Findings from a Study on the Adoption of Electric Pressure Cookers in Uganda

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DRAFT PAPER FOR COMMENT

Please send questions and comments to:

Elliot Avila
Elliot.Avila@A2EI.org

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1. Background

Over 98% of households in Uganda rely on biomass and charcoal fuels for cooking and less than 1% use electricity as a primary cooking fuel (WHO 2020). The government of Uganda has made electric cooking adoption a national priority and has set ambitious targets for electric cooking adoption (Republic of Uganda Ministry of Water and Environment, 2022). The importance of electric cooking has been similarly recognized by Uganda's energy sector: the Electricity Regulatory Authority (ERA) implemented new electricity subsidies under the e-cooking tariff implemented in December 2021, and Uganda's main customer-facing electricity distribution company Umeme distributed 1,500 electric pressure cookers (EPCs) to its staff and customers in 2024 (ERA 2021, Umeme). A national electric cooking strategy has also been drafted.

This research focuses on understanding the effects of the adoption of electric pressure cookers on biomass fuel consumption, cooking time and labor, household electricity demand. This research also investigates the relationship between appliance usage and electricity pricing.

2. Methods

2.1 Overview of Methods

This study involved gathering data from 500 households in the greater Kampala metropolitan area, comprising Kampala, Wakiso, Mukono, and Luweero districts. Participants were all customers who purchased an electric pressure cooker from Umeme, the largest customer-facing electrical utility company in Uganda. Roughly half of participants were staff members at Umeme and the other half were from the general public. The study was conducted over a period of 12 months, with participant enrollment beginning in February 2024 and the study close-out ending in January 2025.

Participant data was gathered from three main sources: surveys, smart meters, and household electricity billing data.

Data Source	Description	Data points, topics
Survey Data	A baseline, midline, and endline survey was conducted with each participant	Household members involved in cooking, fuel purchase behavior, stove usage behavior
Smart Meter Data	A GSM-enabled electricity meter was connected to each participant's appliance to monitor its usage	Voltage, energy, current, phase, timestamps
Electricity Billing Data	The records of pre-paid electricity purchases by participant households were used to track overall consumption of electricity	Payment amount, pre-paid electricity received (kWh units), tariff applicability, timestamp

Table 1: Data sources

2.2 Sources of Error and Filtering of Data

Several potential sources of error were identified during the study period:

1. Data recall during surveys: participants were asked questions about their household behaviors around cooking. Participants may not clearly or correctly recall their experiences and so may report behaviors that differ from their actual behaviors. Additionally, participants that responded to the surveys may or may not be the primary person in the household responsible for cooking or other cooking-related tasks and so may not have complete information about their household behavior. This is mitigated by the use of digital monitoring, reporting, and verification (DMRV) methodologies that estimate the displacement of other cooking fuels based on smart meter data.
2. Smart meter connectivity: EPCs were plugged into external smart meters used for data collection, which creates a risk that the appliances may be unplugged. This was mitigated by using zip ties to fasten the EPC cable to the smart meter but could still be bypassed. Households that were known to have bypassed the smart meters were flagged by the enumerators. This is a potential source of underreporting of EPC usage.
3. Multiple e-cooking appliance ownership: a significant number of households reported owning an EPC other than the one that they purchased and was monitored in this study. As these other device usage was not directly measured, the usage is only estimated through the surveys. This is a potential source of underreporting of overall e-cooking usage.

Participant data was filtered in order to remove potential outliers.

- All households flagged by enumerators as having data quality issues were excluded from the analysis
- For all metrics analyzed, outliers for the specific metric have been removed
- For all metrics involving smart meter data, households were excluded from the analysis if they had a span of data covering less than 4 months during the period of June 1, 2024 to December 1, 2024

Data collected in the study was aggregated and analyzed on the *Appliance Demand Platform (ADP)*, an open-source online platform developed to automate the monitoring and evaluation of studies focused on appliance adoption and usage. All analysis on ADP was done using PostgreSQL and Grafana.

Two-tailed z-tests were used to test for significance differences between groups with a 95% confidence level. Cohen’s d was used as a measurement of effect size.

3. Results

3.1 Usage of EPCs

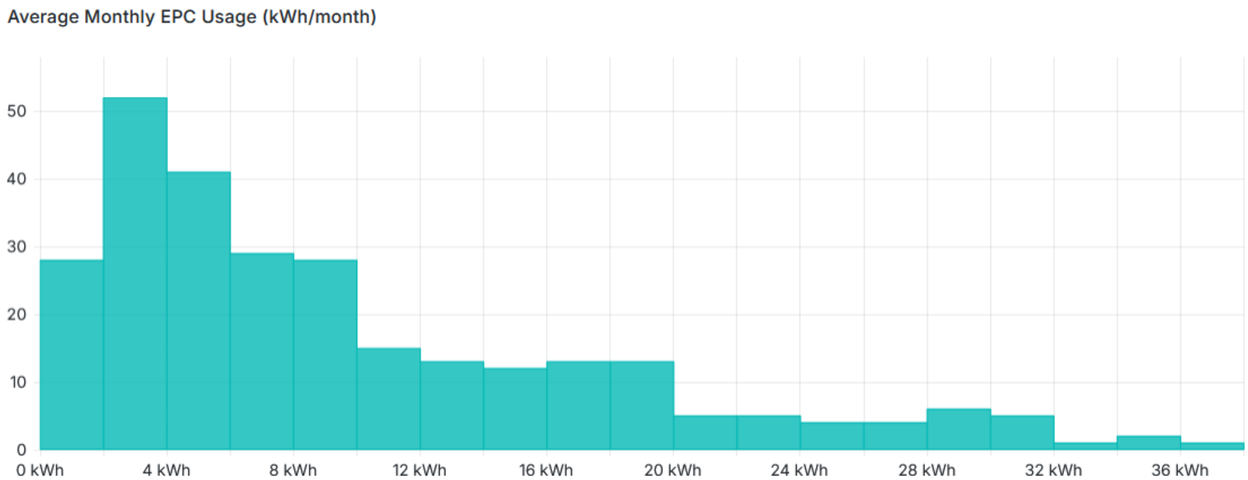

Figure 1: Histogram of average monthly EPC usage.

Participants were found to use an average of 9.84kWh of electricity each month for cooking with their EPCs. This corresponded to using their EPCs an average of 28 times per month. During use, the average cooking event lasted 38 minutes and consumed 312 Wh of energy[1]. Load profiles from the devices show that cooking occurred most often at midday followed by the evening hours.

	Mean	Median	SD	n
EPC Energy Consumption per Month (kWh)	9.84	7.43	8.16	277
EPC Cooking Costs per Month on Cooking Tariff (UGX)	4100 UGX (1.08 USD)	3100 UGX (0.82 USD)	3400 UGX (0.9 USD)	277
EPC Cooking Costs per Month on Domestic Tariff (UGX)	7900 UGX (2.11 USD)	6000 UGX (1.59 USD)	6600 UGX (1.75 USD)	277
EPC Cooking Events per Month	28.1	22.0	22.8	277
EPC Cooking Event Energy (Wh)	312	265	251	43590
EPC Cooking Event Time (min.)	38.1	30	31.2	43590

Table 2: Statistics on EPC usage per month

[1] Cooking events were processed using an algorithm that groups together periods of energy consumption. Due to nuances in the way the algorithm is set up as well as the power cycling of the EPC's power cycling, the resulting event energy and event times are underestimations.

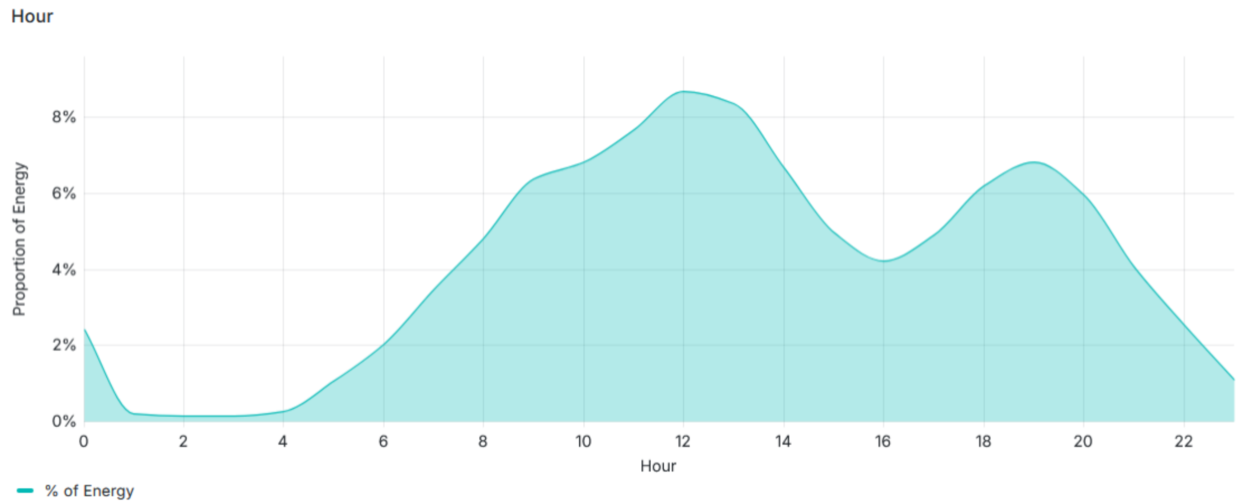

Figure 2: Load profile of EPC usage

3.2 Electricity Purchasing Behaviors

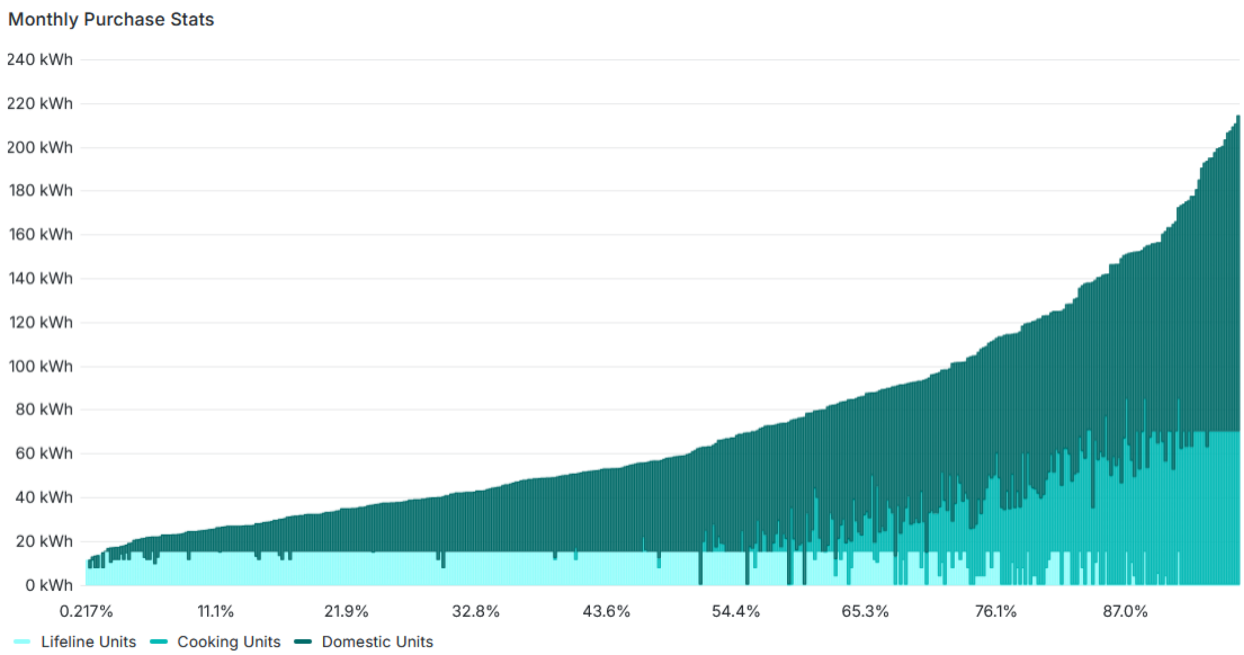

Figure 3: Distribution of electricity purchases per household by tariff band. Each bar represents one household's purchase behavior.

Households in the study were found to use approximately 73 kWh of electricity each month after the adoption of the EPC. Despite this being below the threshold for receiving discounted electricity under the Cooking Tariff, households consumed an average 15.6 units under the Cooking Tariff each month. This effect results from the purchase behaviors of households under the pre-paid electricity billing system: although a household's mean consumption could be 73 kWh, in an individual month they may purchase above 80 units and consequently benefit from the reduced pricing of the Cooking Tariff. As a result of the different block tariffs, the average cost of electricity for participant households was approximately 630 per unit.

When looking at the tariff distribution across all households, we found that approximately 50% of the households received no discounted units under the Cooking Tariff.

	Mean	Median	SD	n
Electricity Unit Purchases (kWh/month)	73.7	56.9	47.7	444
Lifeline Unit Purchases (kWh/month)	11.6	15	5.76	444
Cooking Unit Purchases (kWh/month)	15.6	0	23.2	444
Domestic Unit Purchases (kWh/month)	46.5	40.8	30.9	444

Table 3: Statistics on electricity purchasing

3.3 Awareness of the Cooking Tariff and Perceptions of Affordability

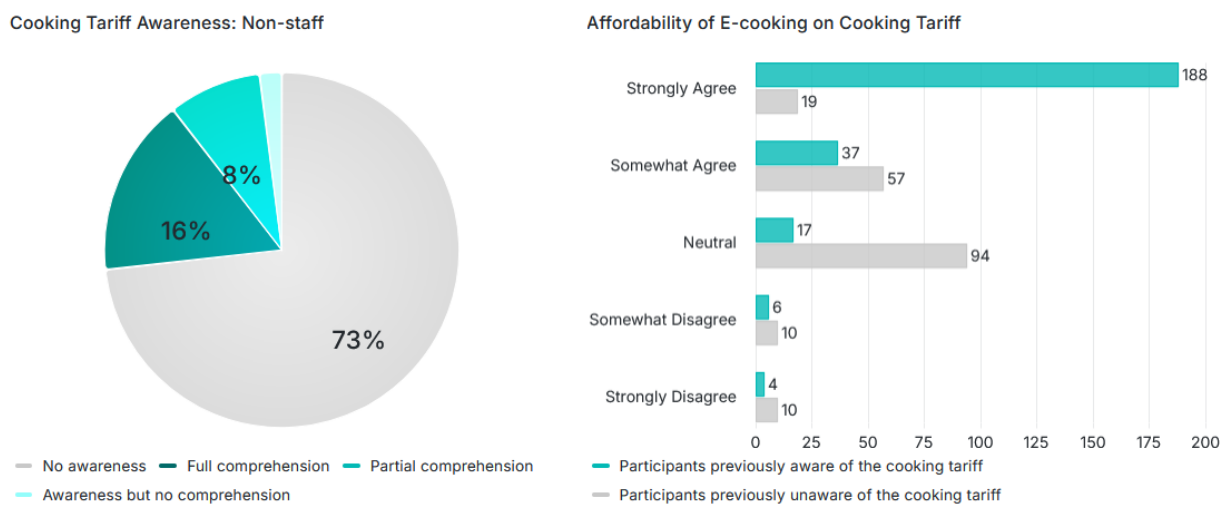

Figure 4: Baseline awareness and comprehension of the Cooking Tariff (left), and perceptions of affordability of electric cooking on the Cooking Tariff disaggregated by awareness (right)

During the baseline survey, participants were asked whether they were aware of the cooking tariff. Participants who responded positively were asked to report the cooking tariff band parameters (start, end, and cost). 73% of EPC customers from the general public (non-Umeme staff) reported no awareness of the cooking tariff.

Participants were also asked whether they believe electric cooking to be affordable compared to charcoal. The majority of participants who reported prior awareness of the cooking tariff responded that they either agreed or strongly agreed that cooking with electricity is affordable. In contrast, participants who reported no awareness of the cooking tariff responded that they were unsure if electric cooking is affordable.

3.4 Correlation of Household Electricity Consumption and EPC Usage

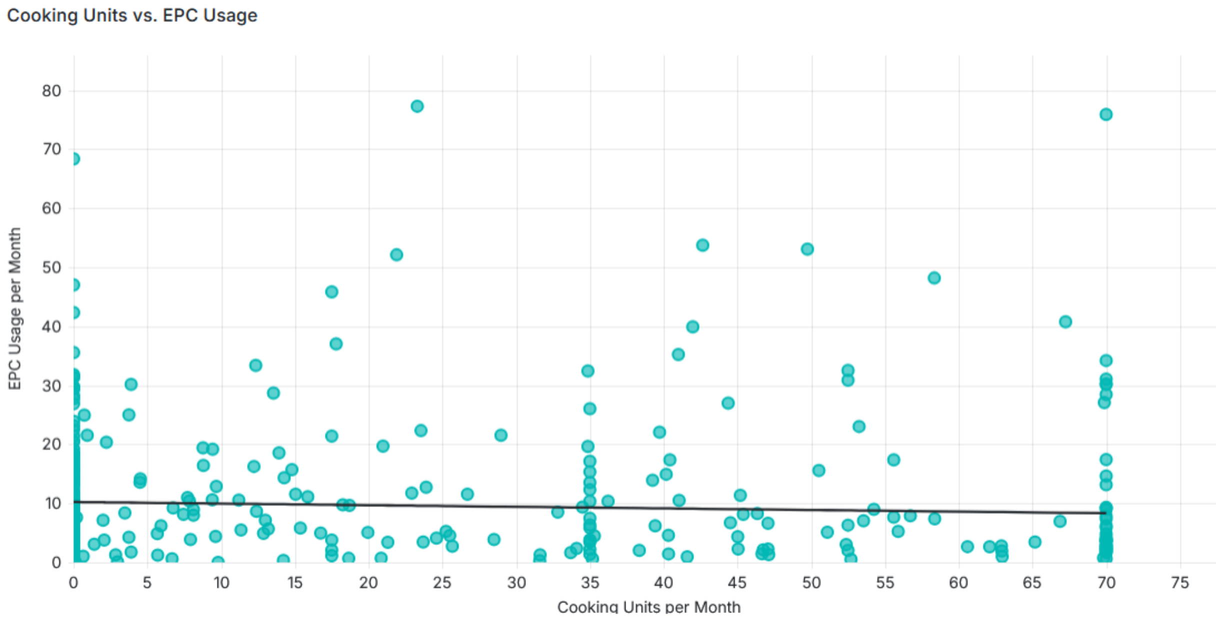

Figure 5: Correlation of EPC Usage to cooking Units per month

Monthly household electricity consumption was plotted against monthly EPC usage and a linear regression was used to find any correlation. The linear regression returned a R-squared value of 0.006, indicating the two variables are unrelated. To put it simply, the amount of electricity that a household uses has no effect on how much the household uses their EPC and vice versa.

Another linear regression analysis was done to compare the EPC usage against the number of cooking tariff units that a household receives and no significant relationship was found.

3.4 Effects of EPC Adoption on Cooking Time

Figure 6: Reported cooking hours at baseline and endline per household

Households were asked to estimate their overall household cooking time, including time spent preparing meals and time spent collecting fuels. The mean reported household cooking time decreased by 13.3 hours from 120.1 hours per month at baseline to 106.8 hours per month at endline, a statistically significant reduction of a small effect size.

The reduction in cooking hours can be attributed to reduced cooking time for women. There was no significant change in cooking time for men, which was reported to be just 8 hours per month in both the endline and baseline surveys.

	Baseline			Endline			Comparison			
Metric	mean	SD	n	mean	SD	n	Diff. of Means	CI	Z-score	Effect size
Total Hours Spent Cooking	120.1	57.2	432	106.8	42.2	432	-13.3	(-20.0, -6.6)	-3.7	-0.3
Total Hours Spent Cooking by Women	112.1	58.8	432	98.9	44.2	432	-13.2	(-20.1, -6.3)	-3.7	-0.3
Total Hours Spent Cooking by Men	8.1	17	432	7.9	14.7	432	-0.2	(-2.2, -2.0)	-0.1	0.0

Table 4: Statistics on reported cooking time

The total cooking time reduction can also be assessed using a DMRV approach that back-calculates the displaced energy from the smart meter data and literature values, which can then be converted into time. Using equation 3 in Annex 1, the time savings are estimated at 16 hours per month.

3.5 Effects of EPC Adoption on Fuel Usage

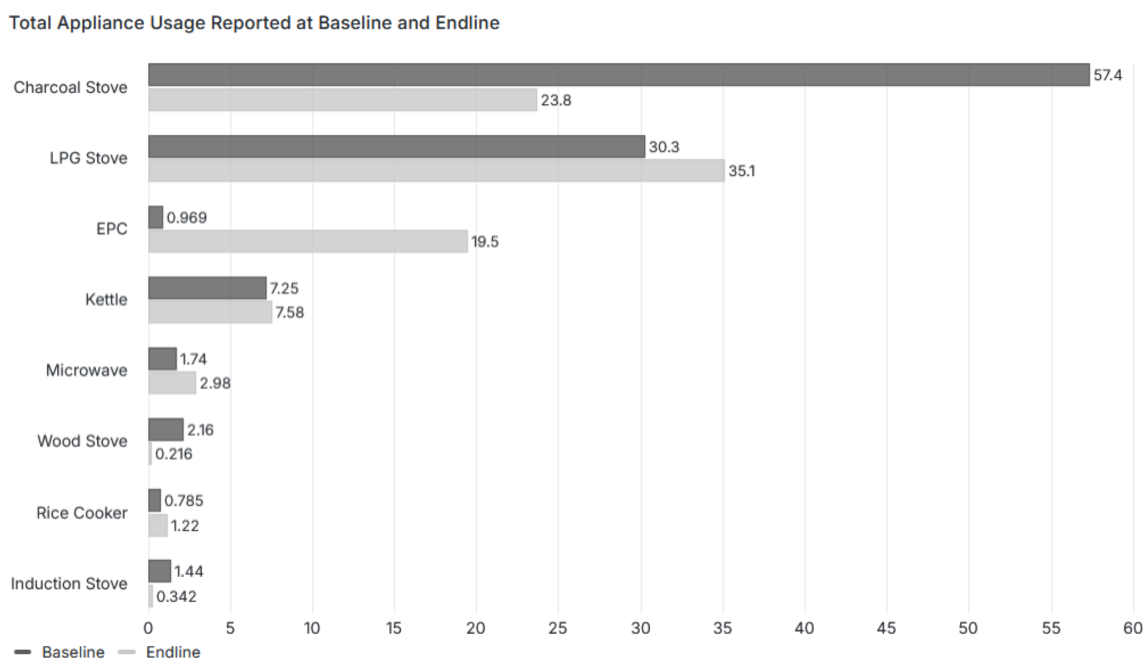

Figure 7: Reported cooking device usage hours

Participants were asked to report the five most-used cooking devices in their household and to estimate the amount of time that each device is used. At the baseline, charcoal stoves were the most used cooking device with an average usage of 57 hours per month which later declined to 24 hours per month at the endline, a large and significant reduction. The decline in charcoal correlated with an increase in the usage of the EPC, which increased by 18 hours per month from the baseline to endline, and a small but significant increase in the usage of LPG cookstoves from 30 to 35 hours per month.

Metric	Baseline mean	SD	n	Endline mean	SD	n	Comparison Diff. of Means	CI	Z-score	Effect size
LPG Stove	30.3	32.1	323	35.1	23.7	391	4.81	(0.587, 9.02)	2.23	0.173
Charcoal Stove	57.4	38.9	364	23.8	23.1	237	-33.6	(-38.6, -28.7)	-13.3	-1
EPC	0.97	26.2	19	19.5	10.7	420	18.5	(6.67, 30.3)	3.06	1.57
Kettle	7.25	3.34	363	7.58	1.71	421	0.33	(-0.051, 0.71)	1.7	0.127
Microwave	1.74	3.12	98	2.98	2.41	174	1.24	(0.521, 1.95)	3.39	0.46
Rice Cooker	0.785	6.05	46	1.22	3.7	69	0.432	(-1.52, 2.39)	0.433	0.0905
Electric Oven	0.87	9.31	32	0.254	6.01	15	-0.616	(-5.05, 3.82)	-0.272	-0.0731
Wood Stove	2.16	24.7	21	0.216	14.5	3	-1.94	(-21.5, 17.6)	-0.195	-0.0809

Table 5: Statistics on device usage hours

We can also estimate the time that the EPC was used and that charcoal cookstoves were reduced using the same DMRV approach as in the prior section. Using the metered energy consumption value and assuming that only charcoal cookstoves were displaced, equations 2.1 and 2.2 in Annex 1 give us a result that the EPC was used for 18.1 hours per month and reduced charcoal cookstove consumption by 34.2 hours per month. These values are closely aligned with our survey results.

3.6 Effects of EPC Adoption on Fuel Spending

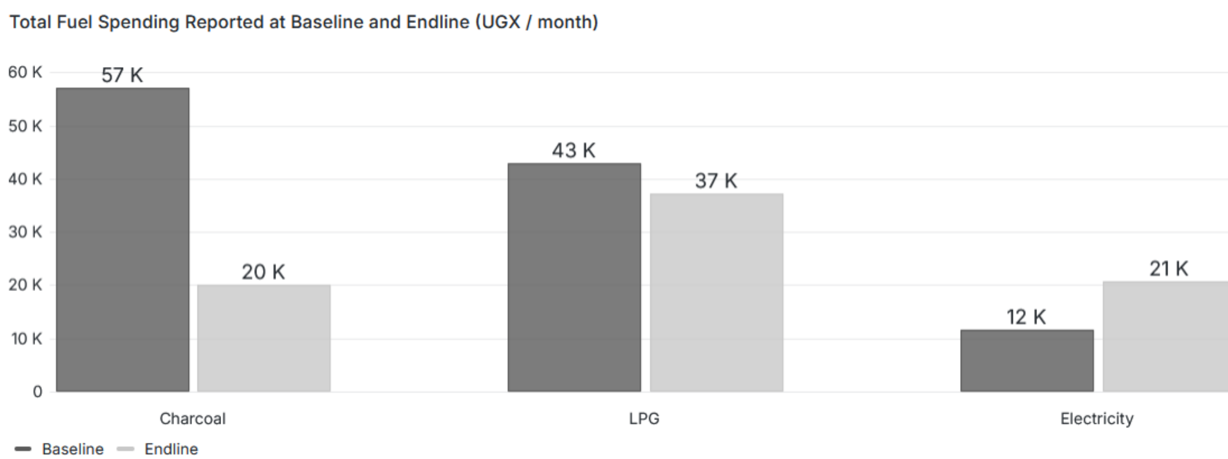

Figure 8: Reported spending on cooking fuels at baseline and endline. Estimations on cost reductions using DMRV methods suggest that participants overestimate their fuel spending.

Participants were asked to report how much they spent on cooking fuels and their frequency of purchase. For electricity, the costs of cooking were estimated based on the reported electric cooking appliance usage, an assumption that most electric cooking appliances use 1kW of power, and the domestic price of electricity.

Households reported a reduction in spending from 112,000 UGX ($30.20 USD) to 84,000 UGX ($21.00 USD), which was found to be a statistically significant reduction of moderate effect size. Spending on charcoal and LPG was found to decrease, while spending on electricity increased.

However, when applying the DMRV approach used in previous sections and Annex 1, we estimated a reduction in spending that is significantly lower than what was reported in the surveys: charcoal spending is estimated to be reduced by only 9500 UGX ($2.56 USD) per month against an increase in electricity spending of 6200 UGX ($1.67 USD) per month.

In contrast with the previous results where participants reported a 16% increase in LPG usage when estimating by appliance usage time, participants reported a decrease in LPG cooking costs of 14% when estimating by fuel purchase behavior. These apparent contradictions suggest a possible weakness in the survey methodology for this particular question.

3.7 Perceptions of the EPC Features

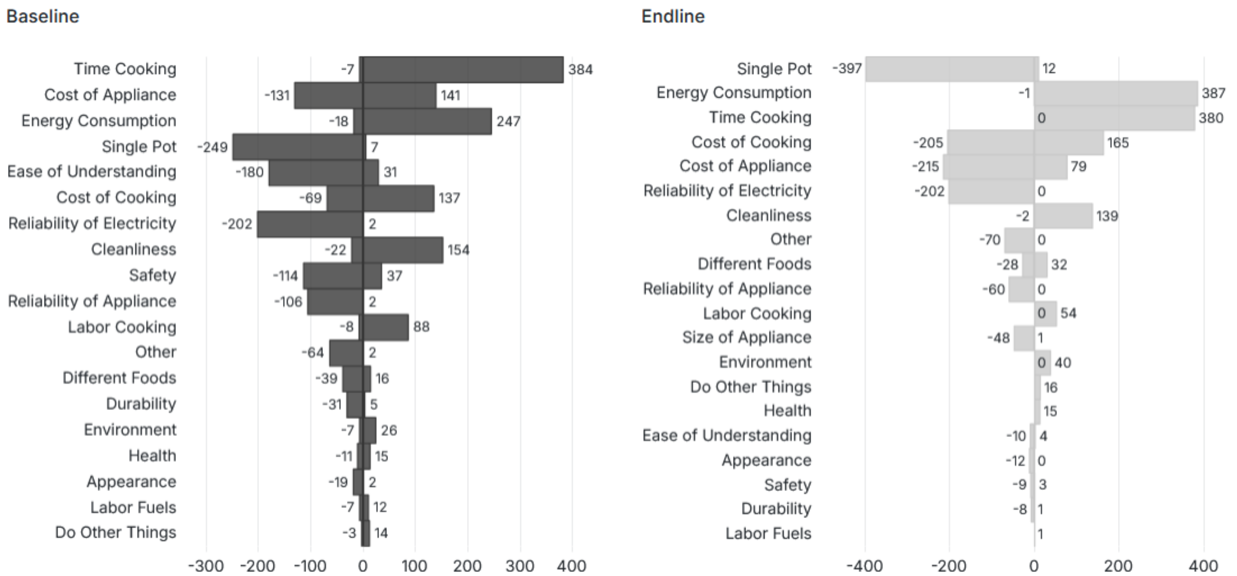

Figure 9: Ranking of EPC features at baseline and endline. Features could be ranked both positively and negatively by respondents.

Participants were asked to rank the features of the EPC at the baseline and endline survey. At baseline, the users had little experience with the EPC and so their responses were based on their perception, whereas users' opinions were based on their experience at the endline.

Time savings, energy efficiency, and cleanliness were consistently rated positively by participants at both baseline and endline. The availability of only one single cooking pot of the EPC was rated negatively on both surveys but more so at the endline, suggesting this was an emerging pain point for users. Reliability of electricity was rated consistently negatively at both baseline and endline.

Perceptions of the cost of the appliance and the cost of cooking both shifted from net positive to net negative from baseline to endline, although both were still divisive. The safety of the EPC and the ease of understanding were negatively viewed at baseline but barely remarked upon at endline, suggesting these concerns are alleviated by first-hand experience.

4. Discussion of Results

On average, participants in the study used their EPC nearly every day. This finding suggests that many households realized benefits from the use of the EPC. The most notable benefits reported by participants are time savings: participants reduced the use of charcoal stoves by 33 hours, resulting in a net time savings of 13 hours per month for women in the household. The EPC's capacity to cook meals quickly was the highest ranked feature for participants at baseline and the second highest at the endline survey. This benefit should be clearly emphasized when promoting the appliance.

However, the continued use of other cooking devices alongside the EPC suggests that there are limitations to the EPC and situations where other appliances are required. One such limitation is that the EPC only has a single pot, which restricts how much food can be cooked in it: cooking multiple dishes in parallel is not feasible with only a single EPC. To increase the percentage of cooking done with electricity, multiple e-cooking appliances are needed and so there is a need for policies that support market development and make appliances more affordable. However, unreliable electricity also creates situations where cooking with electricity is not possible and back-up fuels are needed. Our data shows that the introduction of the EPC leads to a cleaner fuel stack as it displaces charcoal, not LPG.

The analysis on the cost of cooking found that using the EPC resulted in cost savings, however the DMRV methodologies suggest that there are less savings than what was reported by participants. This may point to an issue with the DMRV methodology, which is fairly novel in its application. However, the DMRV estimations are closely aligned with the survey results in other areas, pointing to a possible weakness in these particular survey questions and suggesting that participants generally over-estimate their costs of cooking. Similarly, participants may have been disappointed after over-estimating how much they would save by using the EPC, evidenced by the change in perception of the cost of cooking with the EPC from net-positive at baseline to net-negative at endline. Messaging around costs needs to be precise in order to avoid creating unrealistic expectations; the affordability of the EPC can be emphasized and celebrated without overstating the cost-savings.

Our study found that half of EPC customers do not benefit from the cooking tariff due to the high 80 kWh monthly purchase threshold. Perhaps as a result of this, many households do not actually know about the Cooking Tariff. Regardless of which tariffs were applicable to households, cost-savings from use of the EPC were present, but the DMRV results suggest actual savings were unsubstantial and thus may not have been a significant factor in the decision to use or not use the appliance. Ultimately, we found that EPC usage did not correlate with the cooking tariff: the cooking tariff did not stimulate additional e-cooking demand from this group of EPC users. However, the policy likely still sends strong signals to the market, such as indicating the government support for electric cooking and stimulating discussions around cooking with electricity, and thus has a role to play in stimulating demand through market development.

Lowering the threshold for the cooking tariff would increase the number of households that receive its benefits, resulting in increased awareness, improved perceptions of electric cooking, and ultimately increased adoption of electric cooking appliances. Positioning the cooking tariff after the lifeline tariff would signal that electric cooking is a technology that is relevant for everyone, not just high-income earners. The costs of such a change could be mitigated by reducing the number of units that are subsidized by the block tariff or by adjusting the discount level. As an example of this, we modeled an example of a redesigned Cooking Tariff that discounts units purchased in the range of 15-30 each month. Within our study population, we found that nearly all households would benefit from the model tariff (95.9% instead of 42.3%) but that the overall costs of implementation would be 25% lower as a result of the reduced block width (15 units instead of 70 units). We recommend that further exploration be done on the possible redesign of the Cooking Tariff to lower levels to understand the full implications of such a change.

Tariff	Subsidized units	Applicability Rate	Total Discounted Units
Existing Cooking Tariff	70 units (80-150)	42.3%	8089
Model Cooking Tariff	15 units (15-30)	95.9%	6071

Table 6: Comparison of the existing cooking tariff to a modeled, revised cooking tariff positioned after the lifeline.

The use of DMRV methodologies to transform smart meter measurements into impact measurements produced results that were highly consistent with our survey results on topics related to time savings but not cost savings. These novel methodologies are intended to address issues in data collection such as recall bias. In this study, the methods appear to validate our results in one area and point out a bias in another and thus strengthen the overall findings. Combined with online platforms where IOT data can be aggregated and analyzed, there is huge potential for DMRV to be used to steer and support the scale-up of electric cooking. As this frontier develops, there is a need to strengthen and standardize approaches to data collection and analysis in order to avoid introducing new types of bias. Although smart meters create possibilities to monitor every device in a project, the experience of this study suggests that this is impractical to implement and potentially leads to inaccurate results: an IOT-enabled appliance that reports no data *cannot* be assumed to not be in use, as issues of hardware, software, data connectivity, and user-hardware interaction could result in a loss of data. The expanding field of DMRV requires further development of affordable robust metering hardware that can be integrated directly into appliances as well as methodologies that guide implementers on how to appropriately sample their users and then filter and analyze data. The adoption of digital tools that standardize and simplify the use of data will enable more stakeholders to benefit from DMRV.

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Annex 1: DMRV Approaches to Impact Measurement

Current carbon credit DMRV methodologies allow for project developers to estimate CO2e emission reductions by back-calculating the baseline fuel energy from the measured project device energy, which can then be converted to emissions using emission factors (Gold Standard Foundation, 2022; Clean Cooking and Climate Consortium (4C), 2025). The same logic has been applied to estimate co-benefits such as time and cost savings (Little and Richter 2024).

Building on these approaches, we present steps and equations for estimating the impact of introducing a project device such as an EPC. These steps are a restatement of the DMRV methodologies and can be applied to any metric that is measured or derived from a CCT, whether that is energy, time, cost, fuel quantities, or emissions.

Step 1: Determine how much energy the baseline fuel would have used

Find the displaced energy by multiplying the project device's metered energy by the ratio of the energy used in the displaced and project devices in the CCT.

<u>Example</u>: we measured the average EPC used 9.84 kWh per month. We multiply this by the ratio of the charcoal stove energy consumption (12.55 MJ/test) to the EPC energy consumption (0.42 kWh/test) from our CCT. The displaced energy is therefore 294.0 MJ.

Step 2: Convert energy into another metric

Multiply the energy of the project and displaced device by a conversion factor that has units of the desired output unit over energy.

<u>Example:</u>

Our CCT indicates that the average dish cooked in the EPC takes 0.775 hours to cook and uses 0.42 kWh of energy. We multiply that ratio (0.775 h / 0.42 kWh) by the energy measured in the EPC (9.84 kWh) to find that households cooked an average of 18.1 hours per month.

For the charcoal stove, our CCT indicates that the average dish takes 1.46 hours to cook and uses 12.54 MJ of energy. We again multiply this ratio (1.46 h / 12.54 MJ) by the displaced energy charcoal cookstove (294 MJ) to find that the household would have spent 34.2 hours cooking each month.

Step 3: Find the difference between the two scenarios

Subtract the project scenario from the baseline scenario to find the savings

<u>Example:</u>

Households reduced their charcoal cooking by 34.2 hours by cooking with the EPC for 18.1 hours. The resulting difference between the two is a net time savings of 16.1 hours.

The equations for the steps above are provided below having been generalized for a metric x with the corresponding measurement of that metric in the CCT as SX. Energy consumption is E and specific energy consumption SC.

EQ 1

$$E_{displaced} = E_{EPC} \times (\frac{SC_{displaced}}{SC_{EPC}})$$

EQ 2

$$x = E \times (\frac{SX}{SC})$$

EQ 2.1

$$x_{EPC} = E_{EPC} \times (\frac{SX_{EPC}}{SC_{EPC}})$$

EQ 2.2

$$x_{displaced} = E_{displaced} \times (\frac{SX_{displaced}}{SC_{displaced}})$$

$$x_{displaced} = E_{EPC} \times (\frac{SC_{displaced}}{SC_{EPC}}) \times (\frac{SX_{displaced}}{SC_{displaced}})$$

$$x_{displaced} = E_{EPC} \times (\frac{SC_{displaced}}{SC_{EPC}})$$

EQ 3

$$\Delta x = x_{displaced} - x_{EPC}$$

$$\Delta x = E_{EPC} \times (\frac{SX_{displaced}}{SC_{EPC}}) - E_{EPC} \times (\frac{SX_{EPC}}{SC_{EPC}})$$

$$\Delta x = E_{EPC} \times (\frac{SX_{displaced} - SX_{EPC}}{SC_{EPC}})$$

The CCT results used in the analysis in this paper are derived from a controlled cooking test report from Uganda (MECS 2020). Specific energy, time, and fuel usage are directly reported in the CCT results. Specific costs were calculated by multiplying the specific fuel usage by the price of fuel, here assumed to be 1000 UGX/kg of charcoal and 630 UGX/kWh of electricity (the average price paid by participants per unit after considering the effects of all tariff subsidies).

	Specific Energy	Specific Time	Specific Fuel Usage	Specific Cost
Improved Charcoal Cookstove	12.54 MJ/test	1.4625 h/test	0.40475 kg/test	404.75 UGX/test
EPC	0.4225 kWh/test	0.775 h/test	0.4225 kwh/test	266.175 UGX/test

Table 7: Values derived from controlled cooking tests