Cooking Diary study

Rwanda

Working paper

February 2022

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Energy 4 Impact

This material has been funded by UK aid from the UK government; however, the views expressed do not necessarily reflect the UK government's official policies.

Funded by:

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 learnings from a cooking diary study conducted to understand how Rwandan people transition to different fuels or cooking appliances, particularly electric cooking (eCooking), and how this affects their cooking practices. The study combines qualitative and quantitative evidence to get a deeper understanding of how people cook, their energy consumption, and how their practices affect their choice of cooking technologies.

The main cooks of 25 households (HHs) in Kigali, Rwanda were asked to keep a cooking diary over eight weeks, from May to October 2021. They were asked to record how much time they spent, which process they used and how much energy was consumed for every heating event over the period. For the first two weeks (the baseline phase), HHs were asked to cook as they would normally, with their usual fuels and stoves. For the next three weeks (the transition phase), they were asked to cook only with electricity, which was provided for free, using an electric pressure cooker (EPC) and an infrared cookstove also provided for free, plus any electrical appliances they already owned. For the last three weeks (the end-line phase), they were allowed to use any fuel and appliance they chose. The HHs were also allowed one week cooking with an appliance of their choice with free electricity provided.

Fuel quantities were measured by weighing charcoal or LPG cylinders before and after each heating event, and smart electricity meters were used for the eCooking appliances. The 25 HHs were grouped into five clusters, with three in urban areas and two in peri-urban area, so that data for both traditional and modern cuisines could be captured. A list of common Rwandan dishes has been compiled, too.

The cooking diary key findings have been summarized into appliances and fuel preference, cooking habits and eCooking compatibility, fuel stacking, energy demand and consumption, energy cost, and eCooking load profiles.

Appliance and fuel preference

At the beginning of the study, we conducted a demographics and general conditions survey of the HHs, which showed that charcoal and LPG were the most popular cooking fuels. Each of the 25 HHs owned a charcoal stove and 21 of them owned an LPG stove. There was moderate ownership of electric appliances (10 HHs), and they were only task-specific (kettle, microwave, blender, and toaster). Firewood stoves were found only in three HHs. The baseline survey showed that no HH cooked solely using electricity or firewood, just two HHs solely used LPG and three used only charcoal. During the baseline dairies, the data collected showed LPG was the most used fuel at 58% followed by charcoal at 39%. After three weeks of eCooking, fuel preferences changed. LPG was still the most used fuel at 36%, but this time it was followed by electricity at 23%. Charcoal use was reduced to 16%, and eCooking events increased to 47%. The participants found electricity to be an effective cooking fuel and they revealed that they found most of their dishes compatible with the eCooking appliances.

Cooking habits and eCooking compatibility

Throughout the three cooking diary phases, data shows that more than 88% of the time, HHs prepared meals (breakfast, lunch, and supper) on a single heating event basis, meaning that they usually prepared what is about to be consumed. This means they spend a significant amount of time in the kitchen, and it is not HH members who usually cook but rather paid house workers. The proportion of breakfast, lunch, supper, and water heating remained almost similar when shifting from transition phase to end-line phase, which could indicate that eCooking is adaptable to Rwandan cooking habits. In addition, the proportions of water heating purposes (drinking/purifying, tea/coffee, and bathing) remained similar during both baseline and transition phases, highlighting, again, the compatibility of eCooking to Rwandan habits. Most of the prepared heating events through the day were for lunch and supper, which each accounted for around 35% of heating events throughout the three phases.

For both baseline and transition phases, the most popular dishes stayed in the same order of popularity, suggesting that eCooking was generally compatible with Rwandan cuisine. Boiled dishes were cooked more frequently during the transition phase, whereas deep-fried dishes such as chips and fish were less frequent, as they weren't compatible with EPC. The practice of reheating food continued throughout the study, for all types of meals. However, cooking fresh food was preferred, accounting for up to 75% of events for both lunch and supper, while breakfast stood at 90%. The gap between cooking fresh food and reheating widened as the HHs shifted to eCooking, with cooking fresh food accounting for 90% of the events for lunch and supper and 97% for breakfast. Stews were the most frequently reheated dishes.

The longest time spent cooking breakfast was using charcoal. This was around 120 minutes, which was three times that of eCooking and four times compared to LPG. Preparing supper using charcoal took almost double the time taken with eCooking. At lunchtime, cooking with charcoal also took the longest at 115 minutes, followed by LPG at around 95 minutes and eCooking at around 80 minutes.

Fuel stacking

The fact that each HH owned two or more cooking appliances could be an indication of the fuel stacking that most Rwandan HHs practise. Nevertheless, the study found that fuel-stacking happened in just 2% of heating events during the baseline phase. End-line phase data shows an increase in fuel-stacking. In fact, electricity was combined with LPG in 17% of all the heating events, and again electricity combined with charcoal in 7% of heating events, while LPG and charcoal were combined in 1% of all heating events. Fuel stacking was found to increase when multiple heating events (cooking of several dishes same time) occurred, as cooks try to save on cooking time and usually used several appliances.

Energy demand and consumption

Analysis of the mean energy required to cook a meal showed that cooking with electricity required the least amount of energy, at 0.76 MJ per person, followed by LPG, which required 2.83 MJ per person.
Charcoal accounted for the highest amount of energy per person, at 6.4 MJ. Lunch and supper required comparable and highest amount of total energy when using LPG (1,776 MJ and 1,823 MJ respectively) and electricity (1,049 MJ and 933 MJ for lunch and super respectively). However, when using charcoal, a slightly higher amount was noted for supper (4,675 MJ) compared to lunch (3,828 MJ). Fuel energy consumption changed with the type of food cooked. For instance, the mean per capita energy consumption for cooking beans decreased by 10 times, cooking rice by 8 times and cooking porridge decreased by three times when using the energy-efficient eCooking appliance (EPC) compared to baseline (mostly charcoal).

Energy cost

During the registration survey, the monthly HH cooking fuel expenditure averaged $[1]27.6, including $10.8 for charcoal and $16.8 for LPG. However, that cooking fuel expenditure did not include eCooking, as HHs were not aware of the amount of electricity used to cook. Nevertheless, the monthly HHs average electricity consumption for both cooking and other domestic applications before the study was $11.7.

At the end of the cooking diary, an exit survey was conducted to collect feedback from participating HHs, and data shows 21 out of 25 HHs found eCooking affordable. The affordability of eCooking is also highlighted by the analysis of the prevailing fuel costs in Kigali city during the cooking diary study period. eCooking cost per capita was $0.047 per meal while charcoal was $0.068 per meal and LPG was at $0.073 per meal.

eCooking load profiles

Throughout the cooking diary study, breakfast, lunch, and supper were cooked at similar times of the day, no matter which cooking fuel was used. eCooking load profiles that were computed through smart meter data aggregated across multiple HHs showed two peak periods – midday and evening. The evening peak coincided with peak times for utility and minigrids.

[1] Exchange rate: USD 1 = Rwf 1010

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1. Introduction

1.1. 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 cooking diary 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 study combines qualitative and quantitative evidence to get a deeper understanding of how people in Rwanda cook, their energy consumption and how their practices affect their choice of cooking technologies. This CD report is based on primary data collected by E4I between May and October 2021. E4I carried out five different surveys with 25 participating HHs across five different clusters within Kigali city. This report analyses empirical evidence on energy use, menu choices and cooking preferences as well as participants' feedbacks, and presents outputs highlighting the market potential of eCooking in Rwanda.

1.2. 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)[2].

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

[2] NISR, 2018. EICV5: Rwanda Poverty Profile Report, National Institute of Statistics of Rwanda

factor for morbidity and mortality in Rwanda, and respiratory infection is the leading cause of loss of life (IHME, 2021)[3]. 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. 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)[4].

1.3. 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)[5] 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 manufacturing EPCs in Rwanda, which would reduce considerably most of the barriers to adoption of eCooking.

[3] IHME, 2021. Country profile/Rwanda. Institute for Health Metrics and Evaluation
[4] The World Bank, 2020. Rwanda - Energy Access and Quality Improvement Project
[5] BRD, 2021. Priority sectors- Energy. Banque Rwandaise de Developement

1.4. Aims of the study

The aim of this study is to gain insights into how Rwandan HHs cook, and to what extent their cooking practices are compatible with cooking with electricity.

In particular, the objectives are:

- To find out how and what Rwandan HHs cook
- To assess the user acceptability of electric cooking appliances for cooking popular Rwandan dishes
  - ✓ Can people cook the foods they want?
  - ✓ If so, which appliances are best matched with each food?
- To quantify the amount of energy Rwandan HHs need to cook
  - ✓ To make comparisons between electricity and popular fuels
  - ✓ To generate cooking load profiles for typical HHs

2. Methodology

2.1. Study set up

The study was organised to ensure that accurate data was captured as accurately as possible and the participants well protected. To ensure this the following items were provided in each cluster:

- 1 enumerator, who came from within the locality
- 5 HH's main cooks who will be trained as assistant enumerators
- 5 HHs whose owners have agreed to participate in the study
- 5 weighing scales, 1 for each HH
- 5 EPCs, 1 per HH
- 5 infra-red cookers, 1 per HH
- 2 smart meters in each HH
- Standard kitchen electric wiring
- Protective gear (a pair of apron and chefs head scarf per main cook)

The enumerator recruited from each of the clusters had good knowledge of the neighbourhood and HH characteristics. Specifically, enumerators had the following characteristics:

- University graduates or in the university
- Familiar with the HHs in their locality and well known to the HH owners
- 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 process of most common Rwanda dishes

Enumerators were asked to identify five HHs with the following characteristics:

- Has four or five members
- Cooking is mainly done at home rather than eating out
- The main cook in the house makes the major decisions on cooking
- The main cook is literate
- HHs cooks two to three times a day,

A snowball sampling method was used to identify the HHs that fit the criteria, to ensure there was trust among participants.

2.2. Study area

The cooking diary study was conducted in 25 HHs located in five clusters – Gahanga, Kanombe, Kimironko, Niboye, and Nyamirambo – across Kigali City in Rwanda (figure 1). Five HHs were sampled in each cluster. The study area was limited to Kigali mainly because of its grid power stability and because there are more HHs with higher economic status. Clusters, on the other hand, were selected to include both urban (Kimironko, Niboye, Nyamirambo) and peri-urban (Gahanga, Kanombe) areas.

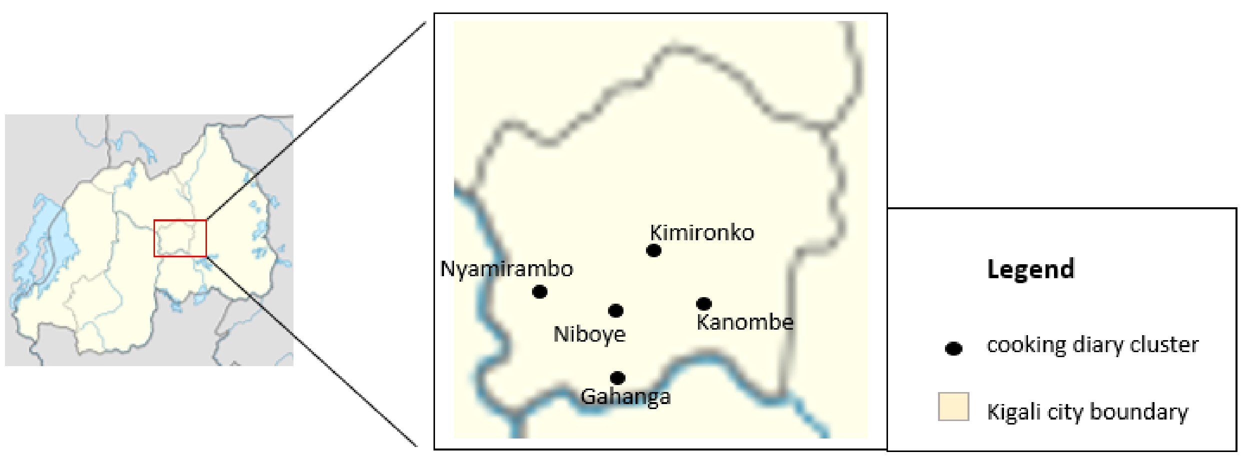

Figure 1: Cooking diary study location

2.3. eCooking concept for the study

The electric cooking (eCooking) appliances used during this study included an Electric pressure cooker (EPC) and an infrared stove, and in all instances the HHs had a grid connection (figure 2).

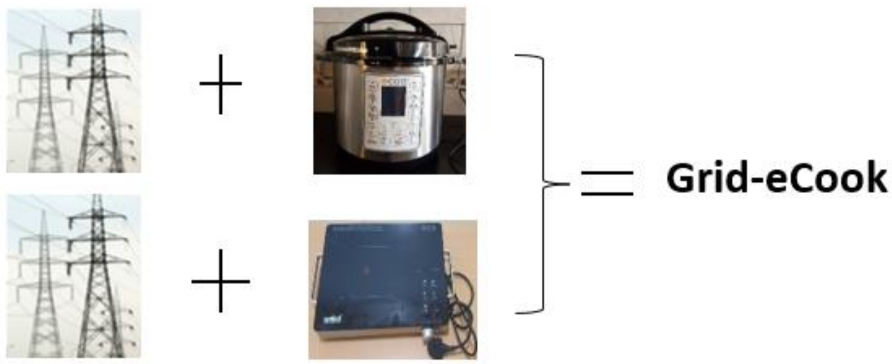

Figure 2: Schematic picture of the eCook used during the Cooking Diary study

2.4. Measuring fuel efficiency

The types of food and cooking practices vary widely across different countries and regions. There are a couple of internationally recognized cookstove tests that have significantly contributed to improving the efficiency of cookstoves. These include the water boiling test (WBT), the controlled cooking test (CCT), and the kitchen performance test (KPT). These tests evolve from lab-controlled conditions (WBT) to field performance assessment; on one hand between two cookstoves using local foods, still under controlled environment (CCT), and on another hand with KPT producing fuel consumption data much closer to real kitchen conditions (Winrock International, 2017). Nevertheless, they still fall short on providing insights into "how" people cook. It is also important to understand how people transition to different fuels or cooking appliances, and how this affects their cooking practices.

To date, studies of "how" people cook have been purely based on observational qualitative data (Leary, et al., 2019). The cooking diary study, however, combines qualitative and quantitative evidence to get a deeper understanding of cooking practice in Rwanda.

2.5. Data collection and recording

For eight weeks, the 25 HHs kept detailed cooking diaries, recording what, when and how they cooked, for every heating event throughout their day. A *cooking diary form* (appendix A) was subdivided into three phases: two weeks of baseline phase cooking, three weeks of transition phase using electrical appliances (EPC and an infrared cookstove), and three weeks of end-line phase using whichever fuel they want. As well as these three study phases, two other surveys were conducted: a registration survey, which collected general HHs information at the beginning of the study, and an exit survey which collected HHs' feedback on the whole study, particularly on eCooking, at the end. Three different forms (figure 3) were used to record data needed for all three study phases and two surveys.

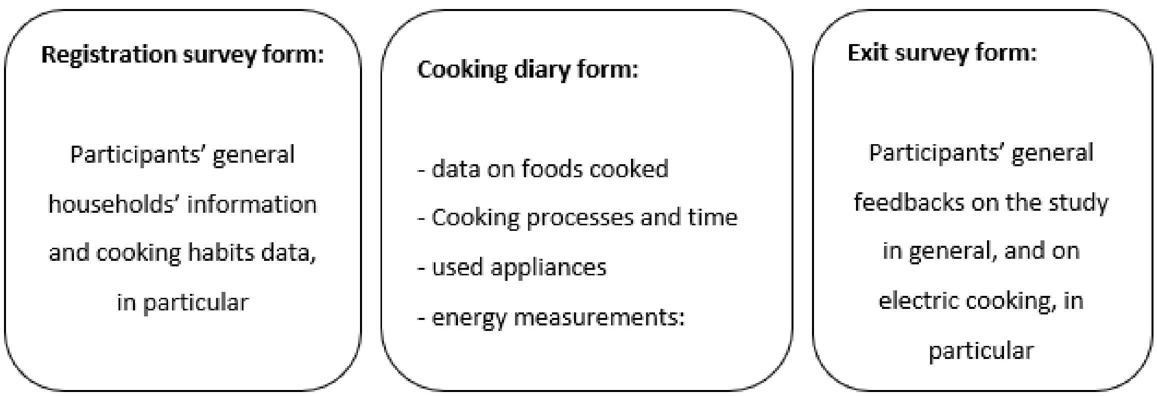

Figure 3: The forms used during the cooking diary study

2.6. Registration survey

The study started with a registration survey. Enumerators clarified the purpose of the research, obtained consent from HH heads, collected information, and submitted them through KoBo Toolbox. During that session, enumerators explained how to complete the cooking diary form and showed participants how to take energy measurements.

2.7. Baseline phase

Baseline data on how HHs normally cooked was captured for two weeks. Before cooking, the main cook would record the time and the energy reading by weighing the fuels. Energy measurements (for firewood, charcoal, LPG, and electricity) were taken before and after each heating event to give "*meal-level* *resolution"* data. Solid, liquid, and gaseous fuels were measured using the difference in weight between before and after cooking from a weighing balance, while electricity consumption was measured using an electricity smart meter. Floor-lying weighing scales were provided to each HH to weigh heavy LPG cylinders (figure 4). An LPG cylinder would be weighed before and after cooking. Another technique used for firewood or charcoal was to weigh bags containing more than enough fuel before cooking, and after cooking weigh the remaining fuel. For both techniques, the weight difference would equal the used fuel.

Figure 4: LPG cylinder weight being measured

After cooking, they would again record time and energy, plus details of what they cooked and how they cooked it. Data was recorded on paper forms which were collected by the enumerators and transcribed into digital form using KoBo Toolbox. Participants were visited every day, or as often as possible, to make sure accurate data was recorded. In later phases, the visits gradually decreased to around twice to three times a week.

2.8. Transition phase

The HHs were then asked to transition into using solely electricity for cooking. Each HH was given one EPC and one infrared cookstove for free and received three days of training on how to use each appliance. To avoid electrical hazards, in each HH the kitchen electrical installation was upgraded with new and reliable wiring, and two smart meters were installed (one for each appliance). Participants could also carry on using any other electrical appliances that they already owned, if they were plugged into the smart meter so that energy consumption data could be captured. Data was recorded for a further three weeks and, to ensure continued use of the electric cooking appliances without fear of depleting their own electricity, free electricity top-ups were provided to each HH.

2.9. End-line phase

The transition phase was followed by a three-week end line phase. During this phase, participants were allowed to cook with any fuel of their choice, including eCooking. However, we withdrew the free electricity top-ups and infra-red cookers, after participants expressed concerns of high electricity consumption. The purpose of the end-line phase was to gather early insights on preferences to eCooking. Participants were asked to keep recording what type of food they cooked, how they cooked it and for how long, no matter which fuel they used.

2.10. Exit survey

An exit survey was conducted at the end of the study to gather participants' views on their experiences of cooking with different electric appliances. Participants were also invited to share their energy-efficient eCooking practices as a group by participating in the eCooking competition. Prizes were offered to the three participants who could cook half a kilogram of rice and beans using the least energy possible.

The complete database was retrieved from KoBo Toolbox and the analysis was performed in Excel.

3. Analysis

3.1. Data overview

3.1.1. Households overview

This overview comes from the analysis of the registration survey data which was conducted at the beginning of the cooking diary study. Demographic Information was collected for each HH (HH) during registration survey, including a description of the head of the HH (age, gender, level of education), description of the HH status (location, construction material, number of people living there), cooking appliances and fuels, and electricity usage.

Figure 5 below shows charcoal and LPG were the most popular fuels (more than 20 HHs each), electricity moderately used (10 HHs), and firewood was the least used (2 HHs). The same figure also indicates that several HHs used more than one fuel type.

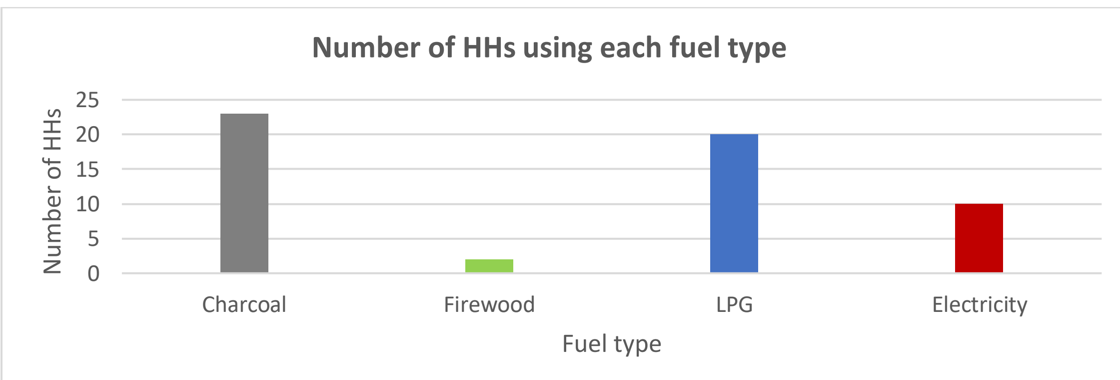

Figure 5: Number of HHs per each fuel type

Figure 6 below shows a charcoal stove was the most widely owned by most HHs, with each HH owning at least one and some owning both basic and improved charcoal stoves. LPG stoves were also found in almost all HHs (21 HHs), and a significant number of HHs owns an electric appliance. Nevertheless, it is important to note that these electric appliances are task-specific: three microwaves (reheating), 11 kettles (water boiling), seven toaster/blender/sandwich makers, one deep fryer and two hotplates.

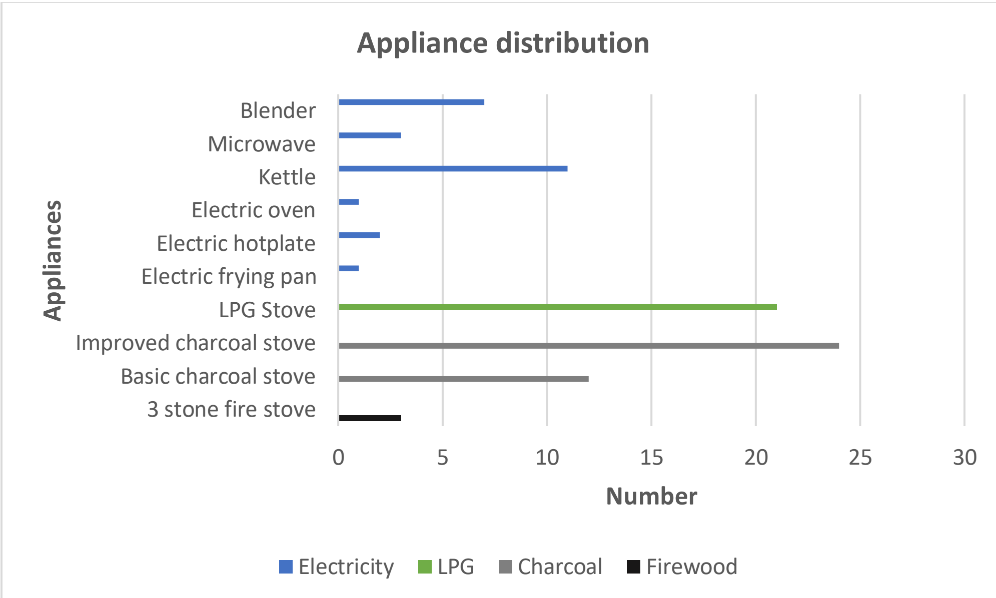

Figure 6: Appliance distribution among HHs

Results from the registration survey showed that fuel expenditure patterns (Figure 7) among HHs presented lowest average monthly expenditure for charcoal (Rwf 10,971), followed by electricity (Rwf 11,800), and LPG (Rwf 17,500), with all three fuels having a low variance (coefficient of variation, CV<1). However, the electricity expenditure presented in Figure 5 does not reflect solely the eCooking usage, as none of the HHs knew what proportion was used for cooking and what was used for lighting or by other HH appliances (fridge, TV, fan, etc.).

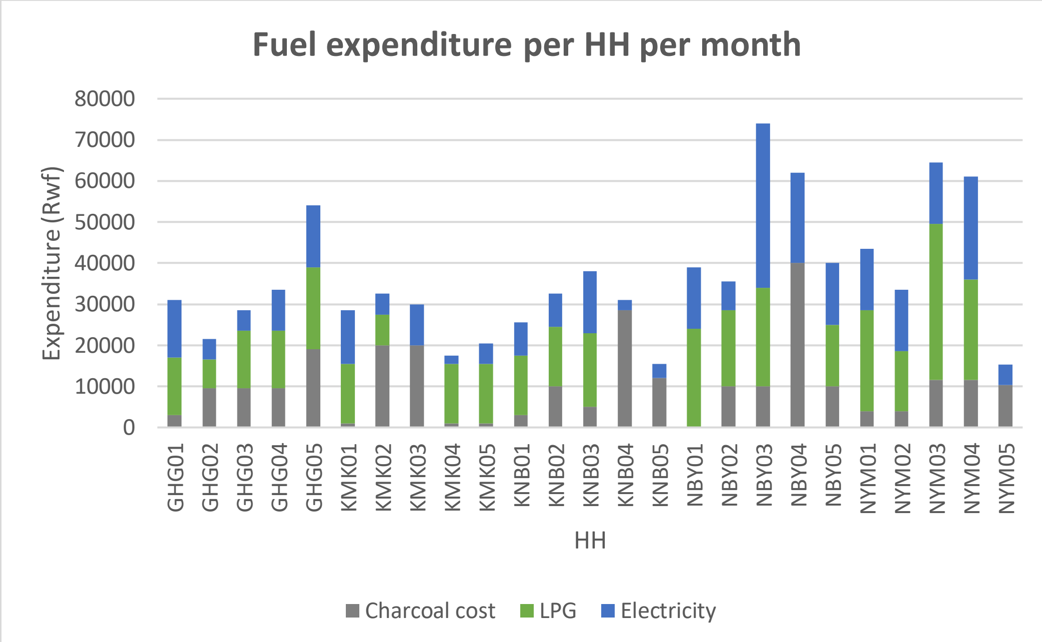

Figure 7: Fuel expenditure per HH per month

3.1.2. Popular Rwandan dishes

Observations carried out during the study identified and described popular Rwandan dishes. These dishes are dominated by a combination of a "staple" food and a "stew", followed by "imvange" and, occasionally, "special" food types. Some other foods have also been identified and have been dubbed "long cooking foods".

- **Staples** are usually boiled and considered to be the main component of the meal. These include rice, irish potato, sweet potato, cassava, yam, banana, pasta, *ubugali* (cassava paste), and *kawunga* (maize flour paste).
- **Stews** are an important component of the meal but considered as supplements for staple food. These can be beans, peas, vegetables, beans and vegetables, meat, and groundnuts, wet-fried with onions and tomatoes.
- **Imvange** are mixed foods prepared by boiling staples and stew foods together, and sometimes wet-fried. An imvange could consist of staples such as Irish potato, sweet potato, banana, cassava, yam, and pasta with any stew food (e.g., cassava and beans, Irish potato and peas, banana, and vegetables, etc.). A combination of banana or Irish potato with meat is called *agatogo*.
- Special foods are prepared on special occasions by deep frying and served as sides to staples and stews. These can be potato, cassava, or banana chips.

- Long cooking foods are usually prepared for more than 60 minutes. These include beans and *isombe* (cassava leaves) and are prepared in quantity to be consumed over a couple of days. Whenever needed, a portion of beans is taken from the precooked quantity and used for stew preparation, whereas with *isombe* the portion is only reheated.

3.1.3. Overview of diary data

The cooking diary data shows that HHs mainly prepare meals on a single heating event basis – they usually prepare food that is about to be consumed, which means they spend a significant amount of time in the kitchen. However, it is not always the HH members who do the cooking. In most cases it is done by a house help. This was witnessed during the training and data recording. Table 1 below shows a consistent trend throughout the baseline, transition and end-line surveys on a single heating event with more than 88% occurrence during the data recording period. The data also shows most of the second heating events involved water heating. Generally, with the introduction of eCooking, frequency of multiple heating events (e.g., cooking several dishes same time) reduced and those of single heating events increased. This could be explained by the fact that people found it easy to put on the eCooking appliance at any time of the day.

Table 1: Number of captured heating events by phase

Heating events	Baseline		Transition		End line	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
1	870	88%	744	93%	1190	93%
2	106	11%	52	7%	94	7%
More than 2	16	2%	0	0%	0	0%

Lunch and supper account for the most heating events of the day, each at around 35% of all events, throughout the three phases (figure 8). Importantly, the proportion of major heating events (breakfast, lunch, supper, and water heating) remained almost the same during the transition phase and end line phase, which could indicate how adaptable eCooking is to Rwandan cooking habits. It is also important to highlight that some irregularities occurred in data recording (electricity measurements were not recorded when a kettle was used to heat water). As a result, several kettle heating events are missing from the dataset.

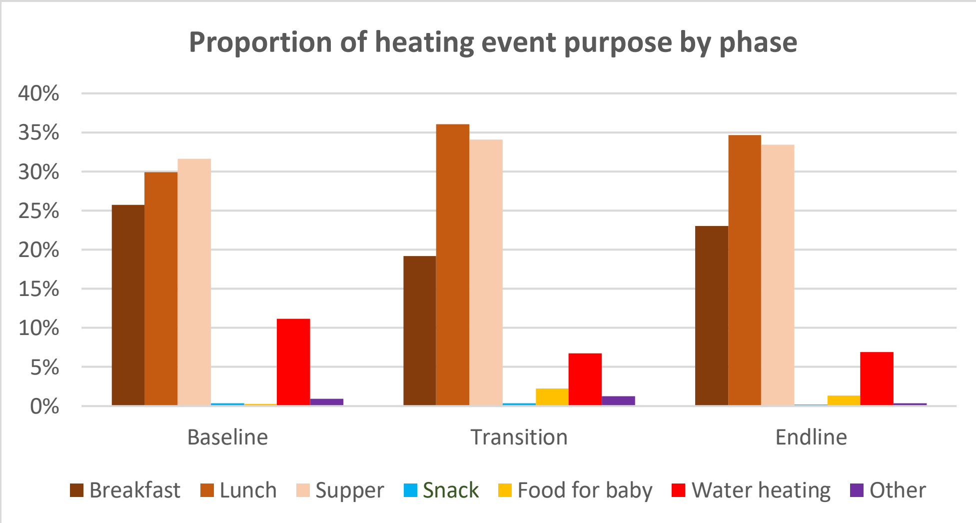

Figure 8: Proportion of heating event purposes by study phase

3.2. Energy consumption

One of the objectives of the cooking diary study was to quantify the amount of energy needed by Rwandan HHs to cook common dishes at "*meal-level resolution*". Energy measurements data obtained from HHs (cooking fuel measured before and after each heating event) and the calorific values of the corresponding fuel are presented in table 2.

Table 2: Calorific values of different cooking fuels used in cooking diary study

Fuel	Calorific value
Wood	15.9 MJ/kg
Charcoal	29.9 MJ/kg
LPG	44.8 MJ/kg
Electricity	3.6 MJ/kWh

3.2.1. Fuel preference

Fuel preference analysis shows that during the baseline phase (figure 9), LPG was the most used fuel (58%), followed by charcoal (39%), while electricity was not used at all. Also noted was a lack of fuel stacking practices, with a combination of LPG and charcoal used in only 2% of all cooking events.

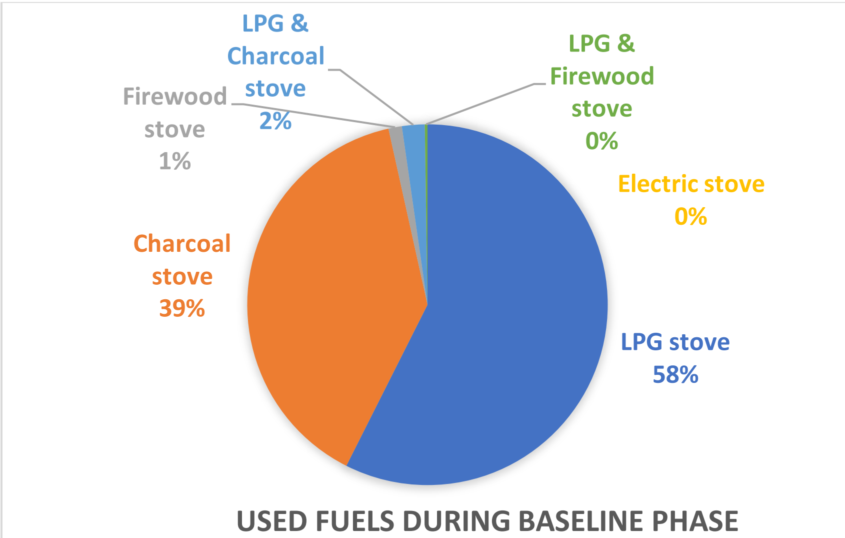

Figure 9: Percentage of times various fuels were used during baseline phase

Data recorded during the end-line phase (figure 10) shows a new trend in fuel preferences, with LPG still the most used fuel (36%), but this time followed by electricity (23%), with charcoal reduced at 16%. The increase in eCooking practices shows that participants appreciate it as an effective cooking fuel. In fact, participants said that they found most of the dishes compatible with the electric cooking appliances provided.

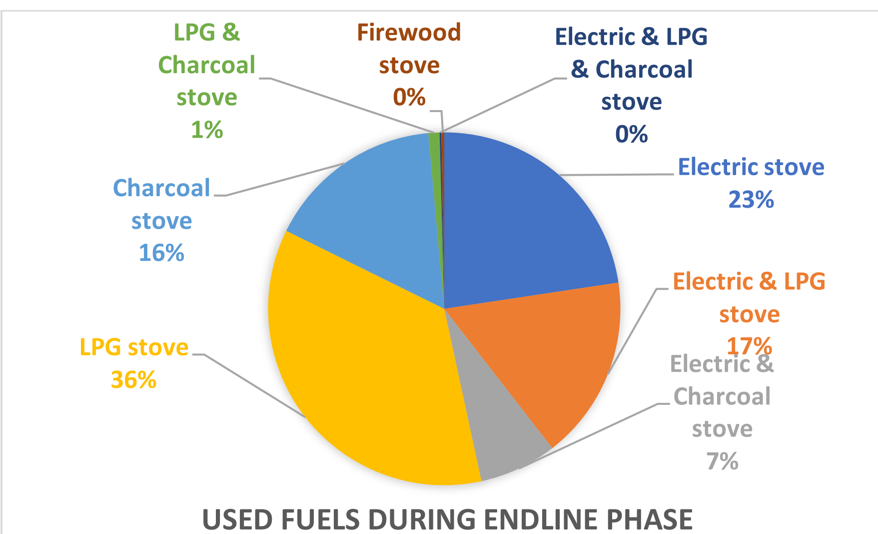

Figure 10: Percentage of times various fuels were used during end-line phase

Figure 10 shows an increased use of modern cooking fuel from the baseline phase (42%) to end-line phase (83%). Some participants reported a shift from charcoal to eCooking, particularly for long cooking foods and for some isolated short heating events such as water heating. There was also an increase in fuel stacking during the end line phase, with the combination of electricity and LPG (17%), and electricity combined with charcoal (7%). This indicates that although eCooking was appreciated, there was still a need for other fuels.

3.2.2. Fuel stacking

During all three phases, fuel stacking increased when there were multiple heating events. In an attempt to save time, cooks often prefer to use several appliances when preparing for multiple heating events, which accounts for the increase in fuel stacking (table 3). For single heating events, fuel stacking doubled from baseline phase to end-line phase and, according to participants' feedback, the main reason was that the electric appliance used (EPC) had only one inner pot. This meant all the components of the meal could not be cooked simultaneously. Another reason mentioned was that some food items were not compatible with the EPC, such as chips, omelette and *ugali*.

Table 3: Statistics around fuel stacking habits during the cooking diary study

Yeah Phase	Fuels stacking	Single heating event		Multiple heating events	
		Frequency	Percent	Frequency	Percent
Baseline	Single fuel	739	88%	11	52%
	Fuel stacking	97	12%	10	48%
Transition	Single fuel	684	100%	48	98%
	Fuel stacking	3	0%	1	2%
End-line	Single fuel	825	76%	58	64%
	Fuel stacking	266	24%	33	36%

Table 4 shows that fuel stacking is a widespread habit across the HHs. During the baseline phase, fuel stacking was recorded in 20 HHs and consisted mainly of a combination of LPG and charcoal, 85% cases, with firewood only used in 15% of HHs that stack fuels. During end line phase, fuel stacking increased even more, up to 92% HHs. Interestingly, except one HH which underwent recurring electrical failure due to tripping protection devices, all other HHs regularly used eCooking during this last phase.

Table 4: Fuel types used by HHs during baseline and end-line phases

HH	Baseline phase			End-line phase		
	LPG	Charcoal	Firewood	Electricity	LPG	Charcoal
GHG01	√	√		√	√	√
GHG02	√	√		√		√
GHG03	√	√		√	√	
GHG04	√	√		√	√	√
GHG05	√	√		√	√	
KMK01	√			√	√	
KMK02	√	√		√	√	√
KMK03		√		√		√
KMK04	√	√		√	√	√
KMK05	√	√		√	√	
KNB01	√	√		√	√	
KNB02	√	√		√		√
KNB03	√		√	√	√	
KNB04	√	√	√	√		√
KNB05		√		√		√
NBY01	√			√		
NBY02	√			√	√	
NBY03	√	√		√	√	
NBY04	√	√				√
NBY05	√	√		√	√	
NYM01	√	√		√	√	√
NYM02	√	√		√	√	√
NYM03	√	√		√	√	√
NYM04	√	√	√	√	√	√
NYM05		√		√		√

3.2.3. Per capita energy consumption

Per capita energy consumption allows us to compare how much energy is required for each heating event for a one-person meal according to the different fuel types. It is calculated by dividing the energy consumption for the heating event by the number of people that the meal was cooked for. Cooking fuels such as LPG, charcoal, firewood, and electricity have been used throughout the cooking diary study. However, firewood was not included in the energy consumption analysis due to its significantly low number of single heating events (less than 10 out of 857). The mean per capita energy consumption for electricity (transition phase) was significantly different (p-value: 2.65E-05) from the baseline phase. In fact, of the three fuel types (figure 11), electricity required the least energy (0.76 MJ) to cook a meal per person, followed by LPG at 2.83 MJ, and charcoal required the most energy at 6.4 MJ.

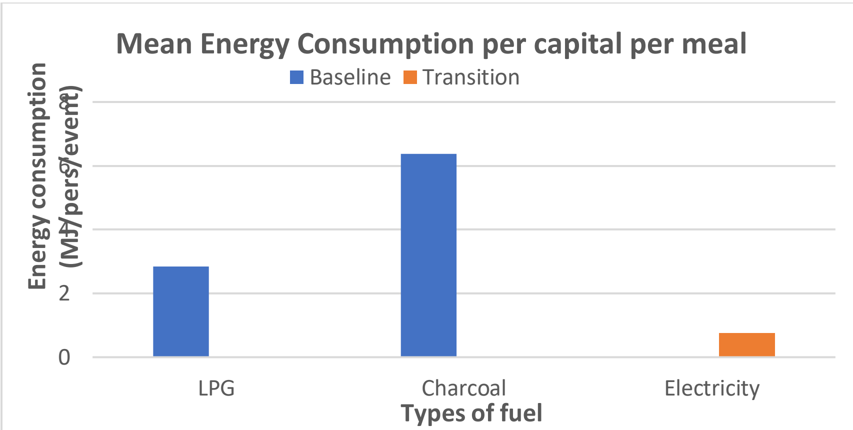

Figure 11: Mean per capita energy consumptions (MJ/person/meal)

To put the energy consumption results into cost perspective, according to prevailing fuel costs in Kigali City during the study period, eCooking is the cheapest option at $0.048 per person/meal (figure 12). Charcoal follows at $0.069, and LPG tops the group at $0.074.

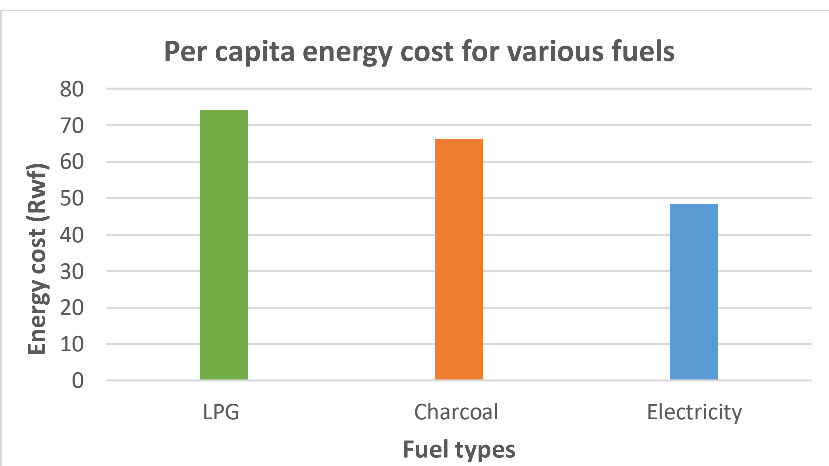

Figure 12: Per capita energy cost per meal for various types of fuels

3.2.4. Energy consumption by heating events

Heating events (meal) considered in this cooking diary study consist of breakfast, lunch, supper, snacks, food for baby and water heating. Two very distinct groups of heating events come out of the total energy consumption figures (table 5). One group, composed of breakfast, lunch, and supper, consumed hundreds of times more energy values than the other group, which was snacks, food for baby and water heating.

Table 5: Total energy consumption for each heating event

Heating event	Breakfast	Lunch	Supper	Snack	Food for baby	Water heating
Total energy (MJ)	2300.3	6654.3	7432.5	24.8	26.9	58.6

Data represented in figure 13 shows that when it came to variabilities within heating events during baseline and transition phases, for both breakfast, lunch, and supper, per capita energy consumption of baseline phase was significantly higher (p-value: 0.019, p-value: 1.77E-06, and p-value: 8.46E-07, respectively) than that of the transition phase.

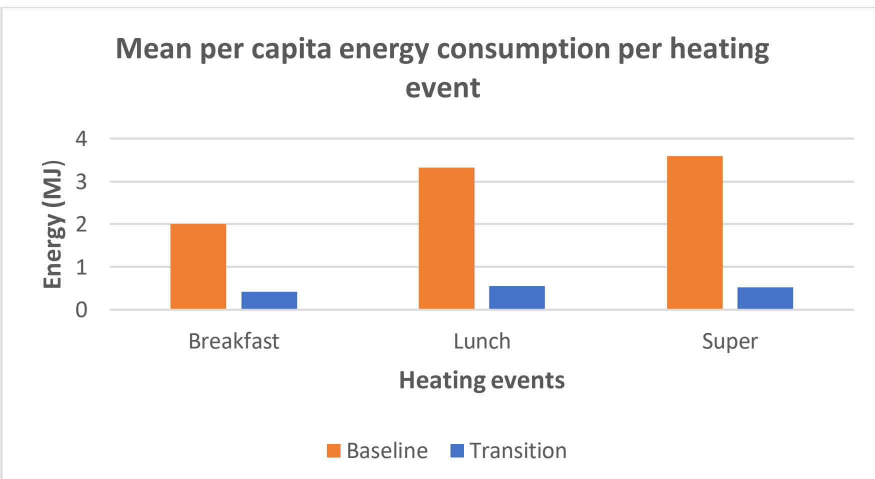

Figure 13: Mean per capita energy consumption per heating event

A closer look at these various heating events reveals that both lunch and supper required a comparable amount of energy (figure 14), indicating a regular and routine cooking fuel use. This was true for both LPG (1,776 MJ and 1,823 MJ respectively) and electricity (1,049 MJ and 933 MJ also respectively), while for charcoal a slightly higher amount is noted at supper (4,675 MJ) compared to lunch (3,828 MJ).

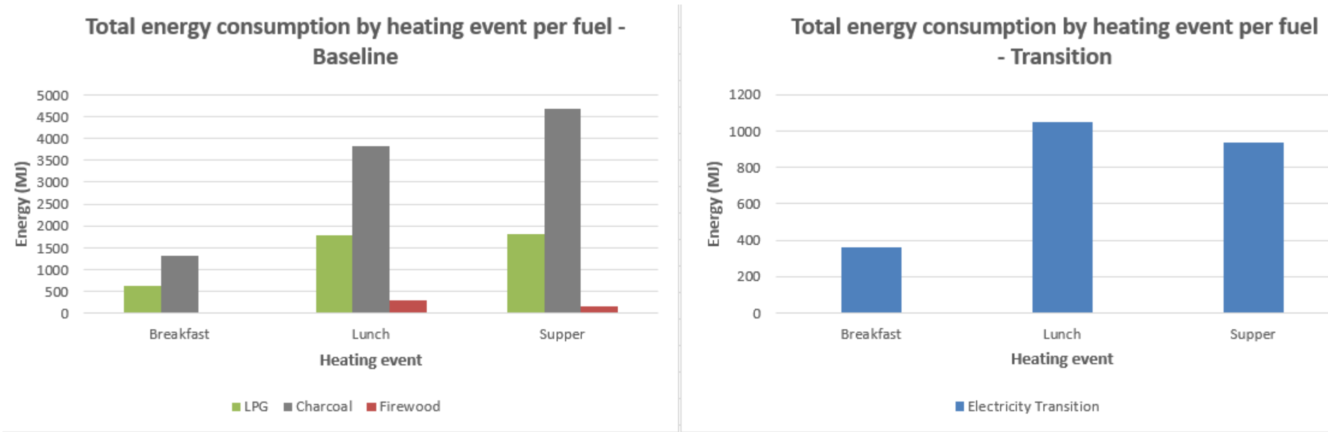

Figure 14: Total energy consumption by heating event per fuel type

Interestingly, in the case of lunch and supper, figure 15 shows higher eCooking frequencies compared with other fuels. The fuels' inverse proportional trend between figure 14 and figure 15 (highest total energy with least frequencies at the same time for charcoal, and lowest total energy with highest frequencies for eCooking) is also an indication of each fuel's energy efficiency ranking, with eCooking presenting the highest, followed by LPG, and charcoal being the least energy efficient.

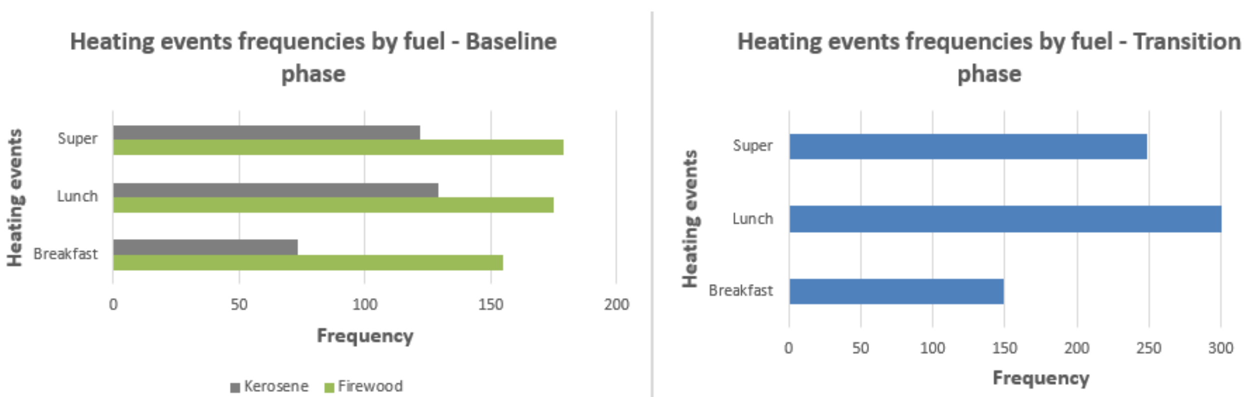

Figure 15: Heating events frequencies by phase for different types of fuels

3.3. Dishes cooked

Breakfast, lunch, and supper typically consisted of sometimes one, but mostly multiple dishes. Beans and its stew, rice, vegetable stew, porridge, leafy vegetable stew, Irish potatoes and green banana were the most cooked dishes (table 6). The same popular dishes kept the same order of popularity for both baseline and transition phases, suggesting that eCooking was generally compatible with Rwandan cuisine.

However, although boiled liquid dishes such as porridge and milk were still popular, the frequency in which they were prepared reduced when transitioning to eCooking, as participants said they took longer to cook in an EPC than with LPG. Other dishes such as chips and other deep-fried dishes (fish, *indagara*) were prepared less frequently because they were not compatible with EPC. The EPC's pot size also impacted on decreased cooking of large items such as pumpkin and yam. As a result, some other dishes, mostly boiled ones, showed an increase in the frequency of being cooked. These are banana, sweet potato, pasta, *imvange*, and all required less attention from the cooks without getting burned when they used the EPC. With more types of cooked primary dishes, the frequency of cooking common stews also increased.

Table 6: Frequency of various dishes prepared during the baseline and transition phases

Dishes	Baseline		Transition		% Change
	Frequency	Percentage	Frequency	Percentage	
Beans/ peas/ peanuts stew	373	17%	319	19%	2.1%
Rice	297	13%	208	12%	-1.0%
Vegetable stew	223	10%	199	12%	1.8%
Porridge/soup	211	9%	126	7%	-2.0%
Leafy veg stew	185	8%	152	9%	0.7%
Irish potato	178	8%	119	7%	-0.9%
Banana/matoke	126	6%	136	8%	2.4%
Meat stew	96	4%	62	4%	-0.6%
Ugali (cassava/maize/wheat)	93	4%	58	3%	-0.7%
Irish potato chips	78	3%	27	2%	-1.9%
Beans/peas	69	3%	51	3%	-0.1%
Pasta/noodles	65	3%	67	4%	1.0%
Sweet potato	34	2%	57	3%	1.8%
Milk	33	1%	7	0%	-1.1%
Indagara/isambaza	29	1%	12	1%	-0.6%
Eggs	29	1%	11	1%	-0.6%
Pumpkin	24	1%	0	0%	-1.1%
Fish	22	1%	14	1%	-0.2%
Agatogo	21	1%	5	0%	-0.6%
Yam	18	1%	10	1%	-0.2%
Cassava	17	1%	13	1%	0.0%
Banana chips	7	0%	2	0%	-0.2%
Sweet potato chips	5	0%	13	1%	0.5%
Chicken	5	0%	6	0%	0.1%

Imvange	4	0%	15	1%	0.7%
Pilau	3	0%	6	0%	0.2%
Chapati/pancake	2	0%	7	0%	0.3%

Among the common dishes prepared during the study, porridge stood out as the most prepared for breakfast at around 45% for both baseline and transition phases (Figure 16 & 17). Interestingly, out of nine common dishes for lunch and supper, eight are similar for both baseline and transition and have almost the same hierarchical order of frequency. For both phases, bean stew and rice are the two most prepared dishes at lunch and supper. Generally, the nine common dishes for lunch and supper consist of five primary dishes (rice, irish potato, banana, ugali and sweet potato) and four stews (beans/peas, vegetables, leafy veg, and meat).

Note that, regarding the cooked dishes, there are two main differences between baseline and transition phases. One is that sweet potato replace Irish potato chips (French fries) among the top nine common dishes when shifting to eCooking, and the second is the increase in frequency of cooking stews, again when shifting to eCooking.

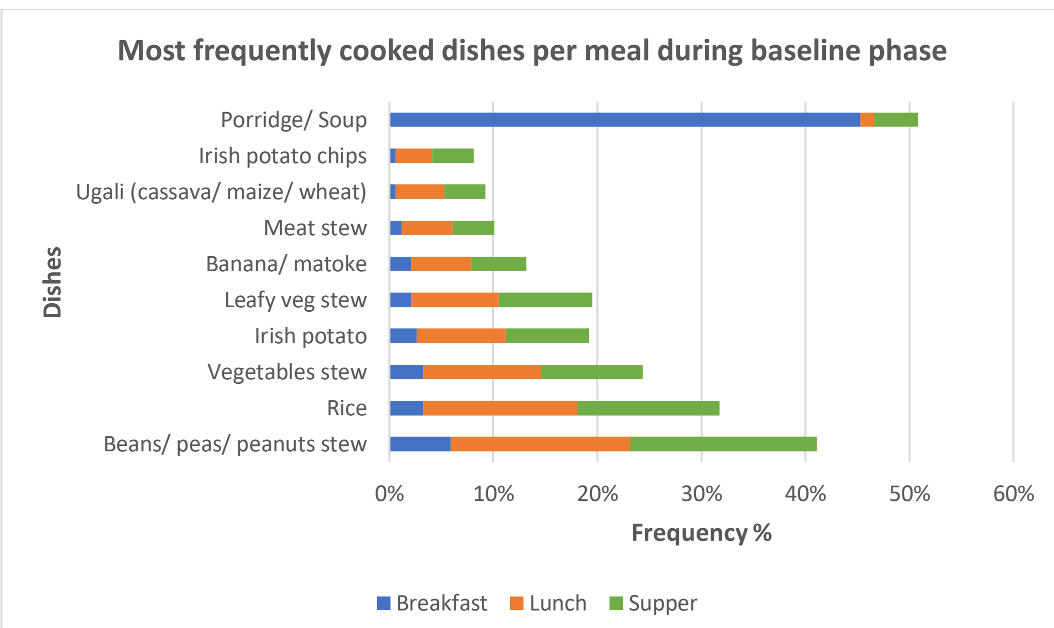

Figure 16: Ten most frequently cooked dishes per meal during baseline phase

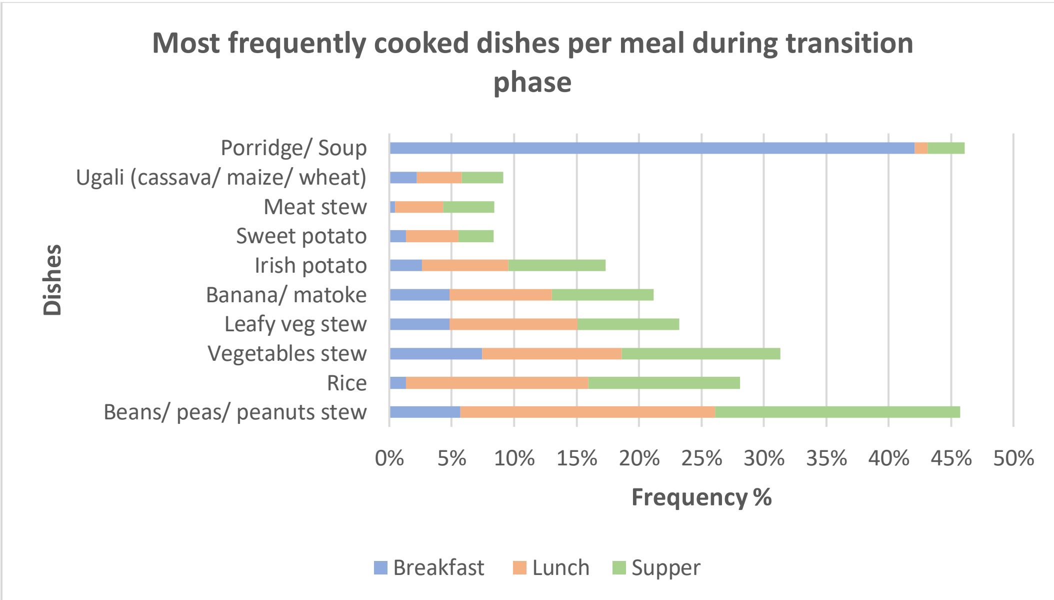

Figure 17: Ten most frequently cooked dishes per meal during the transition phase

Analysis of the number of dishes cooked in a meal (Figure 18) reveals that, for both baseline and transition phases, breakfast was more likely to consist of one dish (at around 65%). For lunch and supper, on the other hand, the number of dishes changed in the transition phase and leaned towards fewer dishes than the baseline, suggesting that meals were simpler. During this phase most meals consisted of two dishes, with meals of one and two dishes amounting to more than those of three or more dishes. In the baseline phase, however, most meals consisted of three dishes, with meals of three or more dishes accounting for two out of three of all meals.

Figure 18: Comparison of number of dishes cooked per meal between baseline and transition phase

Depending on the cooking fuel used, the preference for different dishes can change for various reasons. Figure 19 shows that, although the order changes, the 10 most cooked dishes during baseline phase, either using LPG or charcoal, did not change, except for ugali for LPG being replaced by beans/peas cooking (long cooking dish) when using charcoal. Stews (beans, vegetables, leafy vegetables, or meat), rice, porridge, Irish potato, banana, ugali and French fries were the preferred dishes.

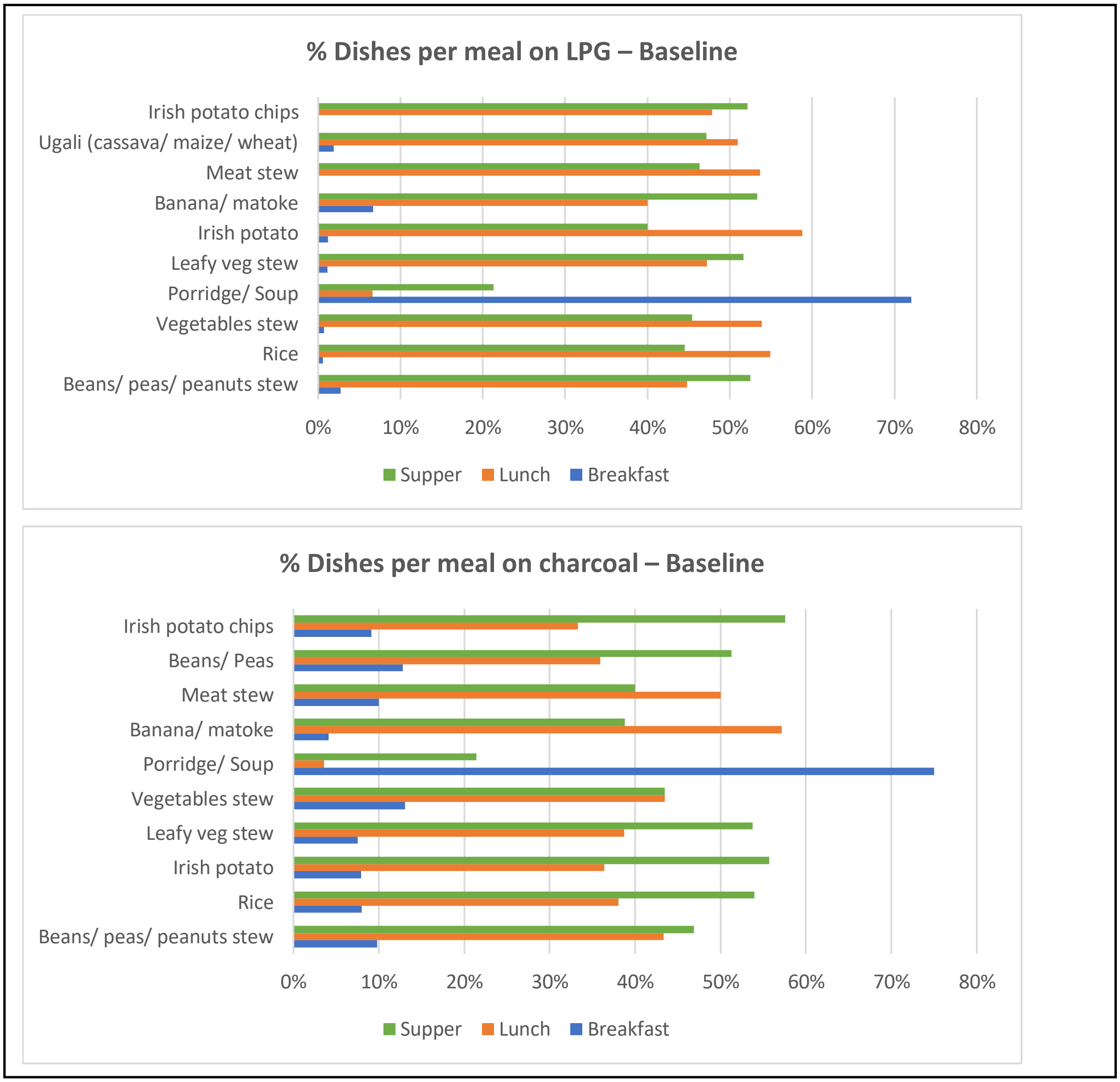

Figure 19: Percentage of cooked dishes per meal on different fuel during the baseline survey

When the HHs shifted to eCooking in the transition phase (Figure 20), pasta/noodles and sweet potato jumped up in the 10 most preferred dishes at the expense of French fries, ugali and beans. Observations and cooks' feedbacks showed that cooking ugali in an EPC (the most used and effective electric appliance) was different from their usual stoves. The EPC's deeper pot made it uncomfortable for the cooks to stir and pound ugali. Although precooked beans do not appear in the top 10 most preferred dishes during the transition phase, they increased in frequency compared with each of LPG and charcoal fuel. On the other hand, even the manufacturer suggests avoiding using the EPC to deep-fry dishes such as French fries, as it might lead to technical faults.

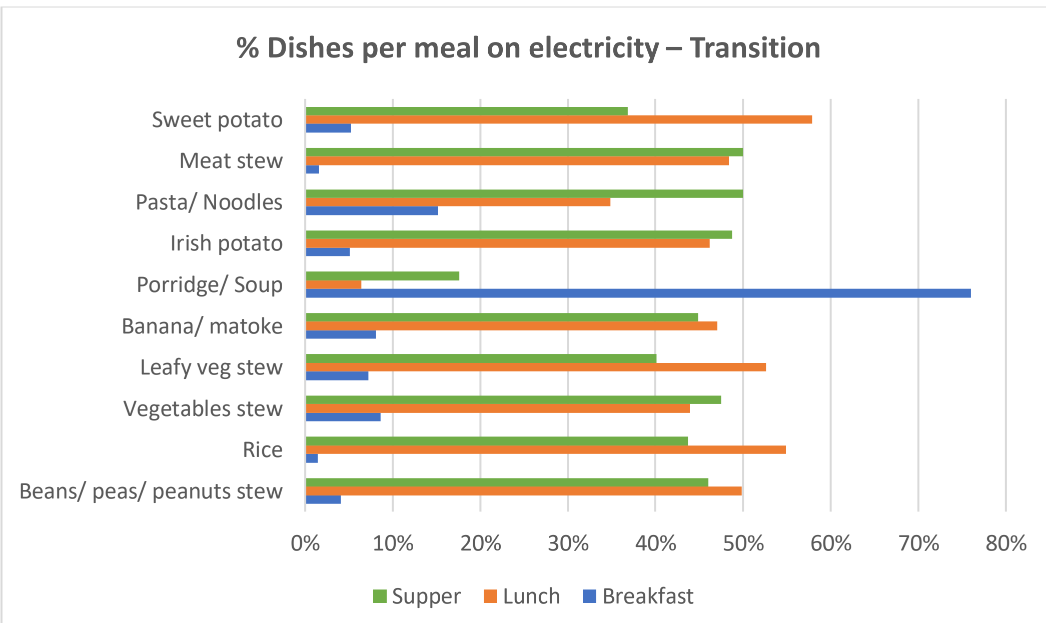

Figure 20: Percentage of cooked dishes per meal on eCooking during the transition survey

As shown on Figure 21 below, the mean per capita energy consumption of porridge, beans and rice during the baseline phase were significantly different (p-value: 2.64E-04, p-value: 3.17E-09, and p-value: 1.33E-07, respectively) from those of the transition phase. In fact, when shifting to higher energy efficient appliance of eCooking (EPC), the mean per capita energy consumption for cooking beans was 10 times less than the baseline using charcoal, and eight times less than that of rice using charcoal. Porridge, using eCooking during the transition phase, consumed only three times less than the baseline using charcoal. This small reduction is explained by the fact that porridge was mostly prepared on infrared stove which is less energy efficient compared to EPC. All this indicates that energy saving varies depending on the dish when switching to a more efficient electric appliance.

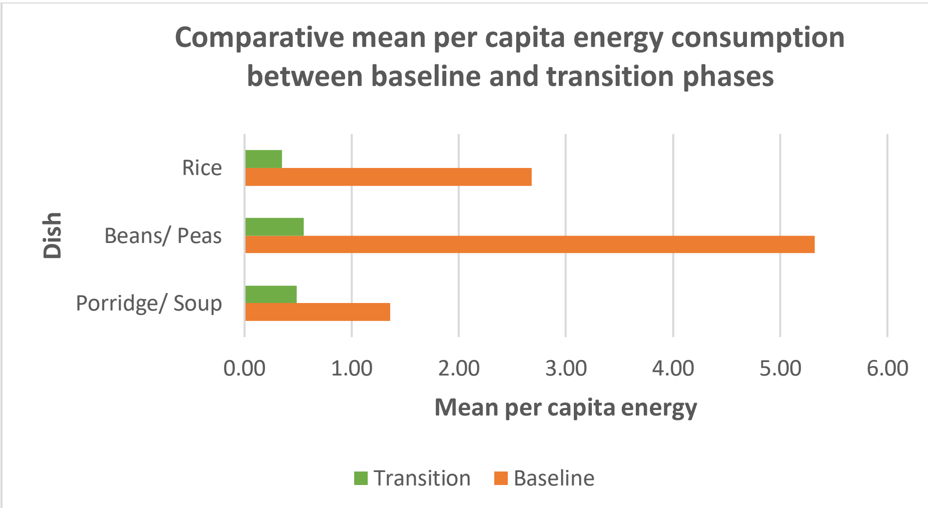

Figure 21: Mean per capita energy consumption of some dishes

3.3.1. Reheating dishes

Reheating dishes is practiced throughout the baseline and transition phase for all meals (breakfast, lunch, and supper). As shown in Figure 22, cooking from fresh remained the preferred way, with up to 75% of events for both lunch and supper rising to 90% for breakfast. The gap between fresh and reheating goes is even greater when shifting to eCooking. Cooking from fresh accounted for around 90% of events for lunch and supper, while breakfast reaches 97%. According to the cooks, when using a one-pot EPC (the most preferred electric appliance), reheating would take almost the same time and effort as cooking from fresh, so the practice decreased.

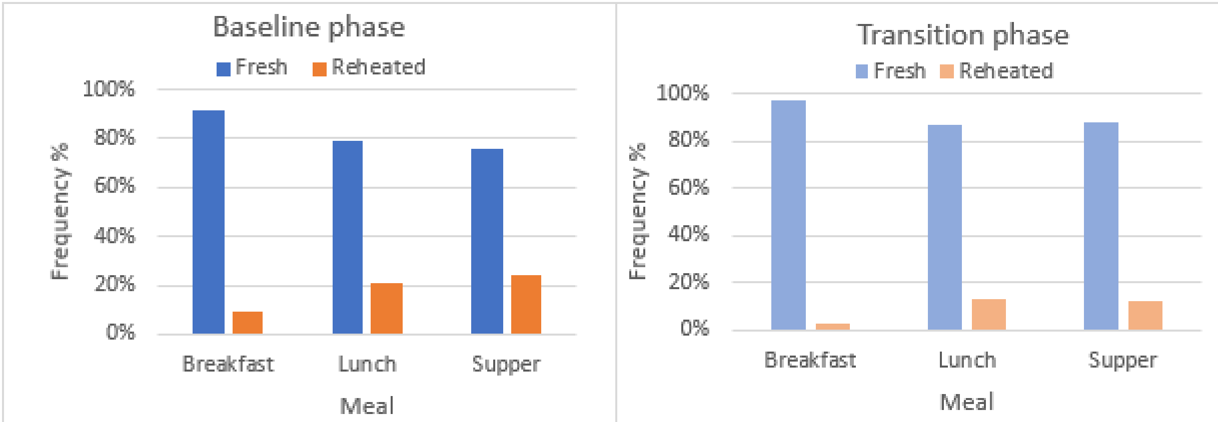

Figure 22: Number of dishes prepared from fresh versus reheated

Figure 23 shows the eight most-reheated dishes, with meat and other types of stew being the most reheated, for both baseline and transition phases. When HHs shifted to eCooking, there was a decrease in reheating for all eight dishes, for the reasons explained in the above paragraph.

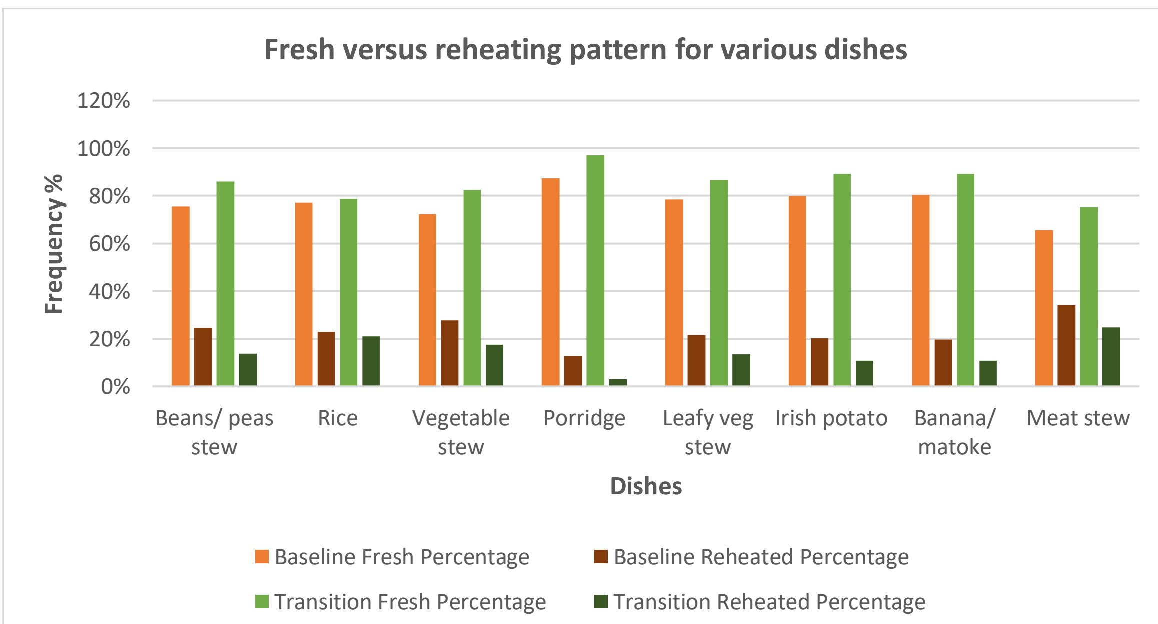

Figure 23: Fresh versus reheating pattern for cooked dishes

Figure 24 shows that for meals either cooked from fresh or reheated, the mean per capita energy consumption is the highest when using charcoal and the lowest when cooking with electricity. In fact, the chi-square test at 5% significance level shows that the mean per capita energy consumption for baseline phase, for meals cooked either from fresh or reheated, is significantly different (p-value: 4.91E-06 and p-value: 3.65E-04, respectively) to that of the transition phase. Interestingly, within both the baseline and transition phase, there is no significant difference between the mean per capita energy consumption of meals cooked from fresh and that of reheated meals (p-value: 0.84, p-value: 0.99, respectively).

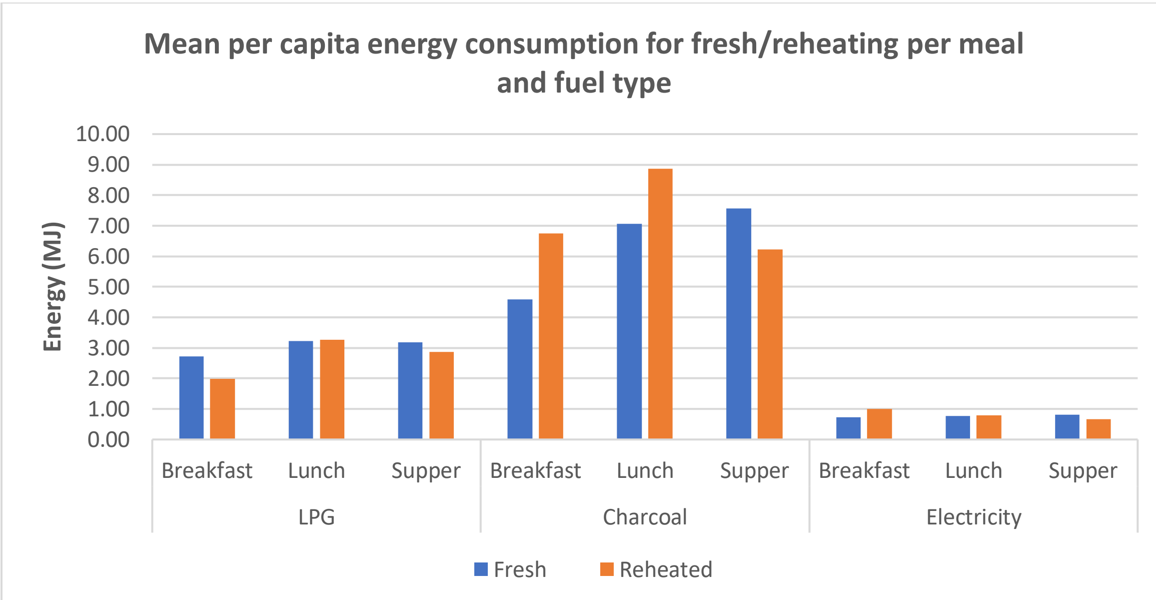

Figure 24: Per capita energy consumption of dishes cooked from fresh or reheated per meal and per fuel type

3.4. Cooking devices

Various cooking devices have been used during the cooking diary study. LPG stoves, charcoal stoves and firewood stoves were all used during the baseline phase, while EPC and infrared cookstoves (both electric) were used during the transition phase. All of them except infrared cookstoves were used during the end-line phase. Pots (*safuriya*) in various sizes (large, medium, and small), and frying pans were also used, particularly for baseline and end-line phases. Whether the lid was on during cooking, or the pot was open depended on the type of dish and the cooking process. For instance, during pressure cooking and for most boiled dishes the lid was on. For deep frying, however, the lid was left off, and for wet frying sometimes it was on and sometimes off.

3.4.1. Cooking devices

Figure 25 compares the usage of various cooking devices. During the baseline phase, almost all heating events were conducted on LPG stoves (59%) and charcoal stoves (40%), whereas when shifting to transition phase, all participants adhered to the recommendations and used eCooking, with EPC dominating at 75% and infrared only used in 25% events.

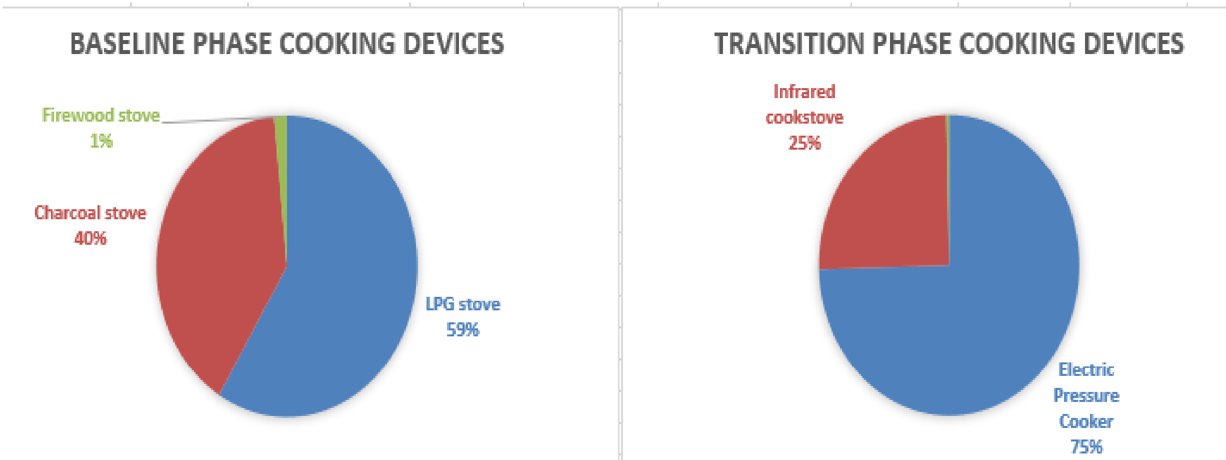

Figure 25: Comparison of cooking devices used during baseline and transition phases

3.4.2. Cooking pots

During both baseline and transition phases, medium pots were the most preferred, at 57% and 47% respectively, followed by small pots at 27% and 36%, while big pots were used in both phases at around 12%. Specific pots such as frying pans were also used during both phases and, interestingly, as shown on figure 26, they were used at the same frequency (4%) for each of the phases. Different sizes of pots were used as shown in Figure 26 during baseline for all the fuels. However, in the transition period, different sizes of pots were only used when using infrared cooker, because for EPC only one pot was available (cooks didn't have a choice of pot).

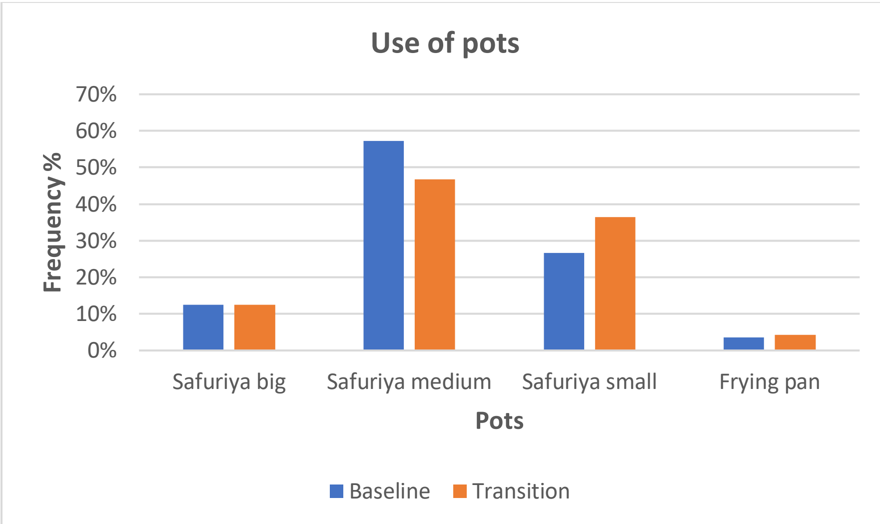

Figure 26: Types of pots and % of frequencies during both baseline and transition phases

A closer look at the relationship between the use of various pots and the cooking stove (Figure 27) reveals that frying pans are widely preferred for LPG stoves (75%) compared to charcoal stoves (25%). The same trend applies to small and medium pots, with 65% and 61% of events respectively, on LPG stoves. However, big pots are preferred on charcoal stoves (54%), which may be explained by the fact that long cooking dishes are traditionally cooked on charcoal stoves and batch-cooked in large quantities. Note that Figure 27 does not include the transition phase as we only have pot data for infrared cookstoves, and it is not enough for analysis.

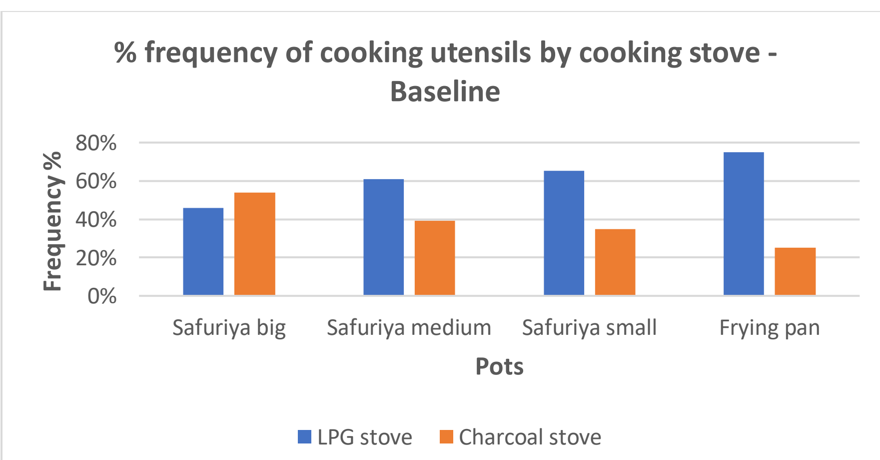

Figure 27: Relationship between the use of various pots and the cooking stove used during baseline phase

3.4.3. Use of a lid

According to participants, the use of a lid is mostly dictated by the cooking process of a particular dish. For instance, when deep-frying, the lid is never used but when boiling dishes, the lid is usually used. When wet-frying (when making stews for example), the lid is sometimes off and sometimes on. Another observation from cooks is that the lid is more likely to be used when cooking on stoves that are less hot. This is corroborated by data during the baseline in Figure 28, where the lid is used more often on a charcoal stove than an LPG stove. During the transition phase, the lid is used more often for EPC and less on infrared cookstoves, as this was mostly used for the deep-frying process. Interestingly, even on EPC the lid was sometimes on and off, which suggest it was compatible with wet-frying, usually used for stews.

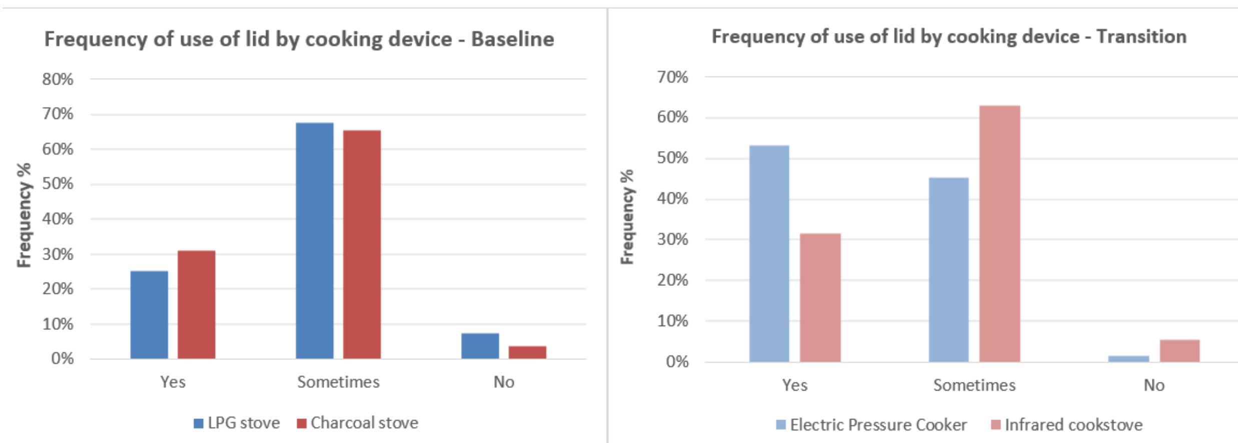

Figure 28: Use of a lid when cooking various dishes on different fuels

3.5. Cooking time

3.5.1. Time spent on meal preparation

Meal preparation time is defined as the time from when the cook starts preparing a meal to the time when the preparation is completed.

Analysis of time spent on preparing various meals, conducted on meals cooked using only single fuels (Figure 29), reveals longer meal preparation time when using charcoal compared to other fuels since only one stove is often used. This would help explain the long time (around 120 minutes, three times the eCooking time and four times that of LPG) spent preparing breakfast using charcoal. In addition, depending on meal type, variations in meal preparation time are observed. Preparing supper using charcoal (155 minutes) takes almost double the time used with LPG (100 minutes) or eCooking (85 minutes). Also, for lunch, cooking with charcoal takes the longest time at 115 minutes, followed by LPG at around 95 minutes, and eCooking at around 80 minutes. Note that the time difference between charcoal and LPG/eCooking decreases with lunch. This might be explained by the fact that lunch is often cooked at midday outdoors and charcoal burns quicker when there is more air circulation, increasing its cooking power. However, supper is often prepared in the evening indoors, where the air is still. The charcoal burns more slowly, leading to slower cooking.

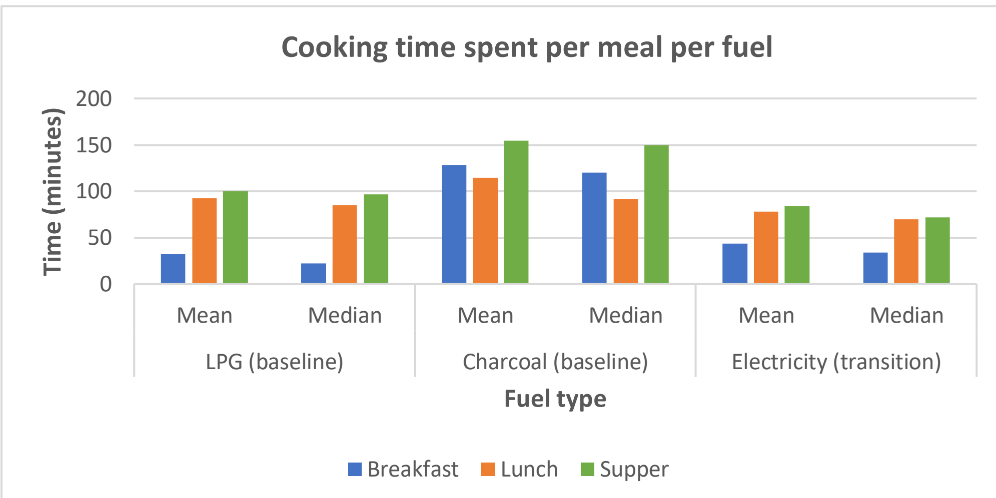

Figure 29: Cooking time spent per meal per fuel

3.5.2. Time of day

Table 7 shows that meal preparation is generally conducted at roughly the same times every day, although there’s a trend for starting earlier when using charcoal compared to other fuels (LPG or eCooking).

Table 7: Time of the day when meal preparation started

Meal	LPG (baseline)		Charcoal (baseline)		Electricity (transition)	
	Mean	Median	Mean	Median	Mean	Median
Breakfast	07:12	07:12	08:21	06:25	07:23	07:23
Lunch	11:20	11:15	10:39	10:58	11:25	11:29
Supper	17:22	18:18	15:00	17:00	17:36	18:23

3.5.3. Electric cooking load profiles

eCooking load profiles have been calculated using smart-meter data aggregated across multiple HHs to give accurate cooking load profiles.

Figure 30 shows that cooking starts as early as 05:00 and is concentrated around midday and evening, as indicated by peaks electricity use. Incidentally, evening cooking coincides with the utility and minigrid peak consumption.

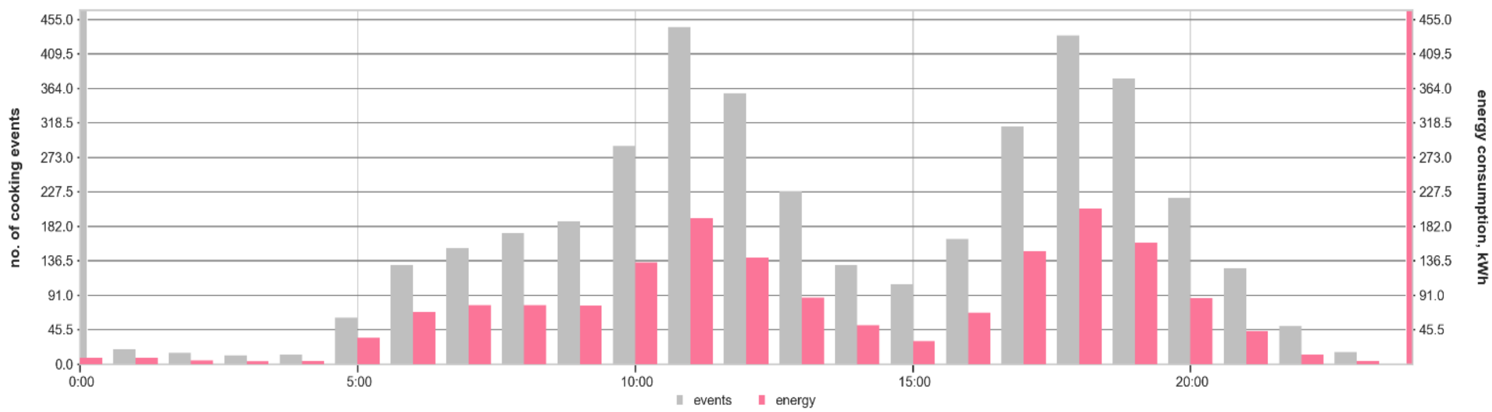

Figure 30: eCooking events and energy consumption over 24 hours

The three-week transition phase corresponds to the highest daily eCooking events recorded (Figure 31), each day recording more than 60 cooking events, with the highest daily eCooking events reaching 125. After the transition phase, daily eCooking events reduced with time during and after the end-line phase.

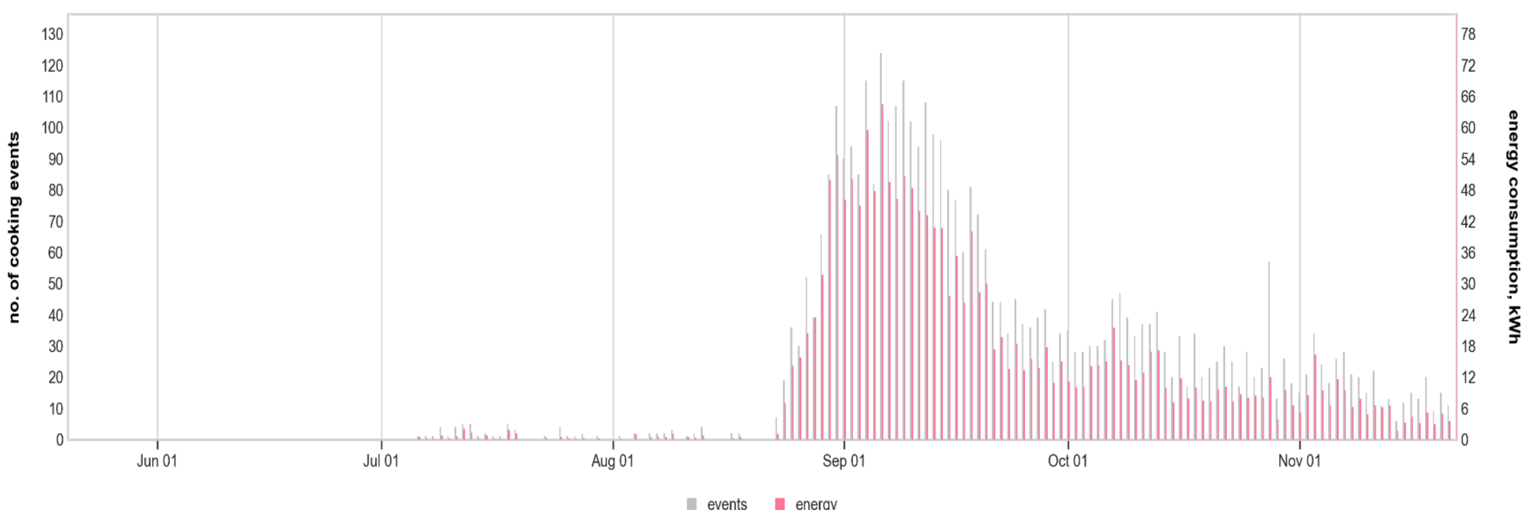

Figure 31: Daily events and energy consumption over the three phases

Figure 32 indicates that around 60% of eCooking events during the transition phase each consumed less than 0.4 kwh, with the mode energy consumption per eCooking event at 0.32 kwh.

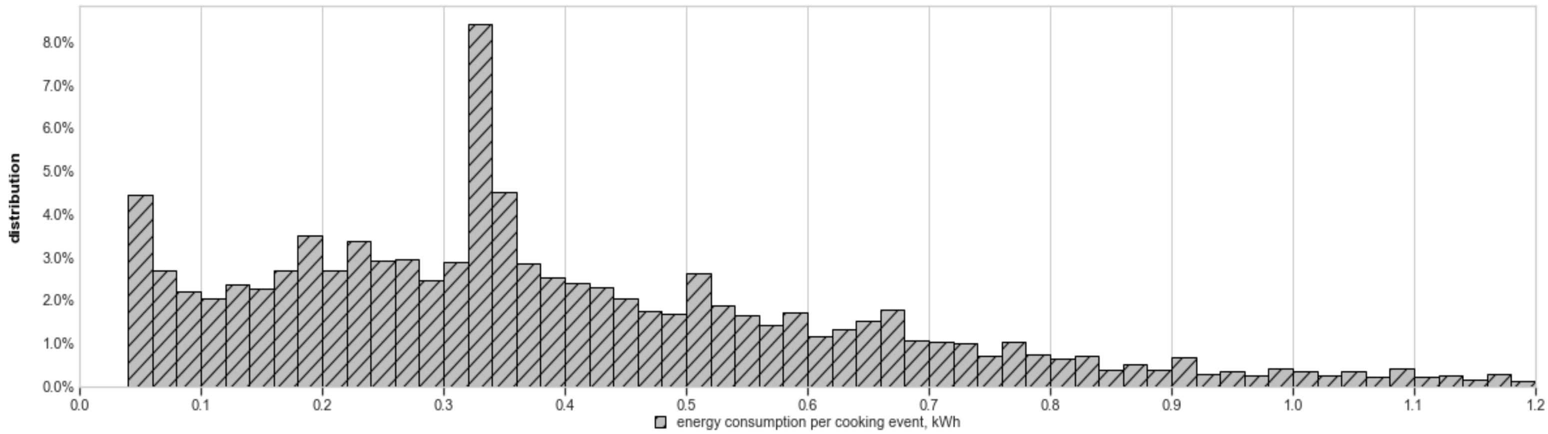

Figure 32: Histogram of energy consumption per eCooking event

Figure 33 shows that 66% of the eCooking events during the transition phase each lasted less than 40 minutes, with the mode cooking time per event at 38 minutes.

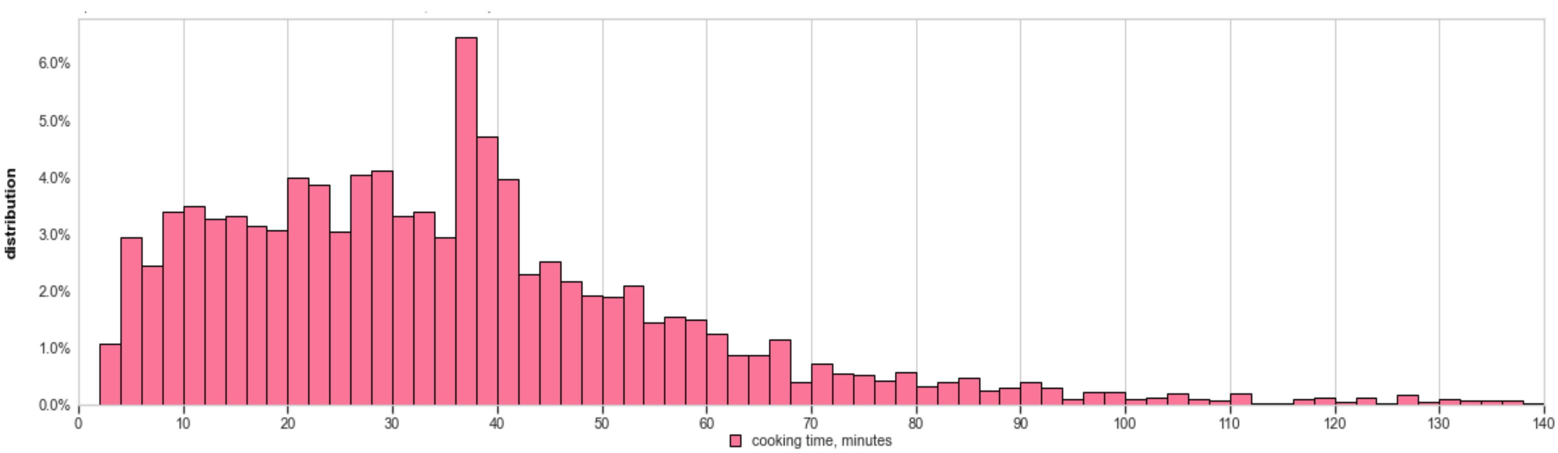

Figure 33:Histogram of eCooking cooking time per cooking event

3.6. Water heating

3.6.1. Number of times water was heated

The number of times water was heated is defined as when water was heated (for drinking/purification, tea/coffee, or bathing) on its own, and not as part of a meal (breakfast, lunch, or supper).

Note that the water heating dataset does not include records of heating water using a kettle. Figure 34 shows comparably high frequencies for bathing and tea/coffee purposes (around 45%), and less (around 10%) for drinking/purification purposes. The reason for this is that water heating for bathing and tea/coffee regularly occurs on daily basis, whereas drinking/purification water is prepared once every three or four days, and it doesn't occur at all in some HHs.

Another point highlighted by Figure 34 is that eCooking did not affect the water heating behaviour, as the frequency percentage and proportions of different water heating purposes remained similar in both baseline and transition phases.

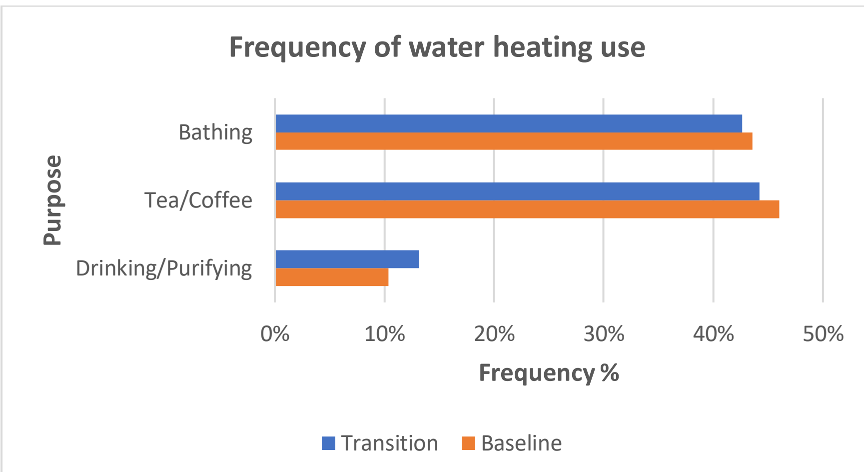

Figure 34: Number of times water was heated for each type of use

Figure 35 show the types of devices used to heat water. The LPG stove was the preferred device during baseline phase, and the EPC was the preferred device during the transition phase.

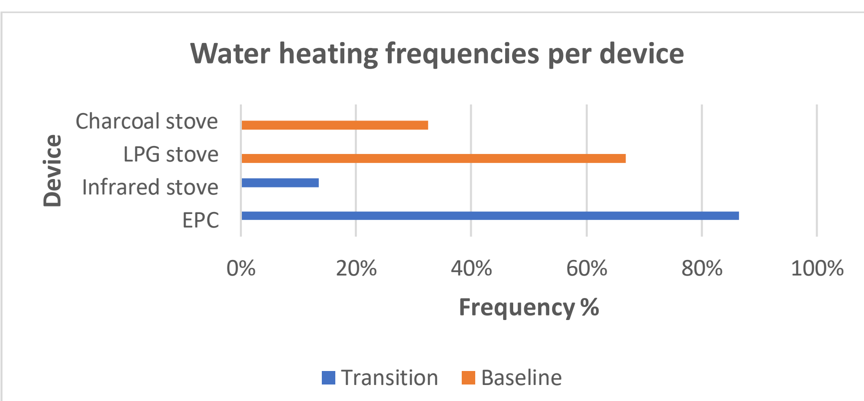

Figure 35: Number of times water was heated per device

3.6.2. Devices and pots used for water heating

Among the devices used to heat water, it's important to note the absence of a kettle, usually an important water heating device. This was due to an omission during data collection and recording.

Figure 36 represents data recorded from devices and pots used for water heating during the baseline phase. During the transition phase there were variations in the size of pot because EPC could only use one kind and size of pot.

Figure 36 shows that a medium *safuriya* pot was preferred for all water heating purposes, followed by a large one, except for when making tea/coffee, when a small pot was the second most popular. This is because drinking/purifying water is prepared for many days and water for bathing is usually of more volume than that for tea/coffee.

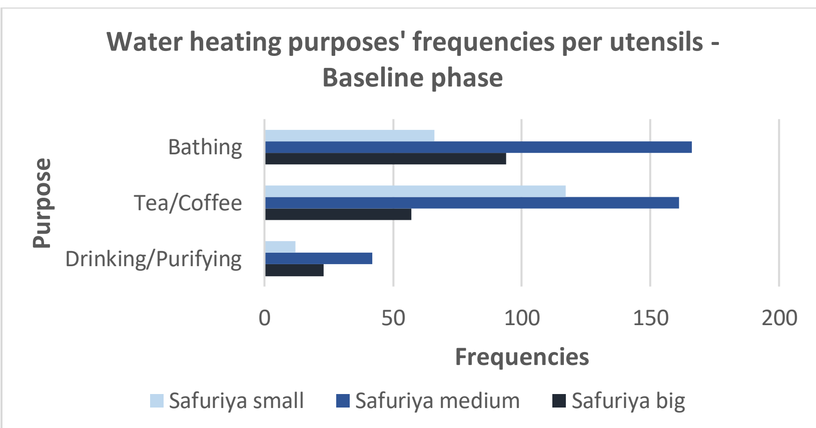

Figure 36: Number of times each pot is used to prepare various use of water heating during the baseline phase

3.6.3. Saving water for later

Figure 37 shows that both baseline and transition phases present similar trends when it comes to saving heated water for later use. Most of the time (around 72%) all the heated water was for immediate use while some of the heated water was saved 25% and 20% of the time during the baseline and transition phases respectively. Rarely was all heated water saved for later use – 3% of the time during baseline and 8% in the transition phase.

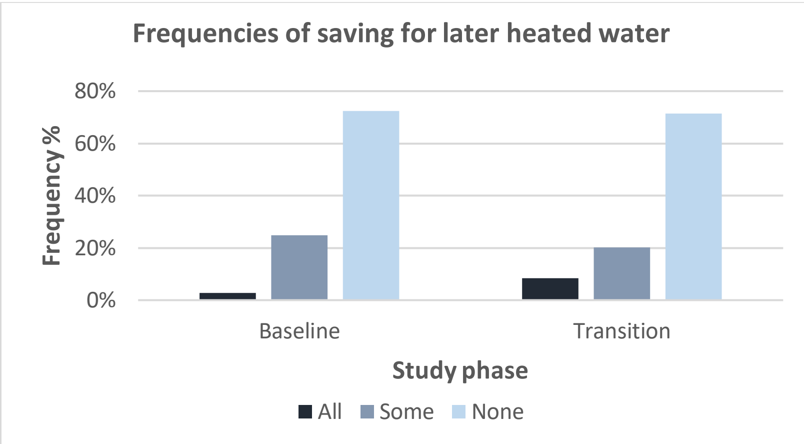

Figure 37: Percentage of times when heated water was saved for later during baseline and transition phases

Table 8 shows that when all the heated water was for immediate use, and even when only some of it was saved for later, the LPG stove was preferred over charcoal stove (around double in proportions). The proportions changed when it came to saving all the heated water, although the frequencies are lower.

Table 8: Frequencies of saving heated water for later per device

Device	Times heated water was saved for later		
	All	**Some**	**None**
LPG stove	5	79	243
Charcoal stove	8	43	108

3.6.4. Time taken to heat water

For each water heating purpose, mean times (in minutes) taken to heat water have been calculated and presented in Figure 38. For all three water heating purposes, eCooking (transition phase) took a significantly longer time (almost double to heat drinking/purifying and bathing water) (p-value= 2.63E-09) than baseline's (LPG and charcoal stoves).

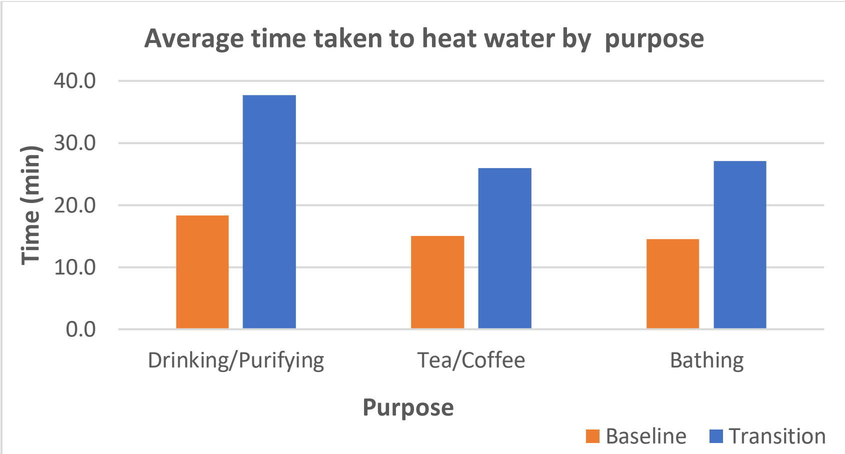

Figure 38: Average time taken to heat water by purpose

To compare the difference in the time taken to heat water between devices, we used the data from preparing tea/coffee. Results shown in Figure 39 indicate that eCooking took longer on average to prepare tea/coffee than the other fuels. In fact, EPC's average time was the longest at 26 minutes followed by infrared cookstoves at 23 minutes. Charcoal stoves took 16 minutes and LPGs took the shortest average time at 13 minutes.

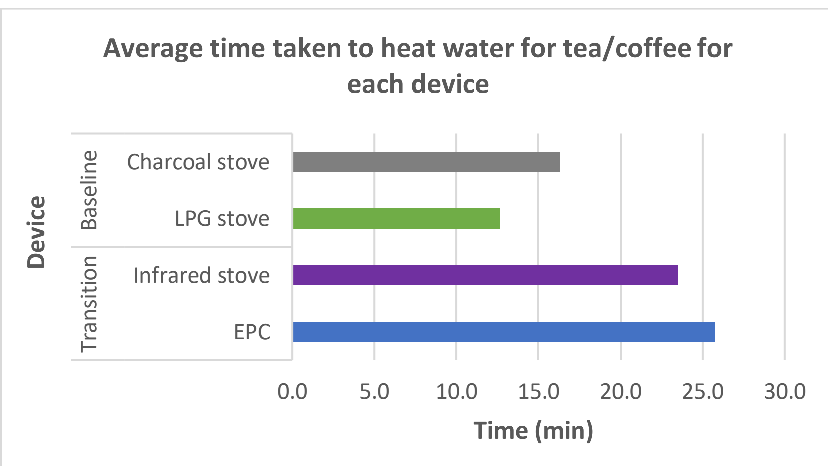

Figure 39: Average time taken to heat water for tea/coffee for each device

4. eCooking user experience

This chapter highlights the HHs feedback on the cooking diary study, particularly on eCooking, collected during the exit survey.

4.1. How eCookers fit with Rwandan cuisine

eCookers, particularly EPC, were found compatible with cooking most Rwandan dishes, as shown in figure 40. This includes cooking process, food taste and appearance such as the ability to multi-task while cooking (1.8/2), ability to cook long-cooking dishes quickly (1.7/2), improved food taste (1.4/2), whether it looked good in the kitchen (1.6/2), and how easy it was to use (1.6/2).

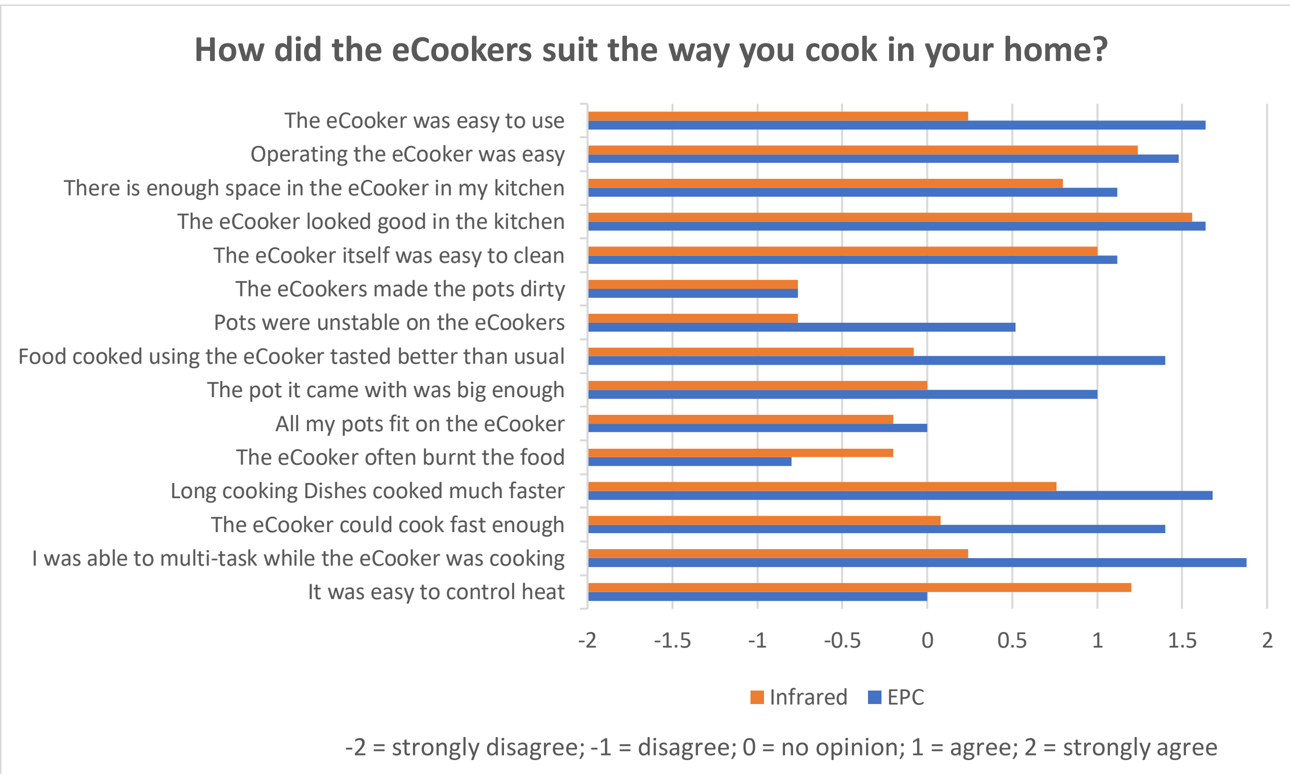

Figure 40: eCooker overall user experience

The compatibility of eCooking with Rwandan dishes was further highlighted by the ease of cooking popular dishes. Figure 41 shows EPC to be the easiest to use, and usually boiled dishes such as rice (1.8/2), imvange (1.8/2), banana (1.7/2), sweet potato (1.4/2), and meat (1.3/2) were found easiest to cook with EPC. Long-cooking dishes such as beans (1.6/2), and cassava (1/2) as well as stews such as leafy vegetables (1.1/2) and meat stew (1.1/2) were also found easy to cook with EPC.

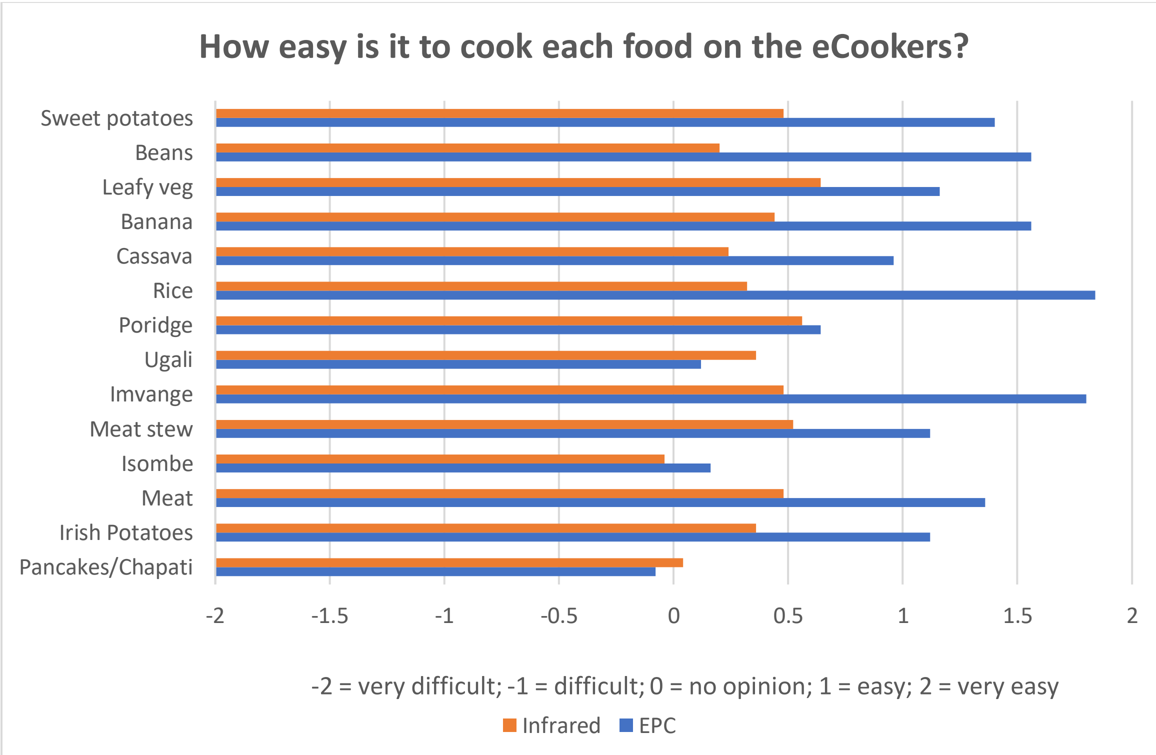

Figure 41: Ease of cooking some selected popular dishes on eCookers

4.2. Number of rings/hobs or appliances needed for cooking

The majority of HHs (56%) needed three hobs/appliances for daily cooking activities, 32% of HHs needed two, and 12% of HHs needed four, as shown in Figure 42. This corroborates the fuel stacking habits shown by the data analysis in a previous chapter.

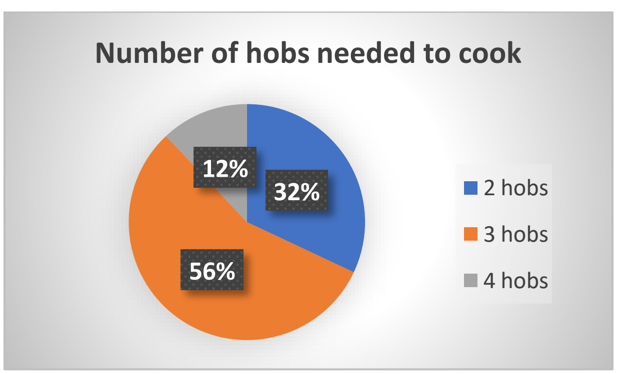

Figure 42: Number of hobs/appliances needed by HHs for cooking

4.3. eCooking affordability

The majority of the HHs (84%) found eCooking affordable, and the same percentage found it cheaper than cooking with other fuels they normally use. All HHs also declared that they would continue using EPC even after the cooking diary study. All HHs found EPC safe to use, whereas infrared cookstove was found dangerous by 52% HHs.

4.4. Cooking diary evaluation

Participants of the cooking diary study reported that enumerator visits were helpful, while a few found the visits and questions too much and interfering with their daily routines. However, the majority (92%) said they were willing to be part of a similar study in the future. Figure 43 shows that, generally, participants were satisfied with the study implementation, with a particular appreciation of the choice of EPC as an appliance, and how the training was conducted.

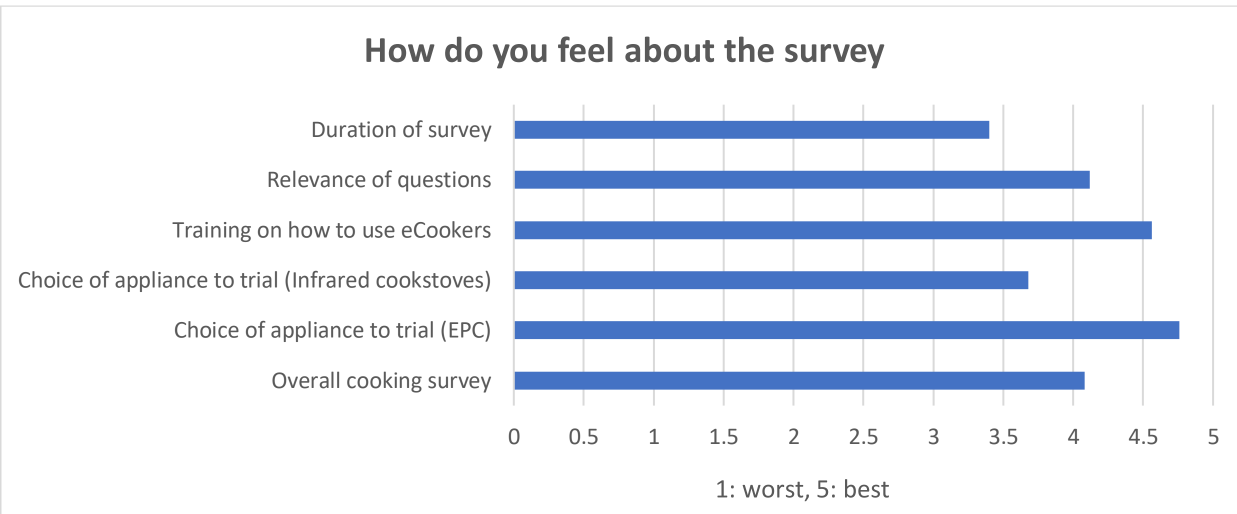

Figure 43: Participant feedback on the cooking diary study

4.5. Participants' feedbacks from Exit survey

At the end of the CD study phases, an exit survey was conducted, with the aim to collect feedbacks from all 25 participants on the study as a whole and eCooking, in particular. Various feelings were expressed, mostly positive towards eCooking, although some reservations were noted too. Interestingly, reservations towards eCooking were not based on its energy consumption or cost, but on consequential cooks' behaviours leading to increased daily cooking events due to some ease in cooking brought by eCooking (utensils' cleaning, stove lighting, etc.). Thus, HH expenses would increase from additional sugar and milk for tea, and other food. In additional to the feedbacks mentioned in figures 40 and 41, below are quotes from selected participants.

“Cooking with electricity has brought the best out of cooks when energy efficiency is concerned. Normally, households lacked knowledge on what charcoal quantity is needed to cook a given meal. So, what we do is just fill the stove with charcoal and cook. Also, most of the LPG canisters aren’t metered, leaving us unaware of efficiency notion. However, because the electricity is metered, we would monitor cautiously power consumption when cooking, and learnt to do some energy saving practices like switching off the appliance and cook with the accumulated heat. Now, we are also cautious about energy waste, even when they are using charcoal. Electricity also brought the best out of us when it comes to kitchen hygiene: Because electric appliances are easy to clean and does not leave pots dirty, cooks felt compelled to even keep the rest of the kitchen clean”.

Female, 30 years old, CD participants from Kimironko

“When we first bought LPG stove, my husband and I were excited to use such a clean cooking energy. However, in a short time we realised that the taste of the food cooked on it was not great as the one when cooked on charcoal. Thus, we stopped using it. Now we are just happy we’ve got another cooking method, eCooking, which is even cleaner, literally”.

Female, 35 years old, CD participant from Kimironko

“Cooking with electricity has changed my cooking habits, in particular my cooking planning. Now I have enough time during the day to do activities that requires to move from my home such as visiting my neighbours, going for shopping, and attending church activities, because I know that whenever I come back it’ll take me a short time to prepare the meal. On top of the short cooking time, I can simultaneously cook and do other household’s chores”.

Female, 39 years old, CD participant from Gahanga

“I can tell you more than ten benefits of eCooking by now, including its cost efficiency. However, I’m afraid I’ll still limit its usage, particularly when I’m not around. In fact, what makes it the best fuel is what I’m afraid of. I mean, the fact that eCooking makes it easy to prepare any dish, my children abuse it and prepare food every now and then. At the end, the electric consumption becomes more important than charcoal’s”.

Female, 42 years old, CD participant from Kanombe

5. Challenges and lessons learnt

5.1. Fuel measurement

5.1.1. Electricity

During the baseline phase some HHs used task-specific eCooking appliances such as a kettle. However, specific data on electric consumption was not recorded because HHs did not have specific smart meters to capture the use. The only available option was to read from the utility meter, which would have led to inflated figures as other HHs appliances were often plugged in too. As a result, recordings from these task-specific electric appliances were not captured. During the transition phase, although HHs had data loggers, it was reported that tea/coffee in a kettle is rarely prepared in the kitchen where the data loggers are plugged in, so several heating event recordings were missed out.

5.1.2. LPG

Measuring LPG used was more challenging and uncertain because the amount of LPG consumed per meal is relatively small compared to the total weight of the cylinder, particularly when 90% of HHs were using 12kg or higher cylinders. The measurement required weighing instruments to have both a relatively high range and accuracy. To put this into perspective, most dishes cooked in less than 25 minutes, such as porridge, tea/coffee, most babies' foods, snacks, and some stews, would use between 10g and 15g of LPG. The LPG's physical properties created another accuracy challenge, as its volume was influenced by the room temperature. At the same time, when the cylinder was full, the reading of the amount used was less than when the gas in the cylinder was low, so the same meal could use different volumes depending on the day's temperature and the level of gas in the cylinder. Further reach is required to ascertain these variations. Our hypothesis is the pressure in the LPG gas directly affects the weight of the gas inside the cylinder.

5.2. General observations

- Most HHs employed house workers for cooking. Due to low education levels, they often struggled to record data adequately, impacting the data quality. Fortunately, each enumerator was allocated a limited number (five) of HHs, allowing for a thorough data review and HHs monitoring.
- Although this CD did not aim to change cooking behaviour, the study noted a lack of ownership of house workers, particularly when it came to cooking fuel expenditures and cooking processes. In fact, house workers choose a fuel for its convenience rather than its cost. The result is that even

if an appliance or fuel allowed cooks to save energy, they would not necessarily opt for it. For the same reasons, energy saving techniques might not be taken advantage of. For instance, it was noted that EPC, the most energy efficient appliance during the CD, was more compatible with boiled dishes. This means that if any HH wanted to fully save energy by using EPC, one of the options would be to adapt cooking processes to more boiling or pressure cooking rather than frying.

- Smart electric meters (data loggers) have been found to be efficient tools in recording data remotely and accurately. However, recorded data is limited for a study such as this cooking diary, as it doesn't show the heating event purpose, the cooking process used, the dish type, or the number of people cooked for. There is always a need for daily data collection through the cooks.

- The participants' main worry about eCooking was regarding safety – electrical hazards, such as short circuits, or the idea of the house or equipment burning. To avoid electrical hazards, in each HH kitchen, the electrical installation was upgraded with new and reliable wiring, which was also used to plug in two smart meters (one for each appliance). Nevertheless, one HH still had to drop eCooking halfway through the transition phase because an old existing circuit breaker was not able to handle the load and the HH owner was not ready to replace it.

Conclusion

The cooking diary study conducted in Kigali Rwanda has shown that cooking with electricity is compatible with common Rwandan dishes. The end-line phase of the study showed that Rwandan HHs have already realised the benefits of eCooking, especially energy saving, and were ready to incorporate it into their daily cooking activities. This was particularly true of EPC, which, in addition to being energy efficient and compatible with most dishes, was found to be cost efficient. Nonetheless, the study also showed that not all eCooking appliances are cost efficient – the infrared cookstove was found to use more power.

The study also showed that modern energy cooking fuel such as LPG has penetrated urban and peri-urban regions, although non-modern fuels (charcoal) are still significant. Fuel stacking has been found to be important for Rwandan HHs and, encouragingly, eCooking has blended in well enough with LPG, providing potential stacking practices.

The cooking diary study also showed that the national grid is stable and reliable enough to sustain eCooking, in both power quality and continuity of service. This is important for full scale development of the eCooking sector in Rwanda.

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Appendix

Appendix A. Cooking diary handout form

DIARY FORM: Please, fill in one form every time you cook or heat water										
Household Identifier: ___			Date: ___							
Before cooking					After cooking					
Time ___:___		Electricity	LPG: ___ kg		Time ___:___		Electricity			LPG: ___ kg
	Firewood: ___ kg	Charcoal: ___ kg	Kerosene: ___ ltrs			Firewood: ___ kg		Charcoal: ___ kg		Kerosene: ___ ltrs
	How long to light charcoal/ firewood? ___ min					Did you save any charcoal/ firewood for later?			Yes	No
Who cooked?			Name: : ___				Gender:	Male	Female	
What did you cook/ heat water for?			Breakfast	Lunch	Super	Snacks	Food for baby		Water heating	Other: ___
How mny people did you cater for?			Adults: ___	Children: ___						
Did you serve any food that did not require cooking?			Yes	No		If yes, specify				
Dish 1	WHICH DISH DID YOU PREPARE?			DEVICE?	UTENSILS?	PROCESS?	LID?	FRESH?	LEFTOVERS?	DURATION?
	Rice	Yam	Fried chicken	EPC	Big pot	Boil	Yes	Fresh	None	Time spent cooking
	Pilau	Banana/ Matoke	Fish stew	Rice cooker	Medium pot	Pressure cook	No	Reheated	Leftovers	___:___
	Irish potato	Fried banana	Fried chicken	Electric hotplate	Small pot	Dry fry	Sometimes	Partially pre-	Pre-cooking	
	Chips	Agatogo	Sambaza/ndagara	Microwave	Frying pan	Wet fry		cooked	Preparing meal in	If electric,
	Sweet potato	Ugali- cassava/maize/wheat	Leafy veg stew	LPG stove	Kettle	Deep fry			advance	Meter reading before
	Fried sweet potato	Meat stew	Other veg stew	Kerosene stove		Grill				___
	Cassava	Beans/peas	Chapati/pancake	Charcoal stove		Bake				Meter reading after
	Pumpkin	Beans/peas/peanuts stew	Pasta/noodles	Firewood stove						___
		Chicken stew	Porridge/soup							
	Egg	Other: ___		Other: ___						
Water 1	WHY WAS THE WATER HEATED?		DEVICE?		UTENSILS?	LID?	HEATED FROI	SAVING FOR LATER?		DURATION?
	Tea/ Coffee	Cleaning	LPG stove	EPC	Big pot	Yes	Fresh	None		Time spent cooking
	Drinking/ purifying	Bathing	Kerosene stove	Rice cooker	Medium pot	No	Still warm	Some		___:___
	Other: ___		Charcoal stove	Electric hotplate	Small pot	Sometimes		All		Meter reading before
			Firewood stove	Microwave	Frying pan					___
			Other: ___	Electric kettle	Kettle					Meter reading after
	ANY OTHER OBSERVATION?									
	Did you burn food?	Yes No	Did the power go off/ run out of gas during cooking?			Yes	No			
	Did the fire take longer than usual to light?		Yes No	Did you eat at a neighbour's house for one or more meals today?				Yes	No	
	Other: ___									

Appendix B. Registration survey form

1. Consent

Do you consent to be part of this study? (Yes/No)

Do you consent to any photos taken during this study being used in research publications? (Yes/No)

____

Name: ____________________________ Signature: ______________ Contact No.: ______________

Date: _______________

2. Details of participant

1. Age: ……………………………..
2. Gender: ☐ Male ☐ Female ☐ Other
3. What is the highest level of school you have attended?

   ☐ None ☐ Incomplete primary ☐ Completed primary ☐ Incomplete secondary ☐ Completed secondary ☐ Higher than secondary

a

2. *Information on your HH*

1. Location: _____________
2. Type of area: ☐ Urban ☐ Peri-urban ☐ Rural
3. How many people live in the HH? ______________
4. Who cooks in your HH?

Name	Relationship to head of HH	What proportion of the cooking do they do? (e.g. 50%, ¼, all)	When do they cook? (e.g. lunchtime only, all meals, special occasions)

5. How many rooms in the dwelling (bedrooms plus kitchen, bathroom, living room etc.)? _______
6. Type of dwelling (options to be edited to suit country context):
☐ Compound house ☐ Flat/apartment ☐ Semi-detached house ☐ Separate house

Construction

a. Walls
☐ Wood / mud / thatch ☐ Mud bricks (traditional) ☐ Corrugated iron sheet ☐ Cement block (plastered or unplastered) ☐ Bricks (burnt) ☐ Other...

b. Roof
☐ Thatch/palm leaf ☐ Wood ☐ Corrugated iron / cement sheet ☐ Cement ☐ Tiles
☐ Other _____________

c. Floor
☐ Dirt/Mud/Dung ☐ Cement ☐ Tiles ☐ Wood ☐ Other _____________

3. Where is the kitchen located?
    - ☐ Outdoor ☐ Indoor, no outdoor area for solid fuel stoves ☐ Indoor, with outdoor area for solid fuel stoves

4. Please indicate how many of the following appliances are owned (even if not used).
   Please take a photo of all appliances.

c

3 stone fire

LPG cylinder-top stove

Electric hotplate (portable)

Kettle

Rice cooker

Electric pressure cooker

Basic biomass cookstove

LPG stove

Electric cooker (portable hotplate & grill)

Microwave

Electric frying pan

Induction stove

Improved biomass cookstove

LPG stove (burners & grill/oven)

LPG/electric burners/hotplates with gas grill/oven

LPG/electric burners/hotplates with electric grill/oven

Electric cooker (hotplates & grill/oven)

Kerosene stove

Type of cooking device (see above for examples)	**Brand or local name/s**	**How many?**	**When is it used?**	**What do you usually use it for? e.g. quick things in the morning, when the gas runs out, when there is a blackout, for beans and long cooking dishes**	**How many hotplates/burners does it have? What is their diameter (cm)?**	**Power rating, W (electric only)**
			☐ Regularly ☐ Occasionally ☐ Never		No. .... Diameter/s (cm)	
			☐ Regularly ☐ Occasionally ☐ Never		No. .... Diameter/s (cm)	
			☐ Regularly ☐ Occasionally ☐ Never		No. .... Diameter/s (cm)	
			☐ Regularly ☐ Occasionally ☐ Never		No. .... Diameter/s (cm)	
			☐ Regularly ☐ Occasionally ☐ Never		No. .... Diameter/s (cm)	
			☐ Regularly ☐ Occasionally ☐ Never		No. .... Diameter/s (cm)	
			☐ Regularly ☐ Occasionally ☐ Never		No. .... Diameter/s (cm)	
			☐ Regularly ☐ Occasionally ☐ Never		No. .... Diameter/s (cm)	

d

5. Measurement of pots/pans/pressure cookers/kettles
   Please take a photo of all pots/pans/pressure cookers/kettles

Is it a pressure cooker, kettle or a big/medium/small pot or pan etc?	**How many?**	**Diameter (cm) and Height (cm) OR Volume (litres)**

6. Fuel Measurements

Charcoal/wood/kerosene/LPG users & fuel stackers only:

	Charcoal	Wood	Kerosene	LPG
How often do you usually buy charcoal/wood/kerosene/LPG?				
What quantity do you usually purchase (kg)?				
How much does this cost (Rwf)?				

All HHs:

- Is your bill pre-paid or post-paid? ________________
- Is your meter individual or shared? ________________
- How often do you usually buy electricity units? ________________
- When you buy electricity units, how much do you normally spend on average per month (Rwf)? _______________
- Do you know how many units this gets you? ________________

e

- How much do you think cooking with electricity would cost you per week?

Appendix C. Exit survey form

Name: _________________________ Date: ______________ Location: _____________

Which appliances did you cook with before the survey? ……………………………………………………………………………

	Had you ever tried cooking with an eCooker or pressure cooker before this study?	Which eCookers or pressure cookers did you already own?
Hotplate		
Rice cooker		
Infrared cookstove		
Electric pressure cooker		

As we come to the end of the survey, we take this opportunity to thank you for your endurance throughout the period. We are glad that all went well from our side, however we wish to hear from you with a few questions below.

Your experience of cooking with electricity

1. How did the eCookers suit the way you cook in your home?

   (score:1 = strongly disagree; 2 = disagree; 3 = no opinion; 4 = agree; 5 = strongly agree)

	EPC					***INFRARED***					
	1	2	3	4	5	1	2	3	4	5	**Comments**
It was easy to control heat											
I was able to multi-task while the eCooker was cooking											
The eCooker could cook fast enough											

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Long cooking dishes were cooked much faster											
The eCooker was hot enough											
The eCooker often burnt the food											
All my pots fit on the eCooker											
The pot it came with was big enough											
Food cooked using the eCooker tasted better than usual											
Pots were stable on the eCookers											
The eCooker made the pots dirty											
The eCooker itself was easy to clean											
The eCooker looked good in my kitchen											
There is enough space for the eCooker in my kitchen											
Operating the eCooker was easy											
The eCooker was safe to use											
I prefer to use an electric kettle for water boiling											

2. How easy is it to cook each food on the eCookers?
(score:1 = strongly disagree; 2 = disagree; 3 = no opinion; 4 = agree; 5 = strongly agree)

	EPC					***INFRARED***					
	1	2	3	4	5	1	2	3	4	5	Comments
Pancakes/chapatti											
Irish potatoes											
Pasta/noodles											
Eggs											
Meat											
Isombe											
Yam											
Milk											
Meat stew											
Imvange											
Peas											
Ugali											
Fish											
Mandazi											
Porridge											
Pilau											

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Chips											
Rice											
Cassava											
Pumpkin											
Banana											
Chicken											
Leafy veg											
Beans											
Sweet Potatoes											

3. Did you miss the smoky flavour of food? If so, for which dishes in particular?

………

………

………

………

4. Do foods taste different when cooked on different fuels? If so, please rank each fuel for each food, giving 1 to the tastiest and 5 to the least tasty. If there's no difference between two or more fuels, please give the same number.

	Wood	Charcoal	Kerosene	LPG	Electricity	Comments
Pancakes/chapatti						
Irish potatoes						
Pasta/noodles						
Eggs						
Meat						
Isombe						
Yam						
Milk						
Meat stew						
Imvange						
Peas						
Ugali						
Fish						
Mandazi						
Porridge						

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Pilau						
Chips						
Rice						
Cassava						
Pumpkin						
Banana						
Chicken						
Leafy veg						
Beans						
Sweet Potatoes						

k

5. How many hobs (rings) or separate appliances do you need for cooking?1☐ 2☐ 3☐ 4☐

6. What were the best things about cooking with electricity?

……
……
……
……

7. And what were the worst things about cooking with electricity?

……
……
……
……

8. What do you like most about cooking with charcoal/firewood?

……
……
……
……

9. What do you like most about cooking with LPG/kerosene?

……
……
……
……

10. What are the best things about not cooking with charcoal/ firewood?

……
……
……
……

11. What are the best things about not cooking with LPG/kerosene?

……
……
……
……

12. Did you change your cooking behaviour? If yes, how and why?

|

……

……

……

………

13. Do you think electric cooking is affordable?

……

……

……

………

14. Do you think cooking with electricity is cheaper or more expensive than cooking with the fuels you normally use?

……

……

……

………

15. Were there times when the electricity was off and you wanted to cook or heat water? If so, what did you do?

……

……

……

………

16. Do you feel that cooking with the electric cooker is safer or more dangerous than cooking with your normal stove, and why? (e.g. risk of fires, burns)

EPC……
……
………
Infrared………

……
………

17. How easy is it to learn to cook on an electric stove?

EPC……

……

………

Infrared………

m

………

………

18. Would people need training on how to use an eCooker, or would they be able to learn by themselves? If so, what should the training focus on?

EPC……

………

……….

Infrared……

………

………

19. Would you ever cook using only electricity and no other fuels - and explain why?

………

………

………

……

20. If you could change one thing about the design of each eCooker, what would you change?

EPC……

………

……….

Infrared……

………

………

21. If you could design your own completely new eCooker, what would it be like?

………

………

………

……

22. We are done with our survey and are leaving the EPC with you. Will you continue using the it or will you switch back to your old stove? If so, what will you continue to use them for?

n

EPC………

………

………

Infrared……

………

………

23. We are not going to ask you to pay for the EPC. Would you buy it if you saw one in a shop now? If so, how much would you be prepared to pay for it (Rwf)?

EPC………

………

………

Infrared……

………

……

Missing data

We have tried our best to learn as much as we can about how you cook, but we appreciate that the tools we are using are limited. Please help us to understand what we may have missed.

24. Are there any meals that were cooked or water that was heated in your HH since the beginning of the study that were not recorded on the forms you have given to us? If so, why?

………

………

………

………

25. Is there anything else that you think is important about the way you cook that we have not yet captured?

………

………

………

……

How you feel about the survey

26. In the table below, please give us your opinions of the study. Tick where appropriate, where 1 is the worst and 5 the best

o

QUESTION	1(worst)	2	3	4	5(best)
Overall cooking survey					
Choice of appliance to trial (EPC)					
Choice of appliance to trial (Infrared cookstove)					
Training on how to use eCookers					
Relevance of questions					
Duration of survey					

27. When you were approached to be part of this cooking survey were you hesitant? Has it been different to what you expected?

……

……

……

………

28. At the beginning of the eCooking phase, what was your expectation and was it met?

……

……

……

………

29. What do you think we could have done better in the survey?

……

……

……

………

30. Were the enumerator's visits helpful or did you feel it was too much or too little?

……

……

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31. If we were to do another similar survey in the future, would you be willing to be part of it?
    Yes ☐ No ☐

END OF SURVEY – Please thank the HH for participating in the survey.

q