In-Depth Exploration of Cooking Entirely with Electricity in Uganda

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EXECUTIVE SUMMARY

This report entails an in-depth exploration of cooking entirely with electricity to understand the current cooking practices in Uganda. It contributes to the MECS programme investigating the compatibility of electric cooking devices with local menus, food that can be cooked, energy consumption and relative costs to traditional fuels.

The in-depth exploration of cooking entirely with electricity combines qualitative and quantitative research techniques to understand if electric cooking can suit all cooking practices and cultures in Uganda.

The study was conducted in two phases (Baseline and phase II). Ten (10) households were selected following a selection criterion to participate in the study. In the baseline study, participants were to continue with their cooking practice as they did before but had to record the details of the meals cooked duration and the appliances that were used. Measuring equipment was provided to enable participants to measure the fuel they used. This was followed by a transition period where participants were trained on how to use electric appliances to cook their meals. In phase II, participants were required to cook all their meals using only electricity. Paper records were copied into Kobo Toolbox by enumerator and uploaded into an excel worksheet. Findings from the two phases are summarised below;

Current or baseline cooking appliances and fuels

Households used various appliances and different fuels for their cooking activities. Fuel stacking was a common practice but charcoal was the fuel used the most since each household had a biomass cook stove that used charcoal and other fuels acted as a back-up fuel.

Appliances owned: Households cooked with different fuels and a variety of appliances. All households had biomass stoves that cooked using charcoal. LPG stoves of various tank sizes and number of burners; electric rice cookers; and/or electric kettles. Cooking appliances that use biomass cook stoves (10), LPG (9), kettle (8)

Fuels mainly used: Three fuels were mainly used which were charcoal, electricity and LPG. Charcoal was used by all the participants followed by LPG that was owned by 90% of the participants who used it for cooking. 90% of the participants of the households used electricity for boiling water however only 40% of the participants used the electricity to cook.

Cost of fuels: Households that used LPG reported paying an average of approximately 10,000 UGX/kg for LPG and tended to purchase 12kg and refilled every (1 to 5 months). Most buy charcoal on monthly basis and cost remains consistent (within the range of UGX 60,000 to UGX 130,000 depending on size). Households cooking with electricity reported an overall month electricity budget ranging from 30,000 UGX to 100,000 UGX.

Appliances used: All the households had biomass cookstove. For water heating, 80% of the households had an electric kettle while the one household had a water heater. 40% of the household had microwave ovens.

Fuel stacking: In the baseline study, multiple fuels were used during the cooking activities while in phase II households were to cook entirely with electricity so we did not observe any fuel stacking in the phase II.

Cooking practices and food preferences

In Uganda, most dishes prepared are boiled or steamed. For breakfast, lunch and supper, a consistency in the mix of foods was observed. Whilst in the baseline phase participants cooked with a mix of fuels with charcoal as the primary fuel, in phase II, participants were encouraged to cook entirely with electricity and were able to adapt to 100% electric cooking without foregoing or changing the type of meals that they cooked which suggests that electric cooking could cater for foods commonly prepared in the households with little compromise. From baseline to phase II, a fluctuation in the number of meals for some dishes is observed. Beans/peas stew had an 18.12% increase in the number of times prepared which suggests cooking with electricity suits this kind of food. However, a few foods showed a decrease in preparation when electricity was introduced for example ground nut paste, chicken stew, millet cassava mix bread; although this decrease is noticed, the cooking practices and patterns do not significantly change.

Heating energies and cooking time

In phase II some foods showed a significant change in the cooking. When using electric appliances, there was a reduction in time spent preparing meals for some foods like beans; average cooking time reduced by almost half from (87 minutes to 41.84 minutes) when switching from charcoal to the electric pressure cooker.

In the baseline study, a combined total of 5.88 MJ per capital was consumed during meal preparation that is electricity (0.23 MJ), LPG (2.35 MJ), charcoal (3.30 MJ) when compared to phase II where preparations where entirely with electricity 0.38 MJ per capital was consumed which shows a significant amount of energy saved of 5.5 MJ after a shift from traditional methods to electric cooking methods

When looking at the time spent cooking dishes using electricity some devices mostly EPCs, have the potential to shorten cooking times compared with cooking using LPG or charcoal. Time savings are greatest for dishes that take a long time to cook, notably beans, boiled matooke and porridge.

Voltage behaviour during phase II of the study

In phase II where different electric appliances were used to prepare meals, hypothesis tests were conducted to verify if the use of many appliances caused a disruption in the voltage and if the voltage fluctuation eventually affected the use of cooking appliances. The first hypothesis stated; Is there as significant difference in voltage when the appliance is off and when it’s on. It was evident that there was significant difference in voltage when the appliance is off and when it is on. Upon verifying that then the next hypothesis stated; Is there a difference in voltage through the day (7AM to 7PM). It was discovered that there was a significant difference in voltage between 7AM and 7PM. And lastly; Do households experience undervoltage when they cook? The conclusion derived from the last hypothesis was high confidence it is an undervoltage event, but it is a small effect hence households could experience undervoltage but to a very small extent that it would not affect their cooking appliances.

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1. INTRODUCTION

This report is an analysis of an in-depth exploration of households cooking entirely with electricity. A sample of ten (10) households were chosen from areas of Kampala and Wakiso districts on whom the study was focused. The study was conducted from October of 2022 to December 2022 to aid MECS in supporting the transition of low-income economies from use of biomass fuels to the use of modern energy cooking services.

1.1. Study Background

MECS is supporting the transition of low-income economies from biomass to the use of modern energy cooking services (i.e. cooking with electricity or gas). MECS recognises the need to understand the complexity and scale of both the opportunities and challenges for modern energy cooking transitions in African and Asian contexts. The Cooking Diaries methodology was developed early in the MECS programme as a means of investigating the compatibility of electric cooking devices with local menus – in terms of what foods can be cooked, energy consumption, and cost (relative to traditional fuels). To date it has focused on each household obtaining and using a single appliance, on the assumption that the upfront cost of multiple appliances would be prohibitive. The focus has tended to be on Electric Pressure Cookers (EPCs), as they offer significant energy savings and appear well suited most menus, being able to cook a majority of everyday meals. The potential for EPCs playing a role in increasing access to clean cooking is now well recognised.

The aim of this study was to expand existing research to explore the use of multiple devices in a household, particularly as mechanisms for mitigating the upfront costs are emerging (e.g. cost reduction of devices, credit facilities, utilities led financing, carbon finance, and results based financing). Data generated on a wide range of devices and how they can be used to meet all households will be generated. This set of data will be used for a range of purposes such as; a) Policy making that supports programme design and decision making on energy access policy; b) Device supply chain whereby device manufacturers have engaged with supplying EPCs to LMIC markets are aware of consumer barriers to purchasing EPCs and are increasingly interested in offering a range of electric devices and the carbon credit market; and c) The new MECS-supported Gold Standard for digitally connected cooking is based on calculations that require evidence on the energy use by the project devices (currently expressed as thermal efficiency, but likely to expand to allow use of data on energy use instead).

As companies start to apply this methodology it is becoming clear that the availability of data on eCooking and other energy efficient devices is required, and data on 100% eCooking is a particular gap.

1.2. Aim of the study

The aim of this study was to gain an understanding of the energy implications at the household level of cooking entirely with electricity. The study sought to address the research questions below using the cooking diary study protocol;

a) How much energy is required to cook entirely with electricity?
b) How much traditional energy can be saved by transitioning to cooking entirely with electricity?
c) What are the cost implications of transitioning to cooking entirely with electricity?
d) How much energy is required to cook individual dishes using a range of electric cooking devices?
e) Which dishes do people prefer to cook using different electric devices?
f) What is the user experience of cooking entirely with electricity?
g) What barriers prevent people from cooking entirely with electricity?
h) What difficulties do people encounter when cooking entirely with electricity and how they overcome these difficulties?

2. METHODOLOGY

This in-depth exploration study was carried out using the cooking diaries 3.0 protocol. It was done in two phases; baseline and phase II which ran over a period of five weeks, each phase lasted for two weeks with a transition period of one week in between the two phases. In the baseline, participating households were asked to continue with their cooking practices as they normally did. However, participants had to record their cooking activity details i.e., the type of food cooked, the device used, fuel used, and duration of meal preparation. After the first two weeks of baseline data collection participating households went through a transition phase where they were introduced to various electric cooking appliances and subjected to training on how to use various electric devices. This aimed to make participants familiar with different electric cooking devices and eliminate barriers that could arise from switching to electric cooking devices. During the transition phase, the training team provided demonstrations on how to use electric devices and provided information on awareness to combat the stigma that arises from the fear of the use of cooking devices. After the training concluded, phase II commenced and participants were provided with electric cooking appliances which they used for all their cooking activities.

Table 1 showing a summary of the phases and the household activities

Phases	**Description of households**	**Description of research team activities**
Pre – testing phase	Communication was established with enumerators	KoBo survey tools were tested, households assigned to interviewers, tested the registration and survey tools
Baseline: (two weeks)	Households maintain current cooking practices while keeping a record of the meals prepared on a daily basis however, they were also required to measure the fuel before and after the cooking activity is finalized	Households were visited daily by enumerators who collected the data concerning the cooking activities and fuels used and also provide participant support during the exercise
Transition period: (one week)	Participants were introduced to electric appliances and trained on how to use them	The enumerators used live demonstrations to teach the participants while answering any questions
Phase II: (two weeks)	The participants were advised to use electric appliances for	Cooking diaries data was recorded daily by the participants

	all their cooking activities since they were provided with various appliances that could handle different cooking tasks	and the data was obtained by the enumerator which were then entered into the KoBo collect and uploaded

Table 2 showing the equipment used in the measurement of fuels

Equipment used	Description
	Used a 50kg with accuracy of 10g calibrated digital scale to measure the weight of charcoal used to cook dishes or boil water. It has a hook that allows easy measurement of the bundled-up fuel. It has an easy- to- read backlit LCD screen with a push-button control that allows taring/ zeroing and switch off and on. It has a power supply of a 3V CR2032 battery
	Used a 30kg with accuracy of 1g calibrated digital scale to measure the weight of LPG. This was a water resistant scale made out of stainless steel encapsulated for a higher protection and had a LED display which eased measurement recording. The stainless steel edges are rounded and the surface is flat.
	Used A2Ei Smart meter with accuracy of 0.001kWh that helps record information such as consumption of electric energy in kWh, voltage levels, current, and power factor. It also has internal back-up memory.

2.1 Selection Criteria

The selection criteria described the attributes considered during the study so as to select a representative sample for the population's cooking habits in Uganda.

2.1.1 Participant selection criteria

Participants were selected from 2 socio- economic strata i.e. Middle/ high income users to represent the market of early adopters who are likely to purchase electric devices for themselves (but may use a credit facility) and Low income users to represent the majority market that are likely to need policy support to encourage adoption/purchase. Furthermore, the criteria below was used for participant selection;

- Participants that were legal adults i.e., at least 18 years and were willing to participate it the study
- Participants who regularly cooked
- Participant's household connected to the grid since the study required cooking entirely with electricity in phase II

- Households that prepared at least two meals per day and had at least three family members
- Households that had a dry and safe place/surface where the electric appliances could be placed

Participants that were willing to participate the study signed a consent form and were briefed and provides with detailed information on how the study would be conducted. Participants were given the liberty to ask questions before choosing to participate in the study.

2.1.2 Appliance selection criteria

Appliances for the study were carefully selected to meet all the cooking needs of the participants as identified in the baseline survey. The appliances selected for the study are shown in table 3 below.

Table 3 showing a brief description of the equipment provided to the households

Appliances distributed	Cooking need	Description
	Streaming, boiling and frying	A 6L electric pressure cooker with a sealed pot having a valve that controls the steam inside. This has got an insulation feature that gives the cook an option to pressurize which enables the food to cook faster. Had a power rating of 1000W.
	Deep frying	A 6L air fryer which is a small countertop convection oven designed to simulate deep frying without submerging the food in oil. It has a fan that circulates hot air at high speed, producing a crisp outside and moist and tender inside without actual frying. The air fryer had a power rating of 2200W.
	Water heating	A 5L electric kettle with a self-contained heating unit, for heating water, and automatically switching off when the water reaches a boiling point or at a pre-set temperature below 100 °C with a power rating of 2200W.

	Meets majority of the cooking needs except oven-based needs	A 2200W induction cooker which uses the principle of direct induction where heat is transferred by currents from an electromagnetic field that is located below the glass surface to the magnetic induction cookware placed on the cooking surface. It requires magnetic pans thus an added cost implication.
	Meets majority of the cooking needs except oven-based needs	A 2200W infrared cooker that operates on the principle of infrared heat radiation with halogen lamps and radiant coils that combine to transfer heat to the cooking vessel through direct infrared radiation. This can use a variety of saucepans.

2.1.3 Appliance distribution criteria

During the process of distributing the electric appliances, the following selection criterion was used to determine which household got which combination of electric appliances.

- Every household received an electric pressure cooker. The pressure cooker was chosen for each household since it could boil and steam which is the most preferred way of preparing meals in Uganda. The EPC could also cook majority of the local dishes making it suitable for the study.
- Electric kettle; this appliance was provided to all participating households for water heating
- Infrared cooker; this appliance was received by five (5) participants. The targeted participants for this appliance were the low-income earners since they can use any kind of saucepan to cook, boil or steam their foods.
- Induction cooker; this appliance was provided for five (5) middle to high income earners since it requires additional accessory costs. During the study, the magnetic saucepans were provided to all participants. The induction cooker requires magnetic saucepans which are quite pricy.
    - The main aim of providing the induction and infrared cookers was to aid in frying for those that could not or were not comfortable frying with an electric pressure cooker
    - Participants were divided into two groups to test which of the two is more efficient for all the cooking activities

Air fryer; this appliance was given to households that had regular deep-fried dishes on their menu and showed interest.

Table 4 below shows a breakdown of the different appliances received by each household during the study

Table 4 showing a summary of the electric appliances received by each household

Household Code	Electric kettle	Electric Pressure Cooker	Induction cooker	Infrared cooker	Air fryer	Total
HHI01	1	1	1	0	1	4
HHI02	1	1	1	0	0	3
HHI03	1	1	0	1	0	3
HHI04	1	1	0	1	0	3
HHI05	1	1	0	1	1	4
HHI06	1	1	0	1	0	3
HHI07	1	1	0	1	1	4
HHI08	1	1	1	0	1	4
HHI09	1	1	1	0	1	4
HHI10	1	1	1	0	0	3

3. Results and Findings

In this chapter quantitative and qualitative data that was collected in the study, analysed and the findings are presented below.

3.1. Household characteristics [demographics, cooking appliances and fuels]

In order to investigate cooking habits, ten households participated in the study and all kept cooking diaries for each meal cooked.

All participants were female since they do most of the cooking activities, the average number of people per household is four (4), and the biggest household had seven (7) while the smallest household contained three people (3)

The study was split into two phases. In baseline, participants were to continue with their cooking habits without making changes however participants were required to fill in the cooking diaries. In Phase 2, households were given electric appliances as stated in table 1 above. This was to encourage them do all their cooking activities using electricity. The number of records obtained from each phase is shown in Table 4 below. Records on cooking activities were kept by participants then entered into KoBo collect and then uploaded to Kobo Toolbox by the enumerators. The data was then converted to an excel worksheet and downloaded for cleaning and analysis. Every row in the worksheet contained the information for one record. Each record covered multiple purposes e.g., an early morning record included breakfast, preparing food for a baby, and heating water (3 events).

Table 5 shows the total number of records and the daily average records per day that were collected from the baseline study that aimed at determining the existing household cooking habits and phase II which aimed at collecting information on the households' cooking habits when electricity only was used.

Table 5 showing the number of records in the baseline and phase II studies

Phase	Number	Percentage	Average Number of records/days
Baseline	438	51.29	31.29
Phase II	416	48.71	29.71
Total	854	100	

Table 6 below shows details of one heating event. Heating events are split between breakfast, lunch and supper. Water heating was recorded and categorised independently.

Table 6 Breakdown of single heating events such as breakfast, lunch, supper, water heating.

Reason for cooking	Baseline	%	Phase II	%
Breakfast	125	28.54	101	24.28
Lunch	127	29	122	29.33
Supper	131	29.91	110	26.44
Water heating	53	12.1	77	18.52
Other	2	0.46	6	1.44
Total	**438**	**100**	**416**	**100**

Figure 1 below which compares the number of meals cooked in the baseline and phase II indicates that after participants started using electricity, the number of meals prepared and recorded slightly reduced except water heating.

However, this reduction in the number of meals in phase II is not significant as seen in figure 5 (showing the cooking patterns in terms of the number of meals cooked per day) which indicates that the cooking patterns in the two phases remained similar; participants' cooking practices and habits did not significantly change when cooking entirely with electricity. This could suggest that with the right combination of electric cooking appliances, a household can fulfil all their cooking activities without compromise.

For water heating, there was a significant increase from baseline to phase II hence water independently was boiled more often in phase II than baseline which suggests that electric appliances used for boiling water like electric kettles are convenient.

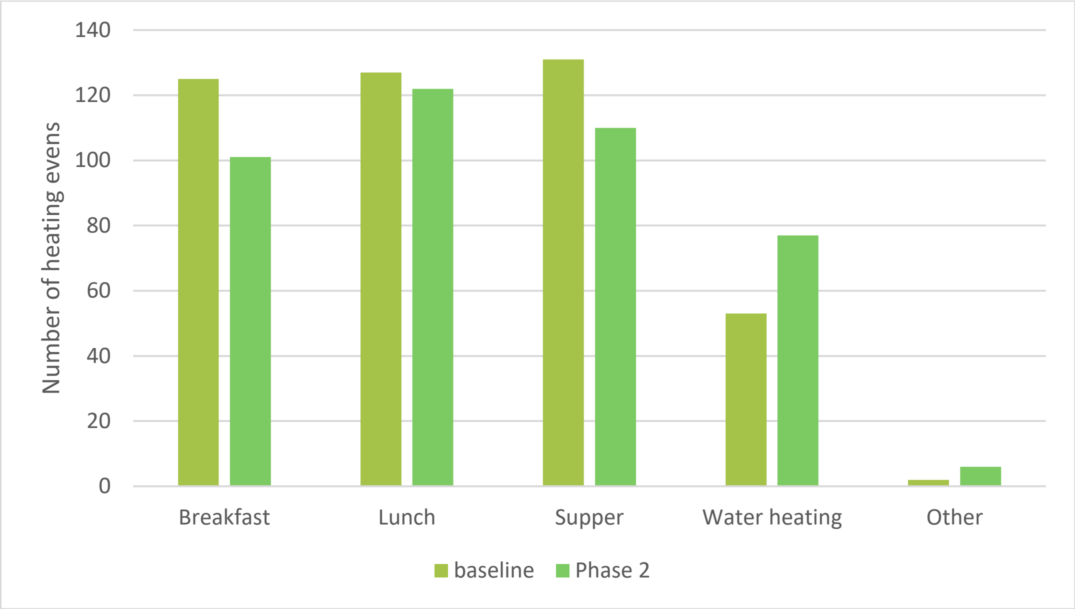

Figure 1 showing a break down single heating events

Table 7 below shows the household composition. It's noted that from the baseline study, the children were on school holiday and this number reduces in phase II since some children were sent to the villages. Adults were more present at home as the festive holiday season was kicking in.

Table 7 Average number of adults and children cooked for

	baseline			phase II		
	N	Mean	Median	N	Mean	Median
Adults:	823	2.36	3	950	2.29	2
Children:	1033	1.88	2	801	1.97	2

Table 8 below shows the total number of adults and children that were present during each heating even for both baseline and phase II. The number of adults and children present is shown as N. The mean and median are computed too. It should be noted that holiday seasons and schools' calendars greatly affect the variation in the number of meals cooked and this is evident in the baseline and phase II records.

Table 8 *Average number of children and adults cooked for by meal*

Reason for cooking		Baseline N	Baseline Mean	Baseline Median	Phase II N	Phase II Mean	Phase II Median
Breakfast	Adults	273	2.2	2	210	2.1	2
	Children	204	1.63	1	169	1.69	1
Lunch	Adults	302	2.38	2	300	2.46	2
	Children	243	1.91	2	224	1.85	2
Supper	Adults	323	2.47	3	270	2.45	3
	Children	228	1.74	2	192	1.79	2
Breakfast Lunch	Adults	1	1	1	-	-	-
	Children	1	1	1	-	-	-
Water heating	Adults	134	10.8	11	160	7.75	8
	Children	147	13.42	12	204	16.38	15
Food for Baby	Adults	-	-	-	-	-	-
	Children	-	-	-	2	1	1
Snack	Adults	-	-	-	7	2.33	3
	Children	-	-	-	7	2.33	3
Total		**1856**	**2.14**	**2**	**1744**	**2.25**	**2**

Figure 2 below shows a graphic representation of the adult children composition in different households which provides a clear view of the variation of the number of adults and children per household for the period the study was conducted. It was noticed that during the baseline, children had returned home for a holiday while parents were still working, whereas in phase II some parents were more at home due to the start of the festive season; however, some of the children were sent to the village to spend the Christmas holiday with grandparents; this explains why the number of children available in phase II is lower than in baseline while adult numbers in phase II are relatively high.

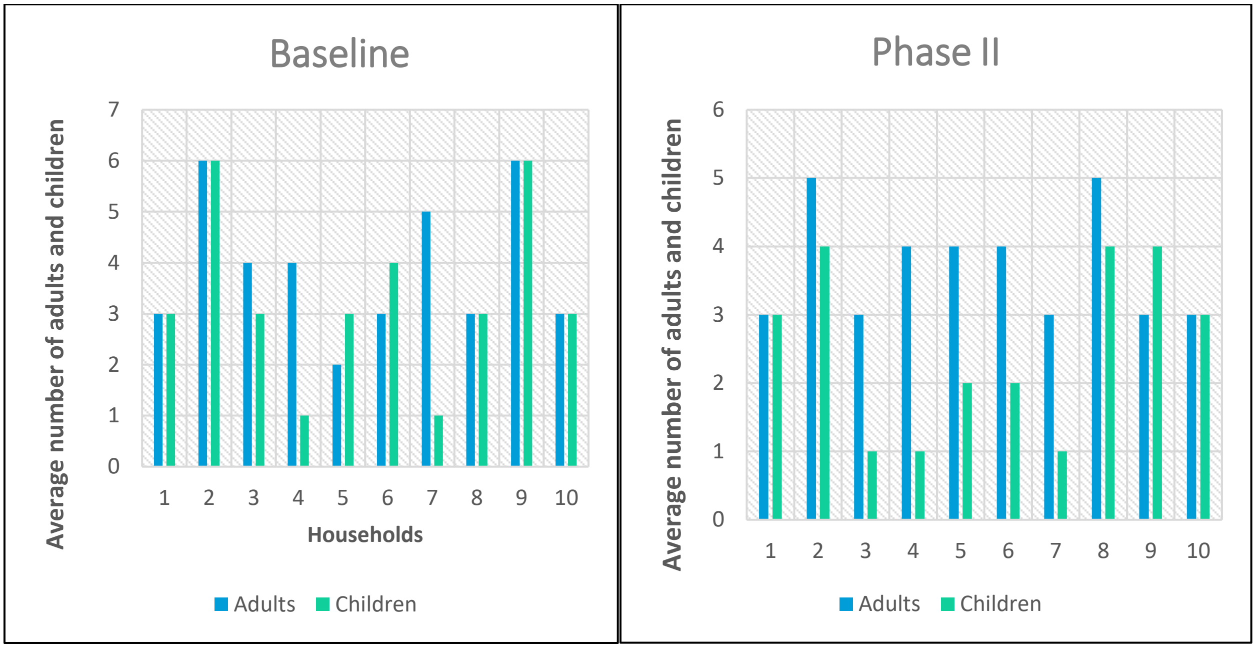

Figure 2 shows the household composition

For the major heating events of breakfast, lunch and supper, phase II consists of fewer dishes than in the baseline as evident across all main meals, but especially supper.

Table 9 Average number of dishes cooked (single heating event records and main meals only)

Reason for cooking	Baseline	Percentage	Phase II	Percentage
Breakfast	125	32.64	101	30.33
Lunch	127	33.16	122	36.64
Supper	131	34.20	110	33.03
Total	**383**	**100**	**333**	**100**

Figure 3 below shows a graphic representation of the main meals prepared and a decrease across all the meals except breakfast and supper. The number of times lunch is prepared reduced by a very small proportion.

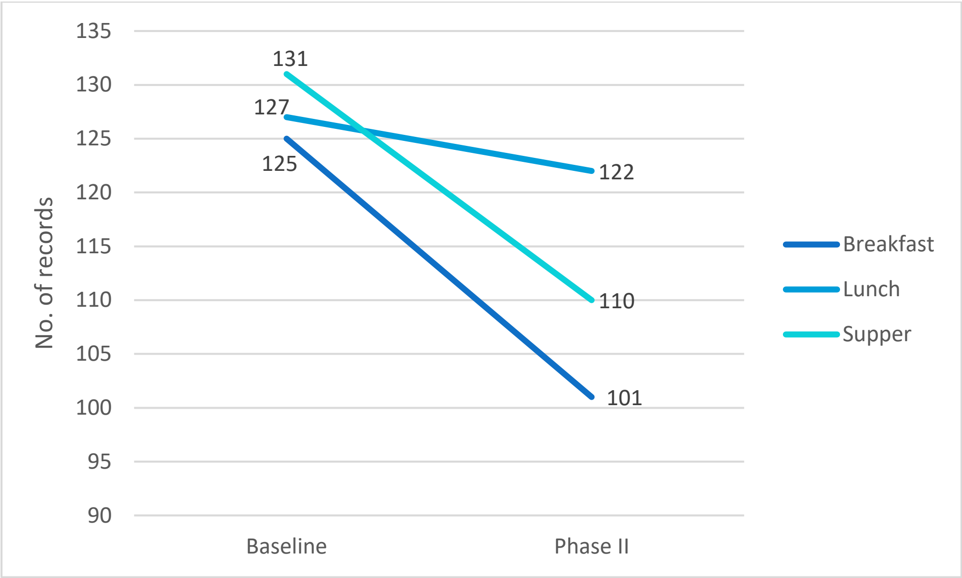

Figure 3 shows a graphic representation of main meals prepared in the baseline phase vs in phase II

Table 9 below shows the number of heating events recorded per day by each household. For different households, the number of heating events within the baseline and phase II study varied per household since different cooking practices are undertaken by different households. From the output in table 8 there is a variation in cooking behaviour for example water may not be heated every day, lunches may only be prepared on weekends, and certain meals may not be prepared if the household eats out.

Table 10 showing Number of heating events per day by household

HH ID	Baseline (4-Nov-2022 to 21-Nov-2022)																		Phase II (26-Nov-2022 to 16-Dec-2022)																				
	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S		S	S	M	T	W	T	F	S	S	S	S	M	T	W	T	F	S	S	S	S	M
1		1			2	3	3	3	3	3	3	3	2	3	3	3	3			3	3	3	3	3	3	3	4	3	4	4	3	3	3	2					
2		4	3	2	4	3	3	2	3	3	3	3	3	3	3	1	3							3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	2
3		3	3	3	2	2	3	3	3	3	3	3	3	2	3	3	3			3	3	3	2	3	3	3	3	2	3	3	3	3	3	3					
4				1	3	4	2	2	2		2	3	4	3	3	2	1				4	5	1		1	2	2	3	2	1	4	1	3	3	2	2			
5			4	3	3	1	4	2	3	3	3	4	2	3	2	2	2			1	3	2	2	2	1	2	1	2	2	1		2	3	1					
6		2	4	2	3	3	3	3	3	3	3	3	1	4	3	3				2	3	3	2	3	3	3	3	4	3	3	3	3	3	3	2	1			
7			4	3	3	3	4	3	2	4	2	2	4	3	3	1	2		2		3	2	3	2	3	2		2	2	3	3	2	2		2	1			
8		3	3	3	3	3	3	3	3	2	3	3	3	3	3	1					2	5	3	3	3	4	4	3	4	3	4	2	2	1	1				
9		3	4	3	3	3	3	3	3	2	3	3	3	3	3	2	1			3	3	4	3	4	3	3	2	5	4	4		3	4	2	3	4			
10	2	3	2	2	2	2	3	2	3	2		1	3	1			1				3	2	2	1	3	2	4	4	3	4	3	3	1	2	2				

Figure 4 below shows a comparison between the number of meals cooked in the baseline study verses in the Phase II study. In the baseline study, the cooking trend is fairly constant compared to phase II. When electric appliances were introduced in phase II, an increasing trend was observed because participants were experimenting cooking different meals with the electric appliances. The trend turned fairly constant which suggested participants had become comfortable cooking with the electric appliances. The fairly constant trend in phase II was similar to the constant trend in the baseline. This suggested that the cooking habits remained fairly the same hence participants may be willing to cook with electricity only without significantly changing their cooking habits. In the last two to three days the trend in both baseline and phase II fall significantly which is caused by some participants finishing the cooking experiment early hence the trend towards the end of each phase is not sufficient to provide a meaningful conclusion.

Figure 4 below shows the trend of daily heating habits by participants over the duration of the study. Total daily meals are represented for each day of the week sequentially. The Y-axis has total number of meals and the X-axis represents weekdays.

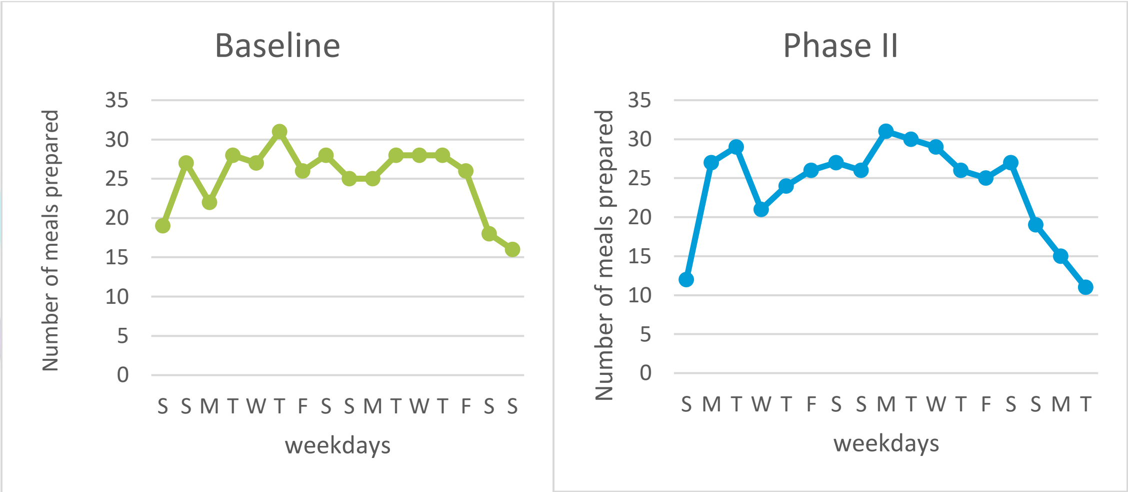

Figure 4 shows the cooking patterns in baseline and phase II

Figure 5 below shows the cooking patterns in the first and phase II after the data has been cleaned to select data where all households were cooking. A relatively similar pattern is observed in the baseline and phase II of the study. After data from the beginning and end of the study is eliminated, it shows that the cooking practices and habits remain relatively similar through the days. This finding is supported by figure

5 that suggests that a shift from traditional methods to electricity doesn't heavily influence the number of meals a household would prepare on a daily basis.

Figure 5 below showing a cleaned comparison of the cooking habits in the baseline and phase II. The total meals cooked by all households is plotted against the days (1st day, 2nd day, …, 13th day)

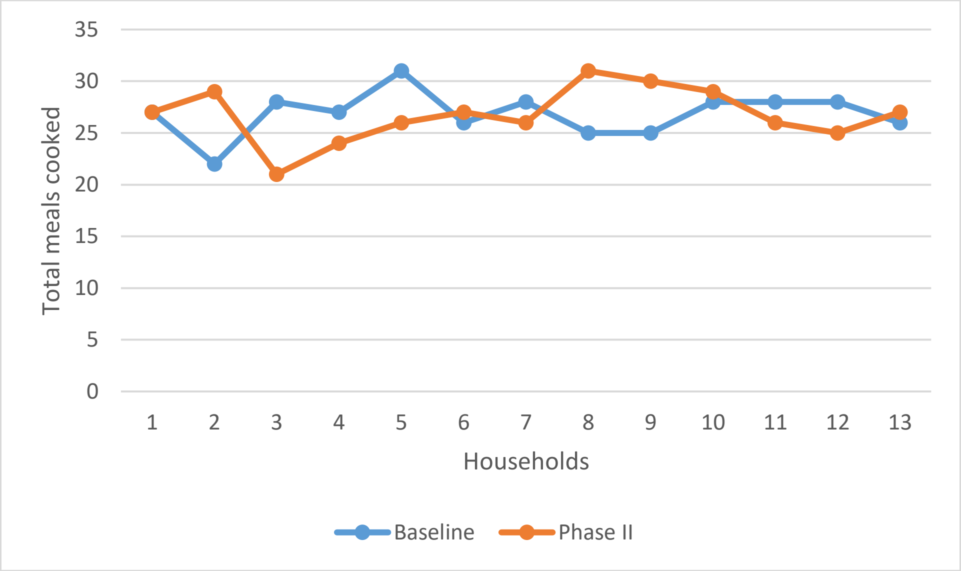

Figure 5 shows a cleaned comparison of the cooking habits in baseline and phase II

3.2. Dishes cooked and reason for cooking

3.2.1 Food types cooked

For the most prepared dishes by the participants, it's evident in table 11 below that participant prepared more of the common dishes in phase II than in the baseline study i.e., beans/peas stew, porridge, eggs, fish stew, matooke, these meals were prepared more when participants switched from traditional method of cooking to using only electricity for cooking.

Table 11 shows dishes prepared in the baseline and phase II

	baseline		**phase II**	
	N	**percentage**	**N**	**percentage**
Beans/Peas Stew	61	14.39	88	14.97
Chicken stew	16	3.77	10	1.70
Eggs	12	2.83	33	5.61
Fish Stew	12	2.83	23	3.91

Goat/Meat Stew	16	3.77	57	9.69
Ground nut paste	16	3.77	5	0.85
Matooke (boiled)	10	2.36	28	4.76
Matooke (steamed)	22	5.19	34	5.78
Millet cassava mix bread (Karo)	8	1.89	2	0.34
Other	79	18.63	130	22.11
Porridge	31	7.31	42	7.14
Rice	69	16.27	98	16.67
Soup (goat, beef, fish)	4	0.94		0.00
Spaghetti (pasta)	22	5.19	5	0.85
Sweet potatoes/ Irish potatoes/ cassava/ yams/ pumpkin (boil and fry)	4	0.94	3	0.51
Sweet potatoes/ Irish potatoes/ cassava/ yams/ pumpkin (boil or steam)	24	5.66	7	1.19
Sweet potatoes/ Irish potatoes/ cassava/ yams/ pumpkin (fried or deep fried)	2	0.47	17	2.89
Ugali (posho)	16	3.77	6	1.02
Total	**424**	**100**	**588**	**100**

Figure 6 below shows a graphic representation of the top meals cooked during the study. For the most prepared meals rice and beans/peas stew, there is a small percentage increase in the number of times they were prepared in phase II compared to the baseline; whereas for certain meals like spaghetti, posho, sweet potatoes, groundnut paste, there is a relatively significant percentage decrease which suggests that for such foods, there is a bit of a learning curve and users may require user training on how to prepare them when using electric appliances.

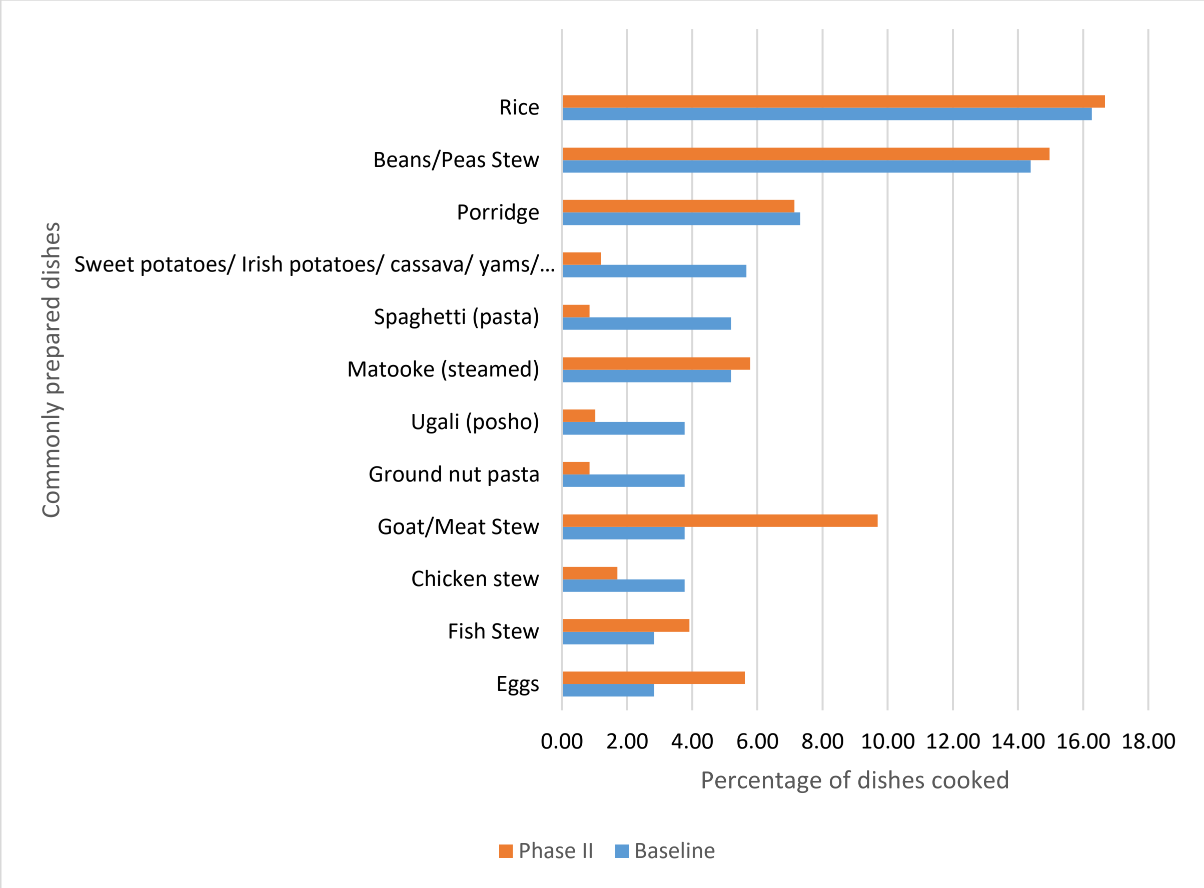

Figure 6 showing the top 13 commonly cooked meals and the percentages showing how much they are cooked

From table 12 below, electric pressure cooker was the most used electric device due to its convenience and efficiency. Induction cooker and infrared cookers were given to different households to test which of the two would be more used. It was noted that participants that had induction cookers used them to cook more often than those that received infrared cookers. This observation may not be conclusive to assess usage as comparison was made for 5 participants for each of the two appliances.

Table 12 showing the number of times appliances were used to prepare meals

Row Labels	Air fryer	Electric kettle	Electric pressure cooker	Induction cooker	Infrared cooker
Beans/Peas Stew			33	1	9
Chicken stew			5		1
Eggs			4	8	6
Fish Stew	1		2	1	6
Goat/Meat Stew	2		18	2	4
Ground nut paste				3	
Katogo			2	3	
Leafy Vegetables (cabbage, nakati, dodo, malakwang, gobe etc)			4	3	1
Mandazi			1		
Matooke (boiled)			19	2	
Matooke (steamed)			12	1	
Millet cassava mix bread (Karo)					1
Other	8	19	21	14	11
Pigeon peas (Lapena)			1		
Porridge			14	10	3
Rice			44	2	
Roasted Meat (Muchomo)	2				
Soup (goat, beef, fish)				1	
Spaghetti (pasta)			5	1	
Sweet potatoes/ irish potatoes/ cassava/ yams/ pumpkin (boil and fry)			8	1	2
Sweet potatoes/ irish potatoes/ cassava/ yams/ pumpkin (boil or steam)	1		14	2	
Sweet potatoes/ irish potatoes/ cassava/ yams/ pumpkin (fried or deep fried)	3		3		
Ugali (posho)			2	1	
Total	**17**	**19**	**212**	**56**	**44**

Figure 7 below shows the number of times meals were prepared using different appliances.

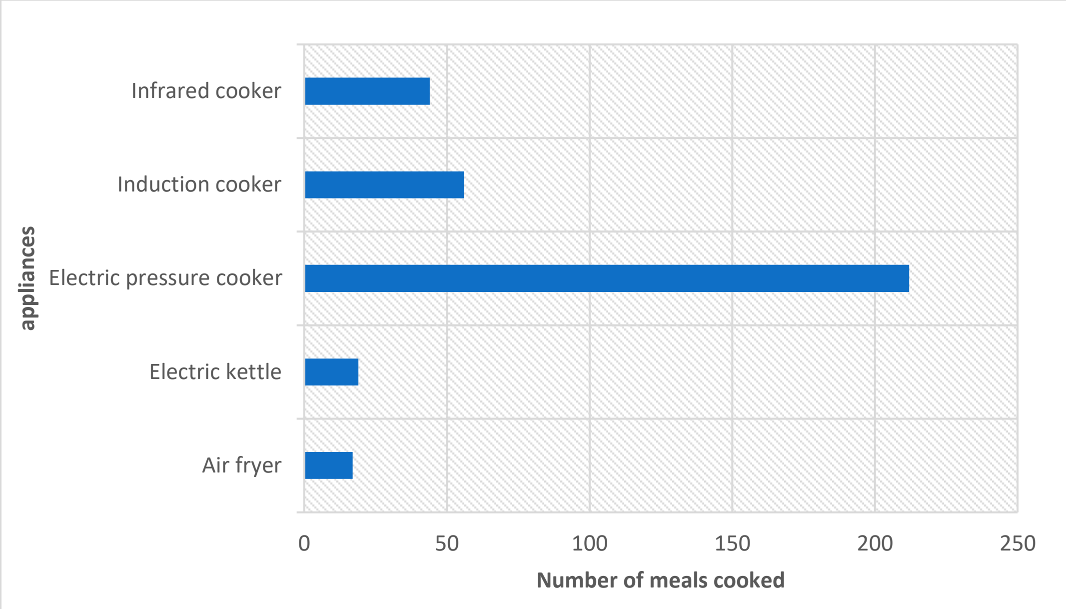

Figure 7 showing the number of foods prepared by different appliances

Table 13 below shows the foods prepared for each meal that is breakfast, lunch and supper. Water heating shows the number of times water was boiled independently when preparing a meal for example for the times rice was cooked, water was heated twenty-two (22) times in maybe an electric kettle then the heated water later used to prepare the rice.

Table 13 showing the frequency of foods prepared for different meals

Foods cooked	Breakfast	Lunch	Supper	Water heating
Porridge	39	9	12	4
Matooke (boiled)	31	40	52	9
Rice	5	100	68	22
Beans/Peas Stew	18	104	46	23
Spaghetti (pasta)	3	3	4	3
Katogo	40	19	5	4
Ugali (posho)	4	82	46	8
Sweet potatoes/ irish potatoes/ cassava/ yams/ pumpkin (boil or steam)	20	51	32	14
Sweet potatoes/ irish potatoes/ cassava/ yams/ pumpkin (fried or deep fried)	5	8	4	4
Matooke (steamed)	4	88	44	16
Eggs	22	3	3	9
Sweet potatoes/ irish potatoes/ cassava/ yams/ pumpkin (boil and fry)	6	8	5	1
Ground nut paste	5	31	21	5

Goat/Meat Stew	5	48	18	5
Leafy Vegetables (cabbage, nakati, dodo, malakwang, gobe etc)	7	34	35	1
Fish Stew	1	12	21	0
Soup (goat, beef, fish)	1	5	2	0
Pigeon peas (Lapena)	0	1	0	0
Chicken stew	2	13	9	3

Table 14 below shows the average number of dishes prepared per meal in both the baseline and phase II. In phase II, participants often cooked two or more meals which suggests that electric devices are suitable for preparing many dishes for different meals

Table 14 shows the average number of dishes prepared by different households

Household	Baseline				Phase II		
	Breakfast	Lunch	Supper		Breakfast	Lunch	Supper
1	1	1	1		2	2	2
2	1	1	1		2	3	3
3	1	2	2		1	2	2
4	2	2	1		1	2	1
5	2	2	2		1	2	2
6	1	1	2		1	1	1
7	0	2	1		1	2	1
8	1	2	2		2	2	2
9	1	2	4		2	3	2
10	2	2	2		2	2	3

From table 15 below, in phase II, fewer meals were prepared by the households compared to baseline except from where three meals and more where prepared. However, from figure 8 below it's observed that the cooking practices do not significantly change since the trend is similar for the baseline and phase II studies.

Table 15 Number of dishes included in a heating event (breakfast, lunch, supper heating events only)

	baseline		phase II	
No. of dishes	N	percentage	N	percentage
0	43	9.82	66	15.87
1	187	42.69	151	36.30
2	156	35.62	118	28.37
3	39	8.90	53	12.74

4	12	2.74	16	3.85
5	1	0.23	12	2.88
Total	438	100	416	100

Figure 8 below illustrates that there is no significant change in the cooking practices after the introduction of electric devices, in both the baseline and phase II, most households cook one meal per day and then the trend fell in a similar manner.

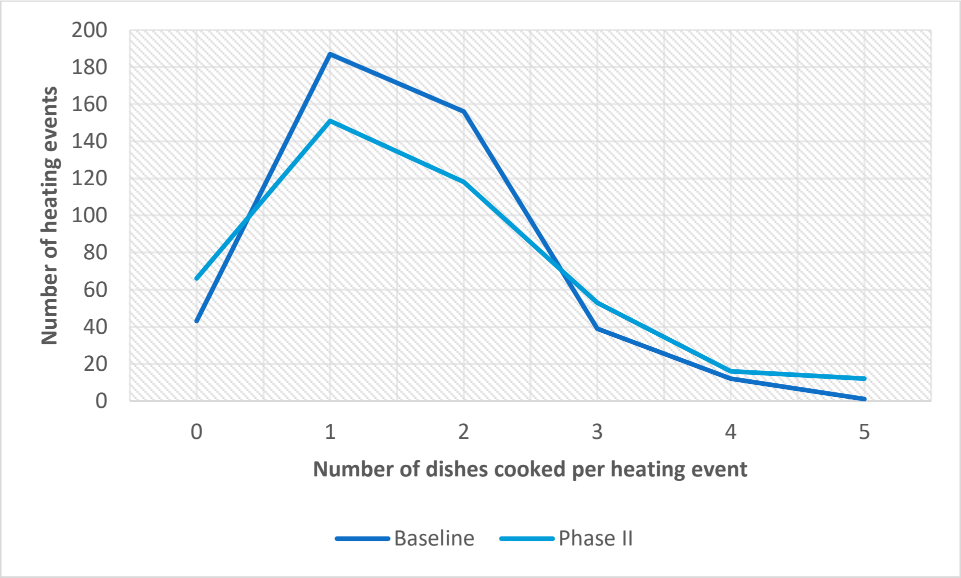

Figure 8 is a line graph that compares the number of meals cooked in the baseline study and phase II

3.3. Heat energy use [per person, per heat event, per day, meal, appliance]

In table 12 below, the calorific values of the most common fuels used and identified in the survey is calculated from deduced fuel consumption. For electricity, fuel consumption was calculated based on the time it took to prepare a meal whereas for charcoal, LPG and wood fuel consumption was calculated as the difference in the weight used for cooking

3.3.1 Energy consumption

Energy consumption data from the A2ei smart meters was captured in two ways, i.e. manually by recording the meter reading in the cooking diaries before and after every heating event and automatically via the A2ei smart meter data recording platform.. The captured cooking diaries records are used to analyse the energy consumed during the preparation of a specific meal while A2ei smart data was used to study the voltage effect when cooking entirely with electricity is adopted.

For the most used fuels, energy consumptions have been computed from deduced fuel consumptions based on before and after the reading and the calorific values computed are shown in table 16 below.

Table 16 shows calorific values and conversion efficiencies

Fuel	Calorific value
Charcoal	29.6 MJ/kg
LPG	49.3 MJ/kg
Electricity	3.6 MJ/kWh

3.3.2 Fuel stacking

For the study conducted, fuel stacking was evident in the baseline study. Charcoal was the most used fuel while LPG and electricity were used as back up fuels however few participants used multiple fuels for their cooking activities.

In table 17 there was fuel stacking in the baseline study, most of the households used one fuel followed by those that used two fuels which were charcoal and LPG. However, in the phase II, all the households used 100% electricity since the appliances provided were able to address all their cooking needs. For the days where the participants experienced power outages and had to revert to traditional methods, cooking diaries records for those days were not considered not but rather that day's record would be replaced by an additional day when electricity was available given that the study objective was to gain an understanding of the energy implications at the household level of cooking entirely with electricity. It is also important to note that the power outages during phase II of the study were minimal.

Therefore, fuel stacking was only evident in the baseline study.

Table 17 Number of fuels used in single heating event.

Number of Fuels per heating event	baseline		Phase 2	
	N	percent	N	percent
1	349	79.68%	416	100.00%
2	86	19.63%	0	0.00%
3	3	0.68%	0	0.00%
Total	438	100.00%	416	100.00%

Table 18 below, during the baseline study, charcoal was the most used fuel recorded (170) times which contributes to 38.81% followed by electricity which accounted for 22.60% followed by LPG that contributes 18.26%. However, in the phase II, 100% electric use in cooking was achieved since participants were provided with all the appliances that could do all the activities regarding their cooking practices.

Table 18 shows the fuel choices of the participating households per heating event

Fuel choice	Baseline	Percentage	Phase II	Percentage
Charcoal	170	38.81	-	
Electricity	99	22.60	416	100
LPG	80	18.26	-	
Electricity LPG	68	15.53	-	
Charcoal LPG	9	2.05	-	
Electricity Charcoal	9	2.05	-	
Electricity LPG Charcoal	3	0.68	-	
Total	**438**	**100**	**416**	**100**

3.3.3 Per capita consumption

Per capita energy consumptions have been calculated by dividing the energy consumption for a given heating event by the number of people that the meal was cooked for. Adults and children have been given equally weighted when calculating the capital consumption.

For proper analysis of the per capita energy consumption of each fuel, records that used various fuels were excluded because only a proportion of the fuel is used for energy consumption.

In the baseline study, electricity was used less as a major cooking fuel but rather used mostly for boiling water as seen from the number of heating events of electricity verses LPG and charcoal. In phase II, electricity was the only fuel participants were to use to handle all their cooking requirements. In the baseline study, fuel stacking was very common while in phase II where there was no fuel stacking, there is a small increase of 0.15 MJ per capita in electric energy consumption from the baseline to phase II when only the energy consumed on electricity is considered.

The average energy consumed in phase II is 0.38 MJ per capita for every meal while during the baseline, charcoal, LPG and electricity combined used energy worth 5.88 MJ per capita. This indicates that a great amount of energy is saved when traditional methods of cooking are abandoned and cooking with electricity adopted.

Table 19 below shows a detailed comparison of the different fuels in the baseline and electricity use in the phase II

Table 19 Per capita energy consumptions (MJ/ person/event) and number of people cooked for - single fuels only

	baseline									phase II		
	Electricity			LPG			Charcoal			Electricity		
Household ID	Average consumption	average number of people	Number of meals cooked	Average consumption	average number of people	Number of meals cooked	Average consumption	average number of people	Number of meals cooked	Average consumption	Average number of people	Number of meals cooked
	0.17	5	3		0		5.32	5	49	0.47	4	70
2	0.19	5	7		6	3	9.06	5	47	0.22	5	126
3	0.25	4	11	0.92	4	41	3.59	4	27	0.20	4	73
4	0.09	3	7	4.55	2	27	6.11	5	15	0.72	3	32
5	0.33	1	14	1.84	3	59	3.01	3	4	0.33	4	44
6	0.17	3	0	1.62	7	1	1.26	3	58	0.22	3	55
7	0.55	2	0		0		1.06	3	38	0.79	2	34
8	0.20	5	4	2.43	5	5	1.88	5	3	0.32	6	59
9	0.08	7	1	2.71	5	14	0.00	0	3	0.24	6	99
10	0.30	6	43		0		1.70	6		0.24	4	78
Average	0.23			2.35			3.30			0.38		
Median		4			3			4			4	
Total			90			150			244			670

Figure 9 below shows a comparison of total energy used in MJ in the baseline versus phase II and its noted that charcoal and LPG use high levels of energy during the preparation of different foods.

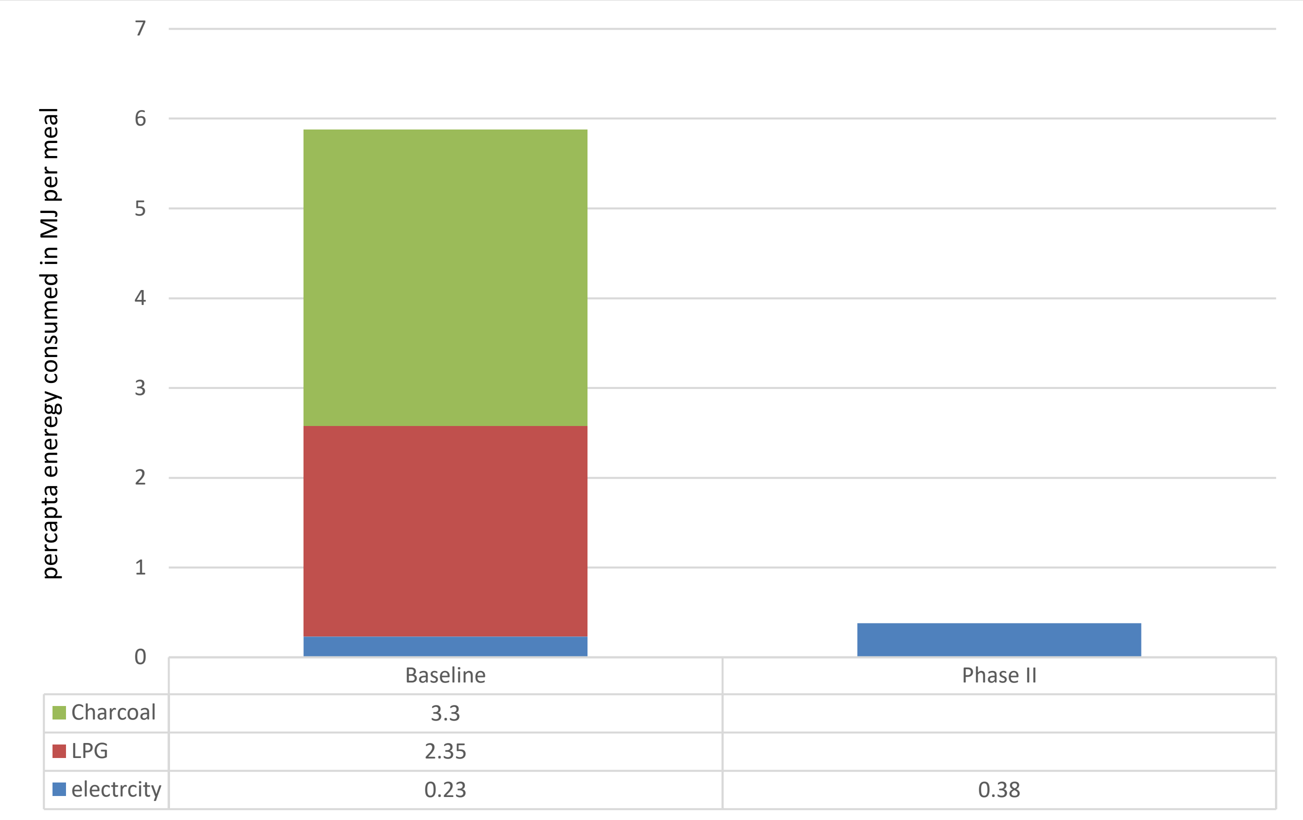

Figure 9 showing the energy per capita burned by different fuels for preparation of meals

3.3.4 Energy consumption by heating event

Table 16 to Table 18 show a breakdown of the energy consumed per heating event for the different fuels in the baseline study and table 19 shows a breakdown of the heating events in phase II.

In table 20, it is noted that for breakfast LPG used the most energy since many of the participants preferred to cook breakfast and other simpler meals using LPG.

Table 20 Per capita energy consumption (MJ/person/event) by LPG in the baseline

	N	Mean	Median	std. Deviation	25th Percentile	75th percentile
Breakfast	31	2.473	2.219	2.378	2.219	2.219
Lunch	19	1.470	1.252	1.274	1.252	1.252
Supper	29	2.770	0.863	5.432	0.863	0.863

Whereas for charcoal in table 21, its highest energy per capita consumed was at Lunch and water heating this is because in the first phase participants cooked longer and energy intensive meals using charcoal, they also preferred to boil water using charcoal

Table 21 Per capita energy consumption *(MJ/person/event) by charcoal in the baseline*

	N	Mean	Median	std. Deviation	25th Percentile	75th percentile
Breakfast	52	4.723	4.366	3.989	1.369	6.494
Lunch	66	5.486	4.674	4.437	1.597	8.943
Supper	47	3.330	2.313	3.594	0.666	4.529
Supper Water heating	1	1.696	1.696		1.696	1.696
Water heating	4	6.762	3.386	7.348	2.932	7.215

In the baseline, participants used electric kettles mostly to boil water for breakfast. This explains why water heating for breakfast has the highest energy consumption for the households that used electricity to cook in the baseline as seen in table 22 8 below.

Table 22 Per capita energy consumption (MJ/person/event) by electricity only in the baseline

	N	Mean	Median	std. Deviation	25th Percentile	75th percentile
Breakfast	47	0.237	0.170	0.332	0.105	0.185
Breakfast Lunch	2	0.390	0.390	0.099	0.355	0.425
Breakfast Lunch Water heating	4	0.498	0.520	0.286	0.318	0.700
Breakfast Water heating	4	0.188	0.185	0.046	0.155	0.218
Lunch	22	0.365	0.235	0.358	0.075	0.593
Lunch Water heating	6	0.217	0.145	0.197	0.078	0.370
Supper	59	0.182	0.160	0.206	0.045	0.225
Supper Water heating	13	0.282	0.240	0.152	0.170	0.410
Water heating	12	0.266	0.160	0.197	0.145	0.327

Table 23 shows heating events in phase II that used only electricity. Breakfast if prepared alone consumes an average of 0.38 MJ/kWh of electricity consumption then lunch alone consumed an average of 0.32 MJ/kWh and supper alone consumed 0.31 MJ/kWh if all meals were cooked in a single day, a total of 1.01 MJ/kWh would be consumed if 100% electricity is used. It is observed that water heating consumes the most energy when electricity is used as the only fuel at hand. However, lunch breakfast and supper have relatively similar energy consumptions

Table 23 showing per capital energy consumption (MJ/person/event) of electricity in phase II

	N	Mean	Median	std. Deviation	25th Percentile	75th percentile
Breakfast	160	0.389	0.229	0.925	0.143	0.324
Breakfast Water heating	36	0.388	0.211	0.725	0.142	0.333
Food for baby	2	0.108	0.108	0.102	0.072	0.144
Lunch	258	0.324	0.225	0.358	0.144	0.377
Lunch Supper Water heating	4	0.108	0.266	0.127	0.194	0.302
Lunch Water heating	7	0.394	0.242	0.418	0.194	0.302
Snack	4	0.260	0.242	0.193	0.145	0.357
Supper	289	0.315	0.189	0.408	0.126	0.312
Supper Water heating	75	0.212	0.158	0.490	0.075	0.193
Water heating	58	0.457	0.222	0.460	0.180	0.587

Table 24 below shows different dishes cooked and the average energy per capita energy consumed in the preparation of the meal at hand. Boiled foods like beans, potatoes had a high energy consumption on average.

Table 24 showing the breakdown of average per capita energy consumed per meal cooked in phase II

Meals	Average (MJ)	Std Deviation (MJ)
Beans/Peas Stew	0.26	0.21
Chicken stew	0.29	0.36
Eggs	0.28	0.81
Fish Stew	0.32	0.25
Goat/Meat Stew	0.24	0.18
Ground nut paste	0.25	0.25
Katogo	0.28	0.24
Leafy Vegetables (cabbage, nakati, dodo, malakwang, gobe etc)	0.15	0.11
Mandazi	0.39	0.11
Matooke (boiled)	0.54	1.39
Matooke (steamed)	0.23	0.18
Millet cassava mix bread (Karo)	0.19	0.03
Other	0.37	0.51
Porridge	0.51	1.26
Rice	0.18	0.12
Roasted Meat (Muchomo)	0.52	0.23
Soup (goat, beef, fish)	0.23	0.33
Spaghetti (pasta)	0.30	0.31

Sweet potatoes/ irish potatoes/ cassava/ yams/ pumpkin (boil and fry)	0.46	0.51
Sweet potatoes/ irish potatoes/ cassava/ yams/ pumpkin (boil or steam)	0.28	0.17
Sweet potatoes/ irish potatoes/ cassava/ yams/ pumpkin (fried or deep fried)	0.37	0.26
Ugali (posho)	0.26	0.22

Table 25 below shows the number of meals cooked fresh, the reheated ones and the partially cooked meals. A low proportion of meals were reheated in the baseline however in phase II an increase in the reheated number of foods increases. This could be explained by appliances like pressure cookers that can contain the food and keep it warm until it can be reheated for consumption.

Table 25 Number of meals fresh or reheated (single heating event records only)

Phases		**Heating event**	**Fresh**	**Reheated**	**Partially cooked**	**Total**
baseline	single heating event	Breakfast	113	21	0	134
		Lunch	149	23	0	172
		Supper	113	45	0	158
Total			375	89	0	464
Phase 2	Single heating event	Breakfast	98	32	0	130
		Lunch	210	43	1	254
		Supper	158	52	0	210
Total			466	127	1	594
Grand Total			**841**	**216**	**1**	**1058**

Energy consumed in computed in table 26 below showing the average energy consumed by each household and the per capita energy consumed. On average 0.37 MJ/kWh are consumed when foods are fresh whereas for reheated foods, consumption was at 0.24 MJ/kWh which implies reheating takes less energy compared to when foods are cooked fresh

Table 26 showing the energy consumed on fresh and reheated foods

	Fresh		**Reheated**	
Household	**mean**	**MJ/kWh**	**mean**	**MJ/kWh**
01	0.44	0.40	0.85	0.77
02	0.31	0.20	0.54	0.35
03	0.23	0.21	0.16	0.14
04	0.61	0.74	0.13	0.15
05	0.38	0.37	0.39	0.38
06	0.22	0.24	0.14	0.16
07	0.35	0.72	0.07	0.15
08	0.43	0.27	0.18	0.12
09	0.59	0.37	0.14	0.08

10	0.31	0.22	0.11	0.08
Total	**0.39**	**0.37**	**0.27**	**0.24**

From table 27, Lunch and supper are more energy intensive meals compared to breakfast for both the fresh and reheated meal. Energy on reheated foods is relatively high for breakfast which suggests that food for the previous day is sometimes warmed for breakfast.

Table 27 showing the energy consumed broken down to meals

	Fresh		**Reheated**	
	mean	**MJ/kWh**	**mean**	**MJ/kWh**
Breakfast	0.27	0.41	0.61	1.22
Lunch	0.39	0.56	0.21	0.42
Supper	0.37	0.50	0.29	0.53

3.4. Cooking Time

3.4.1 Time taken during heating event

Table 28 to table 31 show the mean, median 25th and 75th quartile in terms of time for each food prepared during the baseline study.

Time taken to prepare meals is computed in minutes for different fuels. This gives an overview of time saving when different fuels are used as the main source of fuel. Table 22 to table 24 show the mean, median 25th and 75th quartile in terms of time for each food prepared during the baseline study.

Figure 10 shows the average time to takes to prepare different dishes using different fuels. It is noted that for most of the foods, meals prepared with charcoal took the longest time to prepare followed by LPG.

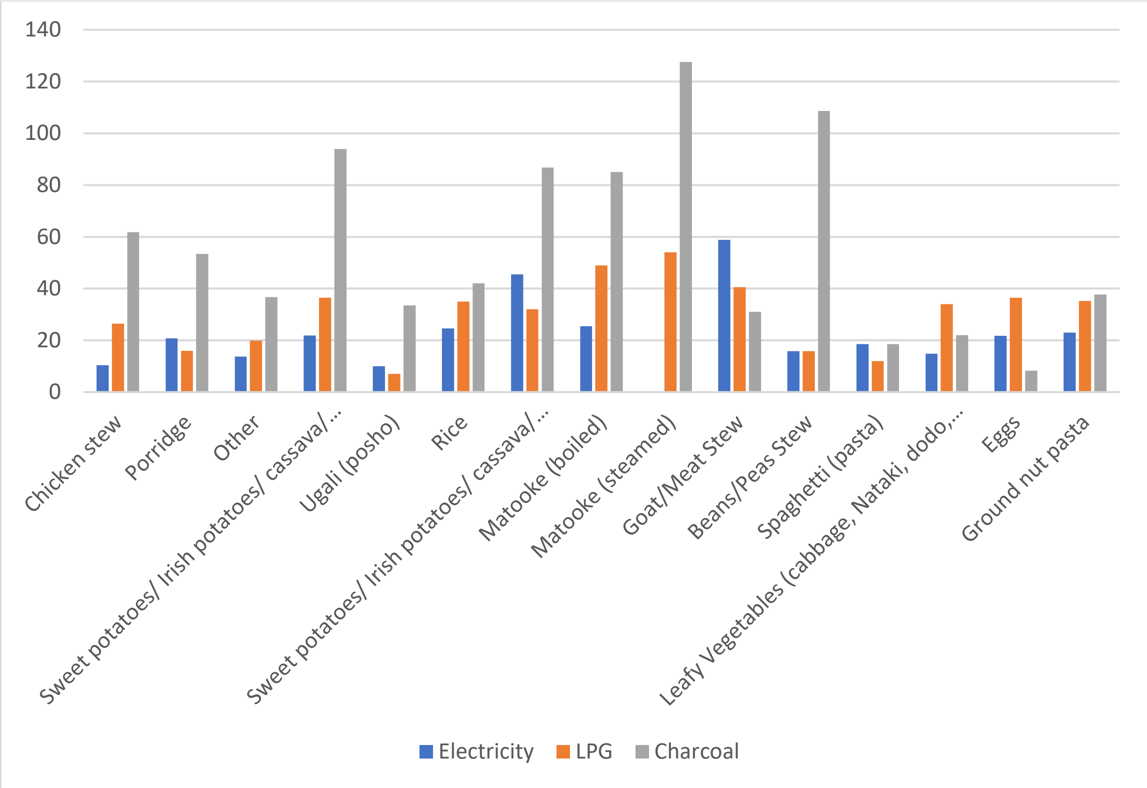

Figure 10 table shows the time variation using different fuels in the baseline

Table 28 shows the time it takes to prepare dishes when only electricity is used as the main source of fuel goat/meat stew took the longest amount of time but this could be as a result of using a combination of different appliances to prepare the same dish for example boiling with the EPC then frying the same meal with an induction cooker.

Table 28 Time taken to cook dishes using Electricity only (minutes) (baseline)

Prepared dish	Mean	Median	25th Quartile	75th Quartile
Chicken stew	10.33	10	7.5	10.17
Porridge	20.71	18	11.25	26.25
Other	13.70	10	6	17.25
Sweet potatoes/ Irish potatoes/ cassava/ yams/ pumpkin (boil or steam)	21.90	20.5	14.25	28
Ugali (posho)	10.00	10	10	10
Rice	24.60	31.5	20	49
Sweet potatoes/ Irish potatoes/ cassava/ yams/ pumpkin (boil and fry)	45.50	45.5	44.25	46.75
Matooke (boiled)	25.50	38	22.5	57.25
Matooke (steamed)				
Goat/Meat Stew	58.80	68	10	92
Beans/Peas Stew	15.86	14	11.5	18.5
Spaghetti (pasta)	18.50	20	14.25	24.25

Leafy Vegetables (cabbage, Nataki, dodo, malakwang, gobe etc.)	14.86	14	11.5	18.5
Eggs	21.71	18	13.5	28
Ground nut paste	23.00	23	12.5	33.5

Table 29 below shows the time taken to cook meals using LPG. Steamed Matooke took the longest average time of 54 minutes and meals like posho and spaghetti took the shortest time to prepare.

Table 29 Time taken to cook dishes using LPG only (minutes) (baseline)

Prepared dish	Mean	Median	25th Quartile	75th Quartile
Chicken stew	26.50	26.50	14.25	38.75
Porridge	16.00	10.00	4.75	22.00
Other	19.90	6.00	5.00	16.00
Sweet potatoes/ Irish potatoes/ cassava/ yams/ pumpkin (boil or steam)	36.50	36.50	19.25	53.75
Ugali (posho)	7.00	7.00	7.00	7.00
Rice	34.95	33.00	23.00	49.00
Sweet potatoes/ Irish potatoes/ cassava/ yams/ pumpkin (boil and fry)	32.00	32.00	32.00	32.00
Matooke (boiled)	49.00	49.00	49.00	49.00
Matooke (steamed)	54.00	54.00	54.00	54.00
Goat/Meat Stew	40.50	40.50	21.25	59.75
Beans/Peas Stew	15.83	7.00	5.00	25.50
Spaghetti (pasta)	12.00	10.00	8.50	14.50
Leafy Vegetables (cabbage, Nataki, dodo, malakwang, gobe etc.)	34.00	27.00	31.75	30.00
Eggs	36.50	36.50	32.25	40.75
Ground nut paste	35.25	38.50	18.50	48.25

In table 30 below, meals prepared with charcoal tool significantly longer periods when compared with other fuels.

Table 30 Time taken to cook food types using charcoal only (minutes) (baseline)

Prepared dish	Mean	Median	25th Quartile	75th Quartile
Chicken stew	61.78	60	47	70
Porridge	53.40	15	32.25	77
Other	36.65	30	20	45

Sweet potatoes/ Irish potatoes/ cassava/ yams/ pumpkin (boil or steam)	93.89	87	60	104
Ugali (posho)	33.48	25	20	38
Rice	42.06	25	13.5	31.5
Sweet potatoes/ Irish potatoes/ cassava/ yams/ pumpkin (boil and fry)	86.75	73.5	41.5	118.75
Matooke (boiled)	85.00	103.5	51.5	123.5
Matooke (steamed)	127.58	81	55	103
Goat/Meat Stew	31.07	31	9	41.5
Beans/Peas Stew	108.58	87	28.5	177
Spaghetti (pasta)	18.50	19.5	13	20.75
Leafy Vegetables (cabbage, Nataki, dodo, malakwang, gobe etc.)	22.00	12	8	15
Eggs	8.22	6	4	9
Ground nut paste	37.75	40.5	29	49.25

Table 31 shows time taken to prepare foods in phase II, foods that require frying like mandazi or deep frying often took the longest to get ready whereas compared to charcoal, there is time saved when electricity is opted for as a cooking fuel compared to charcoal.

Table 31 showing prepared dished in phase II and the time taken for each dish in minutes

Prepared dish	Mean	Median	25th Quartile	75th Quartile
Beans/Peas Stew	41.84	32.00	18.00	51.00
Chicken stew	41.20	29.00	25.00	36.75
Eggs	22.85	16.00	9.00	27.00
Fish Stew	35.26	26.00	17.50	32.50
Goat/Meat Stew	34.26	21.00	16.25	45.00
Ground nut paste	66.20	54.00	47.00	75.00
Katogo	21.43	13.00	10.50	31.50
Leafy Vegetables (cabbage, Nataki, dodo, malakwang, gobe etc.)	34.88	19.50	15.50	28.00
Mandazi	98.00	98.00	98.00	98.00
Matooke (boiled)	46.21	35.00	20.75	54.00
Matooke (steamed)	32.94	27.00	17.00	44.00
Millet cassava mix bread (Karo)	16.00	16.00	15.50	16.50
Other	26.14	18.00	9.00	36.50
Pigeon peas (Lapena)	35.50	35.50	30.75	40.25
Porridge	26.26	20.50	12.25	28.50
Rice	25.94	23.00	15.00	32.00
Roasted Meat (Muchomo)	53.00	41.00	36.00	69.00
Soup (goat, beef, fish)	19.00	22.00	12.00	27.50

Spaghetti (pasta)	22.57	25.00	13.00	30.00
Sweet potatoes/ Irish potatoes/ cassava/ yams/ pumpkin (boil and fry)	49.71	54.00	27.00	75.00
Sweet potatoes/ Irish potatoes/ cassava/ yams/ pumpkin (boil or steam)	25.33	26.00	14.00	35.00
Sweet potatoes/ Irish potatoes/ cassava/ yams/ pumpkin (fried or deep fried)	95.55	20.00	16.50	37.50
Ugali (posho)	22.67	18.00	9.00	39.00

Figure 11 below shows a comparison of time versus the fuel used in both the baseline and phase II. The time it took to prepare foods using electricity is significantly low in both the phases; although there was no fuel stacking in phase II, all foods took averagely 30 minutes to prepare.

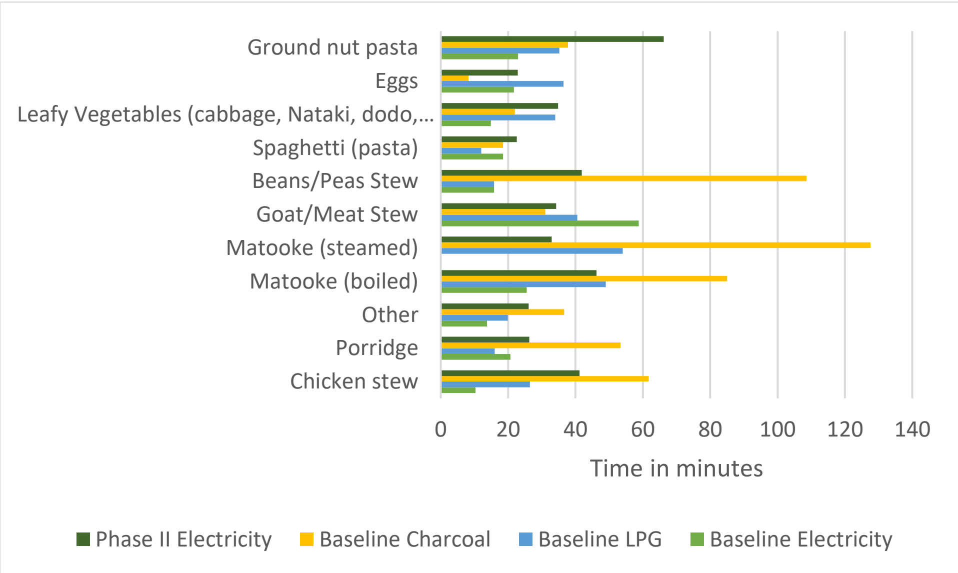

Figure 11 Showing a comparison of times spent in the baseline and phase II of the study

Foods prepared by LPG often took a short time however a unit cost of LPG is approximately UGX 10,000 per kg which makes using LPG to cook long dishes more costly.

4. CONCLUSION

From the study findings, it was evident that participant cooking habits do not significantly change when they move from cooking with traditional method to cooking electricity. In the first stages when electric appliances are introduced, participant are more willing to experiment it the cooking appliances are able to handle all their cooking needs.

4.1 Findings from exit survey

Participants recorded that some of the foods they cook regularly with electric cooking appliances is rice, beans, posho and this was mostly attributed to time saving.

The electric appliances were time saving especially the electric pressure cooker mainly because it can cook as the participants did other work without supervising the whole cooking process.

> *"A participant reported that they would skip some meals due to time constraints but after appliances were introduced, it was possible to concurrently prepare meals while doing other activities."*

Participants liked the fact the cooking with electric appliances saves time and saves energy.

Participants stopped purchasing charcoal and switched to electric cooking and stopped using traditional fuels.

Electric devices are clean compared to charcoal that has dust. The electric devices like induction cookers and infrared cookers do not stain saucepan.

For food, the electric pressure cookers saucepan is easy to clean since food does not stick on it.

Participants reported that although they cooked all meals on the electric appliances, the power consumption was low hence efficiency in power consumption.

For foods like sweet potatoes, when steamed with the EPC, the water does not mix with the food and the meals are cooked faster.

It was noted that most participants used the EPC regularly for cooking hard dishes like beans because of its ability to boil the food in the shortest time with its added advantage of cooking under pressure.

Time poverty has been improved in that with the e- appliances, a lot of time was saved as the participants used it for constructive activities in addition those who used to prepare separate dishes for lunch and supper, it was realized that they would prepare at once and later in the day just warm.

Participants preferred to cook different dishes within the same time frame but there was a limitation of one pan provided for the EPC saucepan and as such the need to empty and clean the pan for the next dish.

Participants loved the e-appliances for their cleanliness, convenience, time savings and low energy consumption; however in cases of power blackout this delayed the cooking process and would have to opt for other cooking means and account for the missed day on another day with reliable power.

The size of appliances especially the EPC limited the number of people cooked for which was a challenge for large families.

With e-appliances, cooking was possible during night hours since it did not require a lot of preparations to start in terms of lighting and it was fast.

Since there was a variety of appliances supplied to the participants, foods that could not be handled by one of the appliances could easily be cooked by the alternative appliance; for example participants reported that frying was slow with the EPC but fast with infrared or induction cooker.

In terms of cost benefit, besides the initial cost of the appliances, it was noted that their usage was cost effective compared to the other cooking fuels and the money saved was used for other activities like laundry and other household expenses.

Cost of Cooking Analysis for different fuels

From the baseline phase, majority of the participants reported they bought charcoal on a monthly basis at a cost ranging from range of UGX 60,000 to UGX 130,000 depending on size of sack purchased. Some of these participants also used an alternate fuel say LPG or electricity. Households that used LPG reported paying an average of approximately 10,000 UGX/kg for LPG and tended to purchase 12kg and refilled every (1 to 5 months). Households cooking with electricity reported an overall monthly electricity budget ranging from UGX 30,000 to 100,000 UGX.

As seen in table 18, majority of the dishes were cooked using charcoal stoves in the baseline phase while all dishes were cooked with electricity in phase II.

To determine the average cost of energy used in phase II, we take the average energy consumption of 0.38 MJ/person/event as seen in table 19, this translates into 0.42 kWh/person/event. Assuming an average of 3 meals a day, this would translate into 1.26 kWh per day. Considering unit cost of electricity at UGX 808.9[1] and including a fixed monthly charge of UGX 3,360, the total monthly cost of electricity used for cooking would be approximately UGX 33,936.

This is much lower than the monthly cost of charcoal ranging between UGX 60,000 to UGX 130,000, and LPG refilling cost of about UGX 60,000 hence making cooking with electricity the cheapest option.

[1] UMEME electricity retail tariffs for Quarter 1 2023 – Domestic Consumers

5. Appendix: An analysis on voltage behaviour during the phase II of the study

In the appendix, hypothesis tests are conducted to test the effect of the electric cooking appliance to the general voltage.

The hypothesis tested were

- Is there as significant difference in voltage when the appliance is off n and when it's on
- Is there a difference in voltage through the day (7AM to 7PM)
- Do households experience undervoltage when they cook?

These were aimed to inform the effect of the electric appliances to the voltage and if the voltage fluctuations eventually affect cooking with electricity.

Energy consumption per day

In phase II where 100% electricity was adopted;

Average voltage per hour with appliance on/off for each day was computed using the smart meter data.

Averaged voltage per hour with appliance on/off for each day. Then, put this into a pivot table. Then, filtered out hours where we had few numbers of days (0,1,2,4,5,6,23). Also filtered out 3 in order to make this easier to read - this is showing daytime 7AM-10PM.

Pivot table average is the average for all days for unfiltered hours. This controls for fluctuations throughout the day and for bias resulting from disproportionate measurements made during certain hours. Use two-tailed two-sample z-test. For this, we use n = the number of hour-samples used.

Assumptions made during the energy analysis;

i. *Should n be the number of measurements? NO - we consider multiple measurements in the same hour on the same day to be the same measurement.*
ii. *Should n be the number of days? NO - we are using multiple samples each day to calculate the average.*
iii. *Should n be the number of hours? NO - we picked 17 out of 24 hours, this is representative of the full day.*
iv. *Should n be the total number of hour-days (sum all hours and days)? YES.*

Table 32 showing the averaged meter readings for different hours during the day

	Hours of the day																	
Appliance state		**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Grand Total**
Average of Average of metered Voltage																		
Appliance Off		235	230	227	225	224	226	225	227	229	229	226	226	221	216	215	220	225
Appliance On		209	215	213	211	211	209	212	210	210	217	212	209	191	190	195	209	207.5
Grand Total	219																	219
StdDev of Average of metered Voltage																		
Appliance Off		13.6	14.1	12.7	14.4	13.8	13.7	16.1	13.5	11.8	13	14.9	11.7	12.1	15.9	20.1	13.6	14.901
Appliance On		14.9	14.5	22.5	19.9	16	17.2	19.5	18.9	22.4	15.7	17.6	16.4	21.6	22.4	20.3	29.3	20.927
Grand Total																		
Distinct Count of Average of metered Voltage																		
Appliance Off		33	32	31	33	33	35	36	32	31	34	35	35	36	36	34	30	536
Appliance On		33	32	33	30	30	29	35	29	30	30	35	36	34	36	31	28	511
Grand Total	1																	1
Total Average of Average of metered Voltage	**219**	**222**	**223**	**220**	**218**	**218**	**218**	**219**	**219**	**220**	**223**	**219**	**217**	**206**	**203**	**206**	**215**	**216.4**
Total StdDev of Average of metered Voltage		**19.3**	**16.1**	**19.6**	**18.4**	**16.1**	**17.5**	**19**	**18.1**	**20**	**15.5**	**17.7**	**16.8**	**22.7**	**23.2**	**22.4**	**23.1**	**20.077**

Figure 12 below shows the voltage and utilization at different times of the day

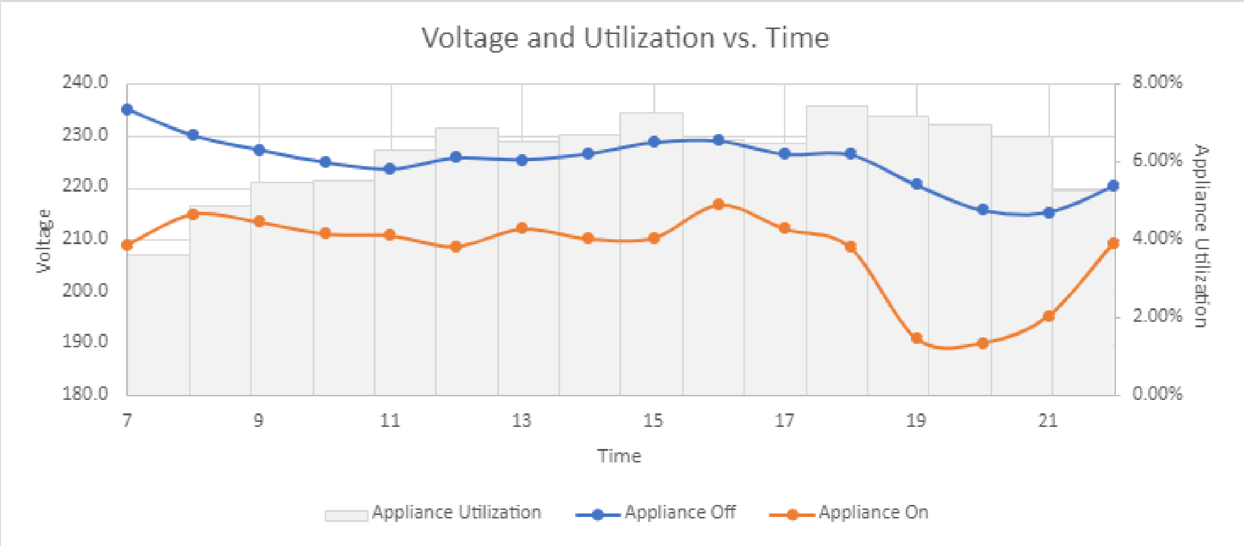

Figure 12 shows the voltage and utilization at different times of the day

Hypothesis: Is there as significant difference in voltage when the appliance is off n and when it's on

In table below, the voltage is significantly different when the appliance is on. The most obvious explanation is that this is caused by the appliance, but there is a chance that it could be caused by something else. For example, households may be more likely to be using other appliances (such as watching television) while using their electric cooking appliances. The probability of this could be reduced if we can relate the dip in voltage to the appliance used (show that higher power appliances result in higher voltage drops) and to show that most households do not have many other high-power appliances that could contribute to the effect. Most other variables are controlled as the households and appliances remain constant.

Table 33 testing if there is a difference in voltage when the appliance is off or on

Appliance state	**hours**	**Remark**
Voff	225	
Von	207.5	
n-off	536	
n-on	511	
s-off	14.901	
s-on	20.927	

Null Hypothesis:	Voff - Von = 0	
Expected Value	0	
Observed Value	17.5	
Standard Error Voff-Von	1.127509418	
z	15.52093466	
Confidence	99.99%	*High confidence*
95% Confidence Interval Lower Bound	15.29008154	
95% Confidence Interval Upper Bound	19.70991846	
Pooled standard deviation	18.09439236	
Effect Size: Cohen's d	0.97	*d > 0.8: large effect size*

Conclusion: significant difference in voltage when the appliance is off and when it is on

Hypothesis: is there a difference in voltage through the day (7AM to 7PM)

in table below its observed that *We have high confidence that there is a significant difference between the voltage in the morning (7AM) and evening (7PM). We conclude that this variation does not result from the use of electric cooking appliances (at least, not from those monitored in this pilot). The effect size is large. This could be a result of external (i.e., not in the household) demands on power, but could also be explained by the usage of other appliances inside the household that draw power in the evening hours.*

Table 34 showing the difference in voltage between 7AM and &PM

Appliance state	**hours**	**Remark**
V7	235.1	
V19	215.2	
hoax	7	
hmin	19	
n-7	33	
n-19	36	
s-7	13.579	
s-19	14.92	
Null Hypothesis:	Voff - Von = 0	
Expected Value	0	
Observed Value	19.9	
Standard Error Voff-Von	3.430898405	
z	5.808380894	
Confidence	99.99%	*high confidence*
95% Confidence Interval Lower Bound	13.20340387	
95% Confidence Interval Upper Bound	26.65252562	
Pooled standard deviation	14.29522398	
Effect Size: Cohen's d	1.394029557	*large effect size*

Conclusion: significant difference in voltage between 7AM and 7PM

Hypothesis: Do households experience undervoltage when they cook?

Utilization undervoltage is defined as 90% of rated voltage (240V) = 216V. Follow same steps as prior analyses: average voltage per hour on each day to remove sampling bias from over or under-sampling a certain hour. N = number of hour-samples used. Use lower-tailed z-test because we care if it is under, not over.

From table below we have high confidence that appliances are regularly operating at a utilization undervoltage (less than 90% of rated voltage) while cooking, although it is a small effect: the undervoltage limit is less than half the standard deviation of the voltage when the appliance is on.

Table 35 showing households experience during under voltage when they cook

Appliance state	hours	Remark
Vlimit	216	
Von	207.5	
hmax		
hmin		
n-limit		
n-on	511	
s-limit		
s-on	20.927	
Null Hypothesis:	Vlimit - Von = 0	
Expected Value	0	
Observed Value	8.5	
Standard Error Von	0.857024127	
z	9.918040496	
Confidence	99.99%	
95% Confidence Interval Lower Bound	6.820232711	
95% Confidence Interval Upper Bound	10.17976729	
Pooled standard deviation	20.94754689	
Effect Size: Cohen's d	0.405775437	*weak effect*

Conclusion: *high confidence it is an undervoltage event, but it is a small effect*