0.05 for each).

Table 14: Effect of settlement type on preferred appliance's characteristics

Variable	Options		Peri urban	Rural	Urban	Pearson Chi-square Value	df	Asymptotic Significance (2-sided)
CPcost	0	Rwf 20,000 and below	1300	663	1950	28.069a	2	<.001
	1	Rwf 30,000	200	153	250			
CPboil	0	can only boil	400	204	600	1.572a	2	0.456
	1	can boil and fry	1100	612	1600			
CPpot_lid	0	pot with no lid	600	306	900	2.883a	2	0.237
	1	pot with lid	900	510	1300			
CPhob_4	0	1 hob	1300	765	1850	48.136a	2	<.001
	1	4 hobs	200	51	350			
STsmoke_wood	0	no smoke	1050	663	1450	66.758a	2	<.001
	1	smoke like firewood	450	153	750			
STweight	0	portable	1100	561	1650	11.885a	2	0.003
	1	too heavy to move	400	255	550			

STsupplement_sometimes	0	sometimes need to use with another stove	1300	765	1850	48.13a	2	<.001
	1	can do all cooking on it	200	51	350			
STpeople_7	0	4 people	1300	663	1950	28.069a	2	<.001
	1	7 people	200	153	250			
STduration	0	3 years	1100	612	1600	1.572a	2	0.456
	1	5 years	400	204	600			
FNavailability	0	only works on sunny days	1150	714	1600	72.699a	2	<.001
	1	works on sunny and rainy days	350	102	600			
FNcleaning	0	awkward to clean	400	153	650	35.497a	2	<.001
	1	easy to clean	1100	663	1550			
FNfinancing_go	0	half upfront and the rest in instalments	600	357	850	6.485a	2	0.039
	1	pay as you go (monthly)	900	459	1350			
FNhobs_tv	0	2 hobs	1300	714	1900	.665a	2	0.717
	1	2 hobs + TV	200	102	300			

a. 0 cells (0%) have expected count less than 5

C. Household's main cooking fuel

Similar to the HH's location, the type of HH's main cooking fuel, Table 15, seems to influence the choice of appliance cost (X^2 = 32.8, p-value <0.001), number of hobs (X^2 = 56.4, p-value <0.001), wood-like smoke emissions (X^2 = 78.2, p-value <0.001), portability of the appliance (X^2 = 13.9, p-value =0.003), usage of supplementary appliance (X^2 = 56.4, p-value <0.001), capacity of the appliance in terms of number of people it cooks for (X^2 = 32.3, p-value <0.001), its availability in terms of weather impact (X^2 = 85.2, p-value <0.001), and how easy it is to clean it (X^2 = 41.5, p-value <0.001). In fact, it seems that firewood and charcoal users are less interested in appliance with many hobs, less bothered by wood-like smoke emissions, portability of the appliance, and impact of weather on the appliance as opposed to LPG users. Firewood and charcoal users are, however, more interested in low-cost appliances, happier to use a supplementary appliance, in appliances that can cook for many people and easy to clean in contrast with the LPG users. For the remaining characteristics (variables), it seems that the HH's location does not have any effect (p-value >0.05 for each).

The uncanny effect resemblance between HH's location and the type of HH's main cooking fuel is not surprising though, since 80% of firewood users were rural HHs whilst 80% of LPG users were urban HHs (Figure 15).

Table 15: Effect of type of household's main cooking fuel on preferred appliance's characteristics

Variable	Options		Charcoal	Electricity	Firewood	LPG	Pearson Chi-square Value	df	Asymptotic Significance (2-sided)
CPcost	0	Rwf 20,000 and below	1820	39	520	1534	32.88a	3	<.001
	1	Rwf 30,000	318	3	112	170			
CPboil	0	can only boil	560	12	160	472	1.842a	3	0.606
	1	can boil and fry	1578	30	472	1232			
CPpot_lid	0	pot with no lid	840	18	240	708	3.378a	3	0.337
	1	pot with lid	1298	24	392	996			
CPhob_4	0	1 hob	1896	33	584	1402	56.401a	3	<.001
	1	4 hobs	242	9	48	302			
STsmoke_wood	0	no smoke	1565	24	500	1074	78.221a	3	<.001
	1	smoke like firewood	573	18	132	630			
STweight	0	portable	1540	33	440	1298	13.926a	3	0.003
	1	too heavy to move	598	9	192	406			
STsupplement_sometimes	0	sometimes need to use with another stove	1896	33	584	1402	56.40a	3	<.001
	1	can do all cooking on it	242	9	48	302			
STpeople_7	0	4 people	1820	39	520	1534	32.889a	3	<.001
	1	7 people	318	3	112	170			
STduration	0	3 years	1578	30	472	1232	1.842a	3	0.606

	1	5 years	560	12	160	472			
FNavailability	0	only works on sunny days	1705	27	540	1192	85.182a	3	<.001
	1	works on sunny and rainy days	433	15	92	512			
FNcleaning	0	awkward to clean	522	15	128	538	41.593a	3	<.001
	1	easy to clean	1616	27	504	1166			
FNfinancing_go	0	half upfront and the rest in instalments	878	15	272	642	7.598a	3	0.055
	1	pay as you go (monthly)	1260	27	360	1062			
FNhobs_tv	0	2 hobs	1858	36	552	1468	.780a	3	0.854
	1	2 hobs + TV	280	6	80	236			

a. 0 cells (0%) have expected count less than 5

D. Household's size

Table 16 suggests that the number of people living in the HH had no effect on any of the selected preferred appliance's characteristics (variables), as there was not enough evidence to suggest relationship with any variables (p-value >0.05 for each). This means both HHs with less than 4 people and those with more than that would have the same preferences on these variables.

Table 16: Effect of household's size on preferred appliance's characteristics

					Pearson Chi-square		
Variable	**Options**		**5 - above**	**1 to 4**	**Value**	**df**	**Asymptotic Significance (2-sided)**
CPcost	0	Rwf 20,000 and below	2093	1820	.525a	1	0.469
	1	Rwf 30,000	313	290			
CPboil	0	can only boil	644	560	.029a	1	0.864
	1	can boil and fry	1762	1550			
CPpot_lid	0	pot with no lid	966	840	.054a	1	0.816
	1	pot with lid	1440	1270			

CPhob_4	0	1 hob	2075	1840	.900a	1	0.343
	1	4 hobs	331	270			
STsmoke_wood	0	no smoke	1668	1495	1.248a	1	0.264
	1	smoke like firewood	738	615			
STweight	0	portable	1771	1540	.222a	1	0.637
	1	too heavy to move	635	570			
STsupplement_sometimes	0	sometimes need to use with another stove	2075	1840	.900a	1	0.343
	1	can do all cooking on it	331	270			
STpeople_7	0	4 people	2093	1820	.525a	1	0.469
	1	7 people	313	290			
STduration	0	3 years	1762	1550	.029a	1	0.864
	1	5 years	644	560			
FNavailability	0	only works on sunny days	1829	1635	1.359a	1	0.244
	1	works on sunny and rainy days	577	475			
FNcleaning	0	awkward to clean	653	550	.664a	1	0.415
	1	easy to clean	1753	1560			
FNfinancing_go	0	half upfront and the rest in instalments	957	850	.121a	1	0.728
	1	pay as you go (monthly)	1449	1260			
FNhobs_tv	0	2 hobs	2084	1830	.012a	1	0.911
	1	2 hobs + TV	322	280			

a. 0 cells (0%) have expected count less than 5

E. Age of the respondents

Respondents' age, Table 17, seems to influence the choice of appliance cost (X^2 = 7.7, p-value =0.005), number of hobs (X^2 = 13.3, p-value <0.001), wood-like smoke emissions (X^2 = 18.4, p-value <0.001), usage of supplementary appliance (X^2 = 13.3, p-value <0.001), capacity of the appliance in terms of number of people it cooks for (X^2 = 7.7, p-value =0.005), its availability in terms of weather impact (X^2 = 20.1, p-value <0.001), and how easy it is to clean it (X^2 = 9.8, p-value =0.002). In fact, it seems that respondents more than 30 years old are more interested in low-cost appliances, in appliances that can perform all the cooking, appliance that cook for many people, with many hobs, that is not impacted by weather conditions (works every time), and that are easy to clean, as opposed to the youth. On the other hand, however, 30 years old and above respondents are less bothered by wood-like smoke emissions as opposed to youth (30 years old or less). For the remaining characteristics (variables), it seems that the respondents' age does not have any effect (p-value >0.05 for each).

Table 17: Effect of respondent's age on preferred appliance's characteristics

Variable	Options		30 - above	Youth	Pearson Chi-square Value	df	Asymptotic Significance (2-sided)
CPcost	0	Rwf 20,000 and below	1742	2171	7.757a	1	0.005
	1	Rwf 30,000	232	371			
CPboil	0	can only boil	536	668	.435a	1	0.51
	1	can boil and fry	1438	1874			
CPpot_lid	0	pot with no lid	804	1002	.797a	1	0.372
	1	pot with lid	1170	1540			
CPhob_4	0	1 hob	1670	2245	13.303a	1	<.001
	1	4 hobs	304	297			
STsmoke_wood	0	no smoke	1317	1846	18.449a	1	<.001
	1	smoke like firewood	657	696			
STweight	0	portable	1474	1837	3.285a	1	0.07
	1	too heavy to move	500	705			
STsupplement_sometimes	0	sometimes need to use with another stove	1670	2245	13.303a	1	<.001
	1	can do all cooking on it	304	297			
STpeople_7	0	4 people	1742	2171	7.757a	1	0.005
	1	7 people	232	371			
STduration	0	3 years	1438	1874	.435a	1	0.51
	1	5 years	536	668			
FNavailability	0	only works on sunny days	1451	2013	20.091a	1	<.001
	1	works on sunny and rainy days	523	529			

FNcleaning	0	awkward to clean	572	631	9.810a	1	0.002
	1	easy to clean	1402	1911			
FNfinancing_go	0	half upfront and the rest in instalments	768	1039	1.792a	1	0.181
	1	pay as you go (monthly)	1206	1503			
FNhobs_tv	0	2 hobs	1706	2208	.184a	1	0.668
	1	2 hobs + TV	268	334			

a. 0 cells (0%) have expected count less than 5

E. Domestic status

Table 18 indicates that the domestic status influences the choice of appliance cost (X^2 = 20.9, p-value <0.001), number of hobs (X^2 = 35.9, p-value <0.001), wood-like smoke emissions (X^2 = 49.8, p-value <0.001), portability of the appliance (X^2 = 8.8, p-value =0.003), usage of supplementary appliance (X^2 = 35.9, p-value <0.001), capacity of the appliance in terms of number of people it cooks for (X^2 = 20.9, p-value <0.001), its availability in terms of weather impact (X^2 = 54.3, p-value <0.001), how easy it is to clean it (X^2 = 26.5, p-value <0.001), and the financing structure (X^2 = 4.8, p-value =0.02). In fact, it seems that the unaffluent HHs are interested in low-cost appliance, in appliance with many hobs, in portable appliances, appliance that can do all the cooking, appliance that is not impacted by the weather conditions (can work every time) and would prefer to pay monthly instalments for the appliance in from of PAYG, as opposed to the Better-off. On the other hand, they are less bothered by wood-like smoke emissions, by cleaning difficulty and would do without appliance that cooks for many people, in contrast to better-off HHs. For the remaining characteristics (variables), it seems that the domestic status does not have any effect (p-value >0.05 for each).

Table 18: Effect of domestic status on preferred appliance's characteristics

Variable	Options		Better-off	Unaffluent	Pearson Chi-square		
					Value	df	Asymptotic Significance (2-sided)
CPcost	0	Rwf 20,000 and below	1586	2327	20.97a	1	<.001
	1	Rwf 30,000	304	299			
CPboil	0	can only boil	488	716	1.175a	1	0.278
	1	can boil and fry	1402	1910			
CPpot_lid	0	pot with no lid	732	1074	2.154a	1	0.142
	1	pot with lid	1158	1552			

CPhob_4	0	1 hob	1706	2209	35.96a	1	<.001
	1	4 hobs	184	417			
STsmoke_wood	0	no smoke	1431	1732	49.87a	1	<.001
	1	smoke like firewood	459	894			
STweight	0	portable	1342	1969	8.879a	1	0.003
	1	too heavy to move	548	657			
STsupplement_sometimes	0	sometimes need to use with another stove	1706	2209	35.96a	1	<.001
	1	can do all cooking on it	184	417			
STpeople_7	0	4 people	1586	2327	20.970a	1	<.001
	1	7 people	304	299			
STduration	0	3 years	1402	1910	1.175a	1	0.278
	1	5 years	488	716			
FNavailability	0	only works on sunny days	1553	1911	54.31a	1	<.001
	1	works on sunny and rainy days	337	715			
FNcleaning	0	awkward to clean	428	775	26.52a	1	<.001
	1	easy to clean	1462	1851			
FNfinancing_go	0	half upfront and the rest in instalments	792	1015	4.845a	1	0.028
	1	pay as you go (monthly)	1098	1611			
FNhobs_tv	0	2 hobs	1646	2268	.497a	1	0.481
	1	2 hobs + TV	244	358			

a. 0 cells (0%) have expected count less than 5

F. Technology proficiency

Table 19 suggests that the technology proficiency had no effect on any of the selected preferred appliance's characteristics, as there was not enough evidence to suggest relationship with any variables (p-value >0.05 for each). This means both proficient and non-proficient users would have the same preferences on these variables.

Table 19: Effect of technology proficiency on preferred appliance's characteristics

Variable	Options		Experienced users	Novice	Pearson Chi-square Value	df	Asymptotic Significance (2-sided)
CPcost	0	Rwf 20,000 and below	2678	1235	.048a	1	0.827
	1	Rwf 30,000	410	193			
CPboil	0	can only boil	824	380	.435a	1	0.959
	1	can boil and fry	2264	1048			
CPpot_lid	0	pot with no lid	1236	570	.005a	1	0.944
	1	pot with lid	1852	858			
CPhob_4	0	1 hob	2674	1242	.082a	1	0.774
	1	4 hobs	414	187			
STsmoke_wood	0	no smoke	2158	1005	.114a	1	0.736
	1	smoke like firewood	930	423			
STweight	0	portable	2266	1045	.02a	1	0.887
	1	too heavy to move	822	383			
STsupplement_sometimes	0	sometimes need to use with another stove	2674	1241	.082a	1	0.774
	1	can do all cooking on it	414	187			
STpeople_7	0	4 people	2678	1235	.048a	1	0.827
	1	7 people	410	193			
STduration	0	3 years	2264	1048	.003a	1	0.959
	1	5 years	824	380			
FNavailability	0	only works on sunny days	2364	1100	.124a	1	0.725
	1	works on sunny and rainy days	724	328			
FNcleaning	0	awkward to clean	826	377	.061a	1	0.806
	1	easy to clean	2262	1051			
FNfinancing_go	0	half upfront and the rest in instalments	1234	573	.011a	1	0.916
	1	pay as you go (monthly)	1854	855			
FNhobs_tv	0	2 hobs	2676	1238	.001a	1	0.973
	1	2 hobs + TV	412	190			

a. 0 cells (0%) have expected count less than 5

4. Conclusion

Although eCooking was found merely existent as a main cooking fuel, the DCM study has highlighted several potential opportunities for eCookers manufacturers and suppliers for the Rwandan market. Preference choices of appliances' characteristics showed that eCookers, EPC particularly, could well fit with the Rwandan cookstove's requirements, in terms of the possibility to use the lid or not whenever they see fit, ability to both boil and fry, to avoiding wood-like smoke's emissions, the ability to move the cooking appliance in and out of the kitchen, the ability to do all the cooking activities, the capacity to cook for many people, to be able to last long, weather-independence, and ease to clean. The study showed also that eCookers' suppliers would need to put in place interesting financing mechanisms if they are to win over the market. However, there's need to resolve the issue of multiple hobs for EPCs. Furthermore, the study showed that a special attention is needed when designing marketing strategies, as there is a distinct importance on various appliances' characteristics depending on settlement location, domestic status, or age of customers. Rural and urban HHs do not necessarily prefer appliances with similar characteristics nor youth and much older customers.

Non-frequent power outages highlighted in this report provide another potential opportunity for eCooking development. In fact, A/C eCooking is a reliable option for grid connected HHs. Further analysis should, however, be conducted for each concerned mini grid to gather data on electricity reliability. Urban HHs generally cooked 3 meals a day with the third coinciding with the utility and mini grid peak consumption. Special cooking tariff by the utility should be explored for future eCooking development.

Respondents reported their existing cooking fuel (LPG, charcoal, and firewood) expensive, which could provide a room for eCooking introduction. In fact, looking at the cooking diary results, eCooking would be cost competitive as it was reported the cheapest fuel to cook a meal for one person compared to charcoal and LPG. In addition, respondents were convinced that many people would change their cooking fuel to eCooking should their price be in the same range. This claim was supported by the fact that people were aware of the health problems associated with smokes' emissions as well as the burden associated with wood collection.

Generally, whether from urban or rural HHs, people seemed familiar with mobile telephone-based technology, which could be a serious option to explore when designing innovative financing mechanisms for eCookers.

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