eCook Zambia Discrete Choice Modelling

October 2019 Working Paper

(final report expected December 2019)

Main authors: N. Scott, J. Leary, N. Serenje, F. Mwila, S. Batchelor

Associate authors: M. Leach, E. Brown, F. Yamba

Innovate Project 132724

Implemented by:

CEEZ Centre for Energy, Environment and Engineering Zambia Limited · Loughborough University · University of Surrey · Gamos

Funded by:

Innovate UK · UKaid from the British people · Gamos

With additional analysis by:

MECS Modern Energy Cooking Services

Acknowledgement

This study would not have been possible without the willingness of the respondents to share insights into their lives and the dedication of the enumerators and the staff of CEEEZ, both those named as authors and the supporting staff. Finally, we thank the donors, UK AID via Innovate UK for partial funding and the directors and shareholders of Gamos who matched the funding for the benefit and public good of Zambia. Additional analysis was carried out under the Modern Energy Cooking Services (MECS) programme, also funded by UK Aid.

Rights, permissions & disclaimer

Executive Summary

This report presents the key learning points from the Discrete Choice Modelling (DCM) survey to inform the future development of eCook (battery-supported electric cooking) within Zambia. The aim of this study is to gain a deeper understanding of how Zambian households cook, how they aspire to cook and how compatible this is with battery-supported electricity.

The study has highlighted several opportunities and challenges for future eCook product/service designers. Urban Zambians tend to fuel stack electricity and charcoal, both of which are available at very low cost compared to other countries. Wood smoke is seen as highly undesirable by most, however most are indifferent to charcoal smoke, which is less visible but also has severe health implications. Most participants cooked 3 meals a day, but electricity users reported spending longest in the kitchen, likely due to the inefficient appliances currently in use. If monthly repayments were on a par, respondents prefer lease-to-own business models, as they would eventually own the equipment. However most saw an energy service model, where the cookers are rented for a service fee (in the same way that power generation, transmission & distribution infrastructure currently is) by the national utility, ZESCO, as a favourable option.

1.1 Methodology

The primary purpose of the Discrete Choice Modelling surveys was to explore people's preferences regarding various aspects of the design and functionality of cooking devices. The survey has also been used to gather valuable data on cooking practices (e.g. the mix of fuels used and the timing of meals), and the quality of electricity supplies. Data on expenditure on cooking fuels is especially useful as this represents disposable income that can be substituted for modern fuel devices.

The surveys were carried out by CEEEZ, who coordinated a team of enumerators to conduct face to face interviews and responses were recorded using the Kobo Collect Android application on a tablet.

Choice models are set up using choice cards, which force the respondent to choose one of the two cards presented. The results provide an understanding of the strength of preference for each attribute, reflecting how important it is in decision making.

1.2 Overview of sample

Roughly three quarters of the sample were drawn from urban areas around Lusaka, and one quarter were drawn mostly from three rural towns located around 50 km from the capital. The sample was female biased, but this is not surprising, as there was no cash incentive offered & the focus on cooking likely attracted more female respondents. The mean household size was found to be 5.2 (including children). 46% of the sample were deprived in at least one of the indicators relating to education, home construction materials & source of drinking water.

Almost all respondents owned mobile phones, indicating high levels of technical proficiency & possibly a greater willingness to adopt new innovations. Half of respondents regularly use the internet & social media platforms, indicating that social media marketing strategies could be employed for ecook products/services, but would likely need to be complimented by other means.

1.3 Load shedding

Participants report that load shedding is most frequent from September to December, which ties in with seasonal rainfall patterns, as when the rains come late, Zambia's hydropower-dominated grid is unable to keep up with demand. Blackouts can be caused by demand exceeding supply (load shedding) or by failures (or planned maintenance) on the distribution infrastructure. Blackouts caused by the latter can occur at any time, however the severity of load shedding varies seasonally & annually. In 2017, when the survey was carried out, load shedding was not occuring, so when reporting on the frequency, severity participants would have been referring to their experience in previous years. However, there may also have been confusion over which type of blackouts were being referred to throughout the survey.

1.4 Fuel stacking & fuel choice

Charcoal & electricity were the most common cooking fuels among participants, followed by wood. Charcoal was the most popular fuel among single fuel users. However, among fuel stackers, electricity was equally likely to be used as a backup for charcoal, as charcoal was to backup electricity. The vast majority of respondents already had some experience with cooking with electricity, however it is unclear whether this was a positive or negative experience.

Half the people who reported cooking with electricity but did not fuel stack with any other fuel were 'appliance stackers', i.e. they cooked with multiple electric appliances. This shows that, just as each fuel has desirable & undesirable characteristics that make it better/worse for certain foods or occasions, so does each electric appliance. Just over half the sample (57%) reported using multiple cooking devices, with some households reporting owning up to 8 different cooking devices! For households with a single cooking device, the basic biomass stove was by far the most popular (83%).

Electricity & charcoal/firewood are useful for other things too. Almost all participants who cooked with electricity reported using it for lighting & refrigeration, whilst half reported using it for water heating. In

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

contrast, charcoal was almost universally also used for water heating & by about a third for space heating.

The LPG market in Zambia is nascent, so most respondents did not have opinions on it. However, of those that did thought it was difficult to access, unsafe & expensive.

Ease of access acts as a barrier to wood use, but not for charcoal, suggesting that charcoal is more readily available.

1.5 Existing expenditures

The mean monthly expenditure on electricity (for cooking & other purposes) was roughly 200 ZMK (15 USD). This works out at 360 kWh/month, or 12 kWh/day, which is very high, however Zambia has one of the lowest tariffs in Sub-Saharan Africa, which does not encourage energy efficiency. Most respondents (59%) reported topping up their electricity meter every 3-4 weeks. This means there is likely to be a disconnect between what people spend on electricity & their cooking practices, as changing the way you cook won't have an effect on how much you are spending for several weeks.

Almost half of the charcoal users buy monthly, however 20% buy in small quantities on a daily basis. Ecook systems with monthly repayment plans are likely to be attractive to the former, however more frequent repayment options will be necessary to reach the latter, who are likely to be the poorer households. It is in possible to top up your electricity meter with just enough units to cook a single meal, i.e. in the same way that many people pay for charcoal. However, only 2 participants reported doing this.

Urban participants reported spending around 40% more on charcoal per month than rural participants: 136 versus 97 ZMK/month or 10 versus 7 USD/month. Internationally, these expenditures are quite low, however grid tariffs in Zambia are also very low.

Interestingly, many rural firewood users also reported paying for it. The mean expenditure for the whole sample was 79 ZMK/month or 6 USD/month. This is lower than the anticipated costs of PV-eCook systems, however, if the trend of decreased access to the bush due to increased urbanisation continues, these prices may well rise & charcoal may well become even more widely used, as it can be transported from further away.

Cost is clearly an important issue. The belief that electricity is expensive appears to act as a driver for use of charcoal. 60% of participants thought that price was the major deciding factor for households

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

considering transitioning to modern energy for cooking, which suggests that there are other important considerations to take into account, such as access, reliability & cultural preferences.

1.6 Health

Electricity is almost exclusively used indoors, whilst wood and charcoal are used both indoors & outdoors. This may suggest that some households are aware of the health implications of using biomass stoves indoors, or it may simply be that biomass stove users, who are likely to be poorer & therefore have smaller homes, have less indoor space to cook in. Unlike direct ac cooking appliances, battery-supported stoves can be used indoors or outdoors, so the cook is free to choose where they want to cook.

Smoke is regarded as a health hazard among all groups, so does not play a role in choice of fuels. However, beliefs in positive aspects of smoke (as an insect repellent and in flavouring food) act as barriers for electricity use i.e. charcoal & wood users held more positive views on these beliefs.

1.7 Cooking time

80% of respondents reported cooking 3 meals a day. Breakfast is typically prepared at 9:00, lunch at 13:00 & dinner at 19:00. 92% of participants heat water for bathing.

Interestingly, respondents who cook with electricity reported spending more time cooking (3.1 hrs/day) than charcoal (2.7 hrs/day) or wood (2.2 hrs/day). This could be because the electric appliances in use are quite inefficient & slow. In which case, there may be an opportunity for eCooking devices such as the electric pressure cooker (EPC) that can cook much faster.

1.8 Gender

Unsurprisingly, participants reported that women are usually responsible for cooking (83%), however, in 11% of households, men do the majority of cooking & in 7% it is a shared responsibility, indicating that marketing ecook products & services to men is also important. In fact, the evidence from the focus groups suggests that appliances such as electric pressure cookers (EPCs) can make cooking much easier, which may encourage more men to cook.

Responses suggest that purchasing decisions are generally made together, both for cooking & power generation equipment.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

1.9 Financing

Mobile money is likely to be a key enabler for ecook, as it can make collecting small, but regular repayments much easier. However, the mobile money industry is still finding its feet in Zambia & only half of respondents reported using it, most of whom do so infrequently.

70% of respondents felt positively about using a cooker provided by ZESCO, which slightly contradicts the finding that opinion on renting equipment was divided, as everything provided to households by ZESCO is rented by the user. Almost all respondents indicated a preference for paying for high value items in instalments. 80% indicated that monthly repayments were preferable to quarterly, however the survey did not include more frequent repayment options, which may well have been more attractive to the 20% of charcoal users who buy fuel on a daily basis.

1.10 Consumer preferences – choice modelling results

The cooking process design features that appear to be most important to consumers are:

- Lid – people have a strong preference for a lid, but not for a sealed pot
- Cooking – prefer to be able to both boil and fry
- Hobs – people prefer multiple hobs, but interestingly people seem almost as keen to have four hobs as two.
- Cost.

Cooking with a lid on the pot is more energy-efficient, so will reduce the size of the battery & make ecook systems more affordable. However, a sealed & pressurised pot is even more efficient, so some compromises maty have to be made for the lowest cost systems.

Discharge rate is a key determinant of battery life. Frying generally requires higher power than boiling & 2 hobs require twice as much power as one. Again, system designers may have to choose to trade off usability for cost in budget models.

The most important stove features are:

- Smoke –avoiding the kind of smoke generated by a wood fire.
- Capacity – people want to be able to cook for larger numbers of people.
- Portable – people would like a device that can be carried in/out of the house
- Cost.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

People's strongest preference is for a device that avoids the kind of smoke generated by a wood fire. Interestingly, people do not register a preference for no smoke over charcoal smoke. Wood smoke is much thicker than charcoal smoke throughout the entire duration of cooking. However, charcoal smoke contains much higher levels of the silent killer: carbon monoxide.

All functionality features explored in the model were significant. In order of preference:

- Finance – strong preference for lease-to-own models if repayment sizes were comparable.
- Availability –strong preference for a system that could cook reliably regardless of the weather.
- Additional appliances - tv, phone charging, then lighting.
- Easy to clean.

People have a strong preference lease-to-own over utility models, with as short a repayment period as possible. However, product/service designers may again have to compromise to reach the bottom of the pyramid, as utility models are likely to have the lowest monthly costs, as they have the longest financing horizon.

Interestingly there was very little difference between the responses given by rural & urban participants. This could be because the rural areas surveyed were close to Lusaka, so culturally very similar. Further research is needed in different areas of the country to see if preferences vary. If not, products/services designed for Lusaka could easily scale across the whole country.

Respondents that use electricity as their main cooking fuel are more tolerant of a lower capacity device that functions only on sunny days. This could be because they are already used to fuel stacking when electricity is not available at mealtimes due to load shedding.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table of Contents

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

2 Introduction

This report presents one part of the detailed in country research carried out to explore the market for eCook in Zambia. In particular, this in country work aims to gain much greater insight into culturally distinct cooking practices and explore how compatible they are with battery-supported electric cooking. The report is rich with detail and is intended to provide decision makers, practitioners and researchers with new knowledge and evidence.

This report presents the key learning points from the cooking diaries study, to inform the future development of eCook within Zambia. It is one component of a broader study designed to assess the opportunities and challenges that lay ahead for eCook in high impact potential markets, such as Zambia, funded through Innovate UK's Energy Catalyst Round 4 by DfID UK Aid and Gamos Ltd. (https://elstove.com/innovate-reports/).

The overall aims of the Innovate project, plus the series of interrelated projects that precede and follow on from it are summarised in in *Appendix A: Problem statement and background to Innovate eCook project*. A much deeper analysis of the data collected during this project was supported by the Modern Energy Cooking Services (MECS) programme, which included the writing of this report.

2.1 Background

2.1.1 Context of the potential landscape change by eCook

The use of biomass and solid fuels for cooking is the everyday experience of nearly 3 billion people. This pervasive use of solid fuels and traditional cookstoves results in high levels of household air pollution with serious health impacts; extensive daily drudgery required to collect fuels, light and tend fires; and environmental degradation. Where households seek to use 'clean' fuels, they are often hindered by lack of access to affordable and reliable electricity and/or LPG. The enduring problem of biomass cooking is discussed further in *Appendix A: Problem statement and background to Innovate eCook project*, which not only describes the scale of the problem, but also how changes in renewable energy technology and energy storage open up new possibilities for addressing it.

2.1.2 Introducing 'eCook'

eCook is a potentially transformative battery-supported electric cooking concept designed to offer access to clean cooking and electricity to poorer households (HHs) currently cooking on charcoal or other polluting fuels (Batchelor, 2013, 2015a, 2015b). Enabling affordable electric cooking sourced from renewable energy technologies, could also provide households with sustainable, reliable, modern energy for a variety of other purposes.

A series of initial feasibility studies were funded by DfID UK AID under the PEAKS mechanism (available from https://elstove.com/dfid-uk-aid-reports/). Slade (2015) investigated the technical viability of the proposition, highlighting the need for further work defining the performance of various battery chemistries under high discharge and elevated temperature. Leach & Oduro (2015) constructed an economic model, breaking down PV-eCook into its component parts and tracking key price trends, concluding that by 2020, monthly repayments on PV-eCook were likely to be comparable with the cost of cooking on charcoal. Brown & Sumanik-Leary's (2015), review of behavioural change challenges highlighted two distinct opportunities, which open up very different markets for eCook:

- PV-eCook uses a PV array, charge controller and battery in a comparable configuration to the popular Solar Home System (SHS) and is best matched with rural, off-grid contexts.
- Grid-eCook uses a mains-fed AC charger and battery to create distributed HH storage for unreliable or unbalanced grids and is expected to best meet the needs of people living in urban slums or peri-urban areas at the fringes of the grid (or on a mini-grid) where blackouts are common.

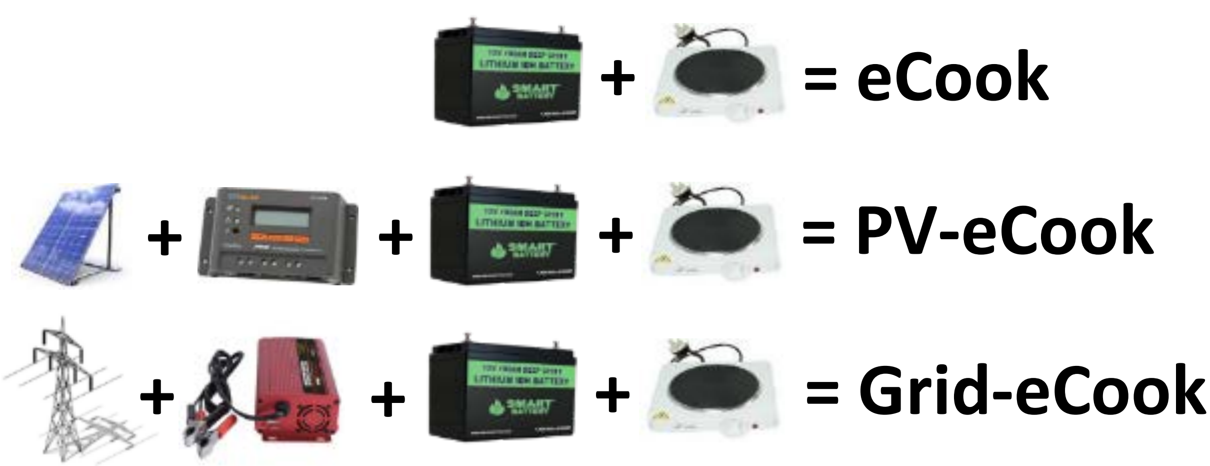


Figure 1: Pictorial definitions of 'eCook' terminology used in this report.

2.1.3 eCook in Zambia

Given the technical and socio-economic feasibility of the systems in the near future, Gamos, Loughborough University and the University of Surrey have sought to identify where to focus initial marketing for eCook. Each country has unique market dynamics that must be understood in order to determine which market segments to target are and how best to reach them. Leary et al. (2018) carried out a global market assessment, which revealed Zambia as the third most viable context for PV-eCook, as 10% of the population already cook on electricity and recent load shedding caused a significant number of these users to revert back to charcoal, rapidly accelerating deforestation.

The accompanying reports from the other activities carried out in Zambia can be found at: https://elstove.com/innovate-reports/.

2.2 Aim

The aim of this study is to explore the preferences of potential users of battery-supported electric cooking products/services

In particular, the objectives of the study are to gather data on:

- user preferences regarding various aspects of the design and functionality of cooking devices.
- existing expenditures on cooking fuels, cooking practices and the quality of electricity supplies.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

3 Methodology

The primary purpose of the Discrete Choice Modelling surveys was to explore people's preferences regarding various aspects of the design and functionality of cooking devices. The survey has also been used to gather valuable data on cooking practices (e.g. the mix of fuels used and the timing of meals), and the quality of electricity supplies. Data on expenditure on cooking fuels is especially useful as this represents disposable income that can be substituted for modern fuel devices. The surveys were carried out by CEEEZ, who coordinated a team of enumerators to conduct face to face interviews and responses were recorded using the Kobo Collect Android application on a tablet.

3.1 Descriptor data

Descriptor data was also gathered from respondents, such as age, gender, level of education and so on. Two composite descriptor variables have been calculated representing characteristics of households that might be expected to influence attitudes towards, and eventual adoption of, modern energy cooking devices. A poverty index has been calculated from five variables including the level of education of the respondent and the quality of the dwelling. A technological aptitude index has been calculated from variables representing personal use of media, phones and the internet services. Preferences have then been disaggregated by descriptors and indices to highlight particular aspects that may be more important to specific customer segments.

3.2 Discrete Choice Modelling (DCM)

Discrete choice modelling was proposed as the theoretical construct to be used in these surveys, to identify the key characteristics (or parameters) that each product should have to find ready acceptance with consumers. The methodology has considerable advantages overstated preference, particularly in this case of exploring a market for a future product, as it is difficult for a consumer to state what they would like about a product if they do not yet have exposure to the product.

Choice models are set up using choice cards (Figure 2), based on the key parameters identified, each of which has a limited number of 'levels'. The respondent must then choose one of the two cards presented. Discrete choice models predict the probability that an individual will choose an option, based on the levels of each parameter given in the option. Parameters were divided into three sections covering cooking processes (e.g. speed of cooking), stove design (e.g. smoke emissions), and functionality (e.g. financing plans). Each section was assigned four or five parameters, each parameter having between 2 and 4 levels. Each section included a cost parameter (the capital cost of the device), which was considered to be a continuous variable. This enables willingness to pay figures to be

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

calculated for different features of a cooking device. The analysis used binary logistic regression to fit predictive models to the data for each section. The results provide an understanding of the strength of preference for each attribute, reflecting how important it is in decision making.

F6-TZ				
Parameta	Chaguo A		Chaguo B	
Gharama ya kila mwezi	45,000 TZS/mwezi		15,000 TZS/mwezi	
Matumizi	Sahani 2 + Taa 3 za LED		Sahani 2 + Televisheni	
Upatikanaji	Linatumika wakati wa jua pekee		Linatumika wakati wa jua pekee	
Muundo wa malipo	Malipo ya kila mwezi (matumizi)	TANESCO	Kukopesha kwa muda wa miaka 6	6
Usafishaji	Rahisi kusafisha		Shida kusafisha	

Figure 2: Example choice card from the eCook Tanzania DCE survey.

Fractional orthogonal design[1] was used to limit the number of choices to 16 choice cards per section (Mangham, Hanson, & McPake, 2009). A simple constant comparator approach was used (De Bekker-Grob et al., 2010), in which one of the 16 choice cards was used as a 'reference'[2], and the 15 resulting pairs presented respondents with a choice between this comparator and each of the other choice cards. The literature suggests that respondents get fatigued when presented with too many choices, and a review suggested studies rarely used more than 16 choices (De BekkerGrob, Ryan, & Gerard, 2012). For each technology the choice cards were therefore split in two sets (with 7 & 8 pairs in each), included in a Questionnaire A and Questionnaire B. We then hypothesised that by interspersing the three sections with the descriptor questions, the respondent would be prepared to answer three sets of 7 or 8 pairs. Piloting of the survey instrument confirmed that respondents could indeed respond to 3 sections within a given questionnaire, with a maximum of 8 choice pairs per technology.

Data sets derived from choice modelling are quite different to those from other types of surveys. Firstly, each respondent is asked 7 or 8 questions in each section, resulting in multiple responses per individual. Secondly, each choice comprises a pair of choice cards i.e. two records are generated for each of the questions. The data is, therefore, 'expanded' into a matrix of continuous and

[1] Using SPSS software.

[2] The constant comparator choice card was selected on the basis that the mix of levels represented a mid-level of attractiveness, so one would expect the number of times the comparator was chosen and reject to be roughly balanced.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

categorical dummy variables that represent the characteristics of each choice (the level for each parameter), along with a categorical 'choice' variable – the dependent variable indicating whether the respondent chose or rejected the choice card in the pair presented (World Health Organisation, 2012).

The analysis used binary logistic regression to fit predictive models to the data for each technology because the dependent variable was a dichotomous categorical variable (representing whether the choice card was chosen or not). All of the parameters were entered into the model, which calculated regression coefficients for each, along with p values indicating whether the parameter was significant in the model. The modelling was done using SPSS and further notes on interpreting the results are given in *4.7.1 Interpreting the results.*

3.2.1 Sampling design

According to Rose & Bliemer "*an archetypal SCE [stated choice experiment] might require choice data be collected on 200 respondents, each of whom are observed to make eight choices, thus producing a total of 1600 choice observations*" (Rose & Bliemer, 2009). The literature goes on to point out that if the survey design is to include other questions that can be used to disaggregate the data, larger samples are required (Orme, 2010). However, the literature also states that to a large extent, sample size is determined by budgetary constraints. Work by the Consortium for Research on Equitable Health Systems (CREHS) confirms that sample sizes for discrete choice experiments have generally been based on experience rather than mathematical calculation (Wafula et al., 2011), and propose 100 – 150 respondents per sub-group. When considering the acceptable range of sample sizes, the WHO guidelines suggest the sample size must be more than 30 (World Health Organisation, 2012), and at the upper end a review of studies suggests that precision improves only marginally for sample sizes over 300 (Johnson et al., 2013). One of the leading experts in choice modelling states:- "*For robust quantitative research where one does not intend to compare subgroups, I would recommend at least 300 respondents.* ***For investigational work and developing hypotheses about a market, between thirty and sixty respondents may do.***" (Orme, 2010) (Our emphasis).

As an initial scoping exercise to test the market for a new cooking concept, the research team decided that given the resources available, a sample of 200 respondents would be sufficient. This would allow disaggregation of the results by several variables (e.g. location, poverty levels, primary fuel use). If necessary, follow on surveys could then be conducted to gain greater clarity on specific issues that may require further disaggregation of the data. Given that each respondent would be working with one half of each set of choice pairs, 200 respondents only yield 100 complete choice pairs. However, as identical

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

surveys were carried out in parallel in 3 countries (Zambia, Tanzania and Myanmar), the full dataset is actually 300.

3.3 Computer Assisted Personal Interviewing (CAPI)

Surveys were conducted on tablets with an Android operating system. Compared with paper collection, the reliability of the data is greatly improved and there are significant time savings from completely eliminating the data digitisation step (transcription from paper to computer).

While the team has extensive experience of collecting data on tablets, it was not immediately clear whether CAPI systems could use graphics, and whether respondents would be able to browse options for themselves before making a choice. The first issue of concern was whether respondents would be comfortable with handling the tablet (recent experience of self-administration in rural areas of DRC was mixed), and secondly, the particular software needed to include graphics (for nonliterate respondents).

The KoboCollect digital survey tool was selected because it was designed for challenging contexts and offered the ability for enumerators to show respondents graphics representing the choice cards (Figure 2). The precursor to the eCook DCE surveys was carried out in Kenya in 2016 using the Poimapper Plus platform (Batchelor and Scott, 2016), however bugs in the software and programming challenges lead the team to switch onto the Kobo platform. One disadvantage to CAPI is that it is difficult to create a word document for inclusion as an annex in reports such as this.

3.4 Training and piloting

CEEEZ recruited a team of 3 enumerators, who carried out the surveys alongside 2 members of CEEEZ. Training was conducted by CEEEZ and Gamos, guided by instructions from the survey designers at Gamos. Although the enumerators did not have experience with carrying out surveys on tablets, they had good knowledge of smart phones and android devices which proved sufficient during training.

The survey methodology had previously been tested in Kenya, focussing on both health and cooking technologies (Batchelor and Scott, 2016). However, this version of the survey had been adapted to focus solely on cooking, so the field training also acted as pilot testing of the updated survey itself. Further updates were made after discussion within the piloting group to adapt the survey to the local context, for example converting currencies and choosing price ranges aligned with current expenditures on cooking fuels. This pilot data was downloaded and verified by the survey designers at Gamos.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

The surveys were carried out at busy marketplaces to ensure access to as many potential respondents as possible. No cash incentives were offered, as previous experience with DCE in Kenya showed that when some respondents knew that an incentive was being given after the interview then occasionally it became the main motivation for completing the interview, in which case some respondents gave less well considered responses.

With any household study, it is assumed that poverty will be a key determinant of adoption behaviour and preferences. It can also be asserted that early adopters of new technologies will tend to be those who have already adopted other technologies and are intensive users of other technologies. Where a device meets a need, it is more likely to be adopted by people who are aware of those needs. For example, respiratory infections associated with traditional cooking methods are a major cause of deaths, yet demand for improved cookstoves will only be stimulated when people become aware of the consequences of traditional cooking methods. Some of the supporting questions were designed to explore these issues of poverty, adoption of technology, and general level of understanding (or awareness). Given that level of education and ownership of assets are commonly used as determinants of wealth, a high degree of interconnectedness is to be expected between these three issues.

Principal component analysis has been used to create a combined 'wealth' index that accommodates various characteristics of the respondents:

- household characteristics;
- asset ownership;
- cooking fuels and expenditure; and
- use of technology.

A proxy wealth indicator was calculated on the basis of the first factor extracted from a factor analysis of these supporting indicators, and households were divided into wealth quintiles.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

4 Results

4.1 Geographical locations

Face to face interviews were conducted using Kobo Toolbox CAPI software. The sample of 193 interviews were conducted by a team of five enumerators. Roughly three quarters of the sample were drawn from urban areas around the capital, and one quarter were drawn mostly from three rural towns located around 50 km from the capital (N.B. some of the sample from the capital has been classified as rural) – see Table 1 and Figure 3.

Table 1 Regions and type of settlement

Name of district	is your household in an urban or rural area		Total
	rural	urban	
	1	1	2
Chilanga	9	0	9
Chongwe	13	0	13
Kafue	14	0	14
Lusaka	20	131	151
Rufunsa	1	3	4
Total	58	135	193

THE SAMPLE WAS HEAVILY WEIGHTED TOWARDS URBAN PARTICIPANTS, BUT ALSO INCLUDED SOME RURAL RESPONDENTS.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

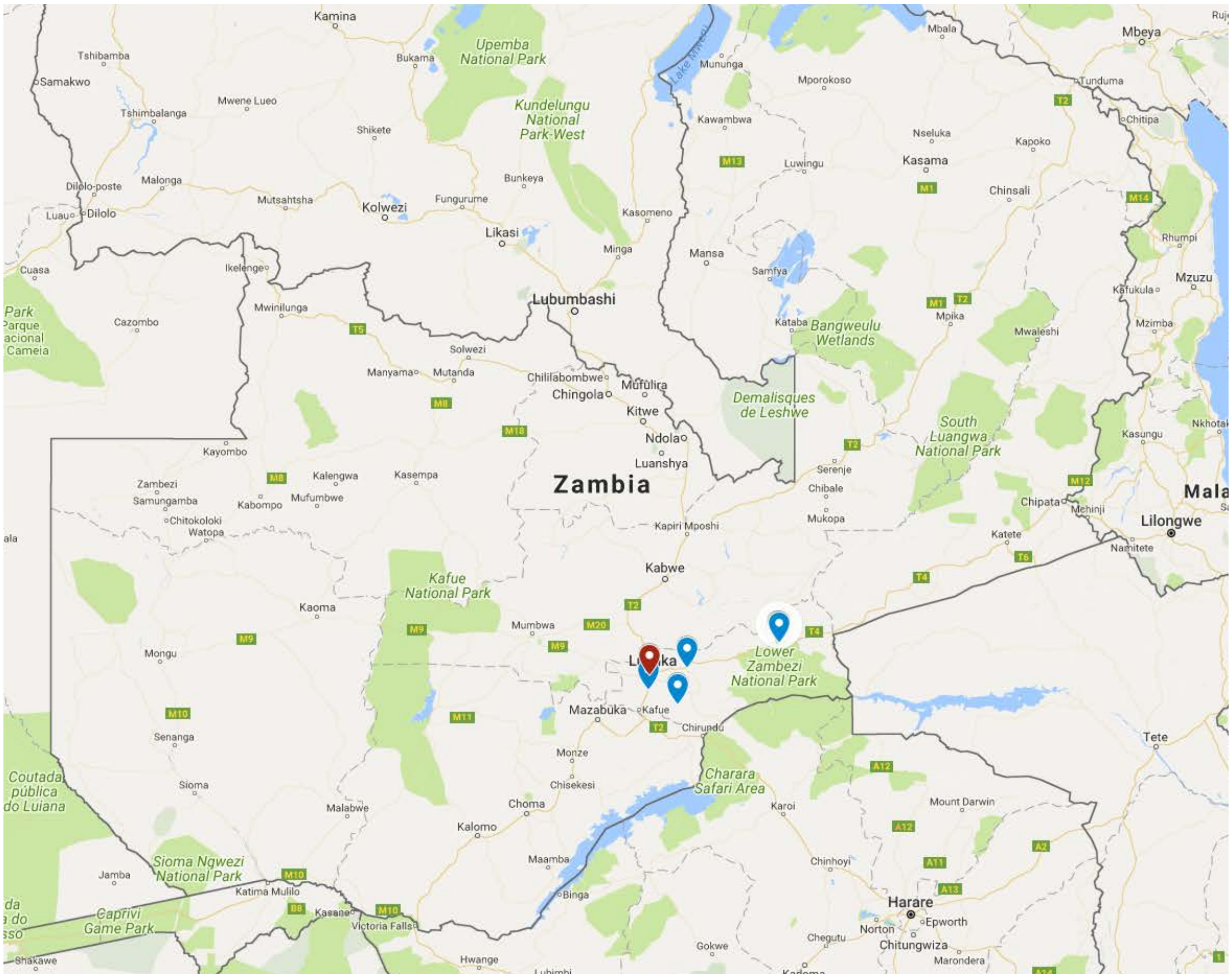


Figure 3 Geographical spread of survey

The mean time taken to walk to the nearest market was 15 minutes for urban respondents and 20 minutes for rural respondents, so it appears that rural respondents lived reasonably close to their local marketplace. Although they were in a rural area, they did not live in remote areas, far from markets and other facilities. Both rural and urban samples included outliers that lived an hour or more from their market.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

4.2 Respondent characteristics

4.2.1 Personal characteristics

The sample was female biased – 42:58 (male:female).

76% of respondents were either the head of household or the spouse of the head of household.

The mean age of respondents was 33.1 years, but the sample included respondents of a wide age range – see Figure 4.

The sample was split roughly one third with primary education, one third with incomplete secondary education, and one third with complete secondary education (see Table 2).

THE SAMPLE WAS FEMALE BIASED, BUT THIS IS NOT SURPRISING, AS THERE WAS NO CASH INCENTIVE OFFERED & THE FOCUS ON COOKING LIKELY ATTRACTED MORE FEMALE RESPONDENTS.

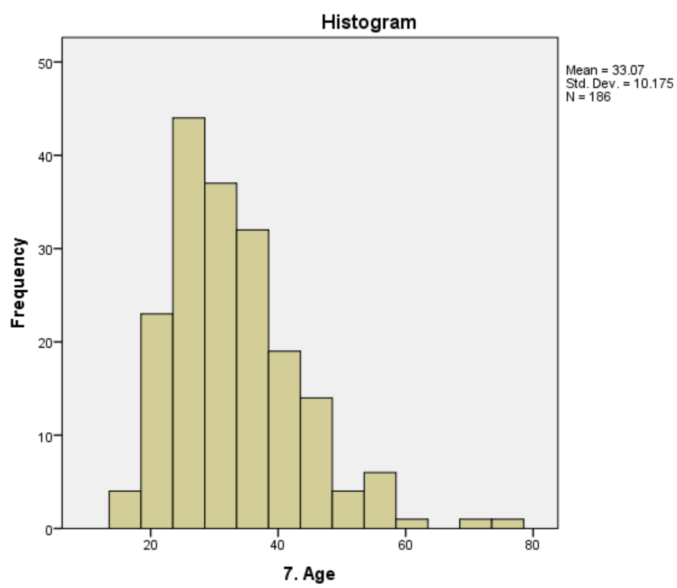


Figure 4 Age distribution of respondents

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 2 Highest level of education attained

		Frequency	Percent
Valid	none	6	3.1
	incomplete primary	29	15.0
	completed primary	27	14.0
	incomplete secondary	56	29.0
	completed secondary	60	31.1
	higher than secondary	14	7.3
	Total	192	99.5
Missing	System	1	.5
Total		193	100.0

Most respondents both listen to the radio and watch TV; TV is more popular than the radio (Table 3). They correlate only weakly (r = 0.243, p = 0.001), showing that overall, those who watch more TV also listen to the radio more often. 8% (n=16) were isolated in not accessing either of these types of broadcast media.

Table 3 Frequency of use of broadcast media

	Radio		TV	
	Frequency	Percent	Frequency	Percent
not at all	50	25.9	34	17.6
less than once a week	9	4.7	6	3.1
at least once a week	53	27.5	44	22.8
daily	77	39.9	105	54.4
Total	189	97.9	189	97.9
Missing	4	2.1	4	2.1
Total	193	100.0	193	100.0

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Patterns of mobile phone use can serve as a proxy for technical proficiency and ability to adapt to technological innovations. 96% of respondents owned a mobile phone (or SIM card), one half of which were basic phones (Table 4). Although most respondents used a phone several times a day, there remains a small minority who did not use a phone at all (Table 5).

ALMOST ALL RESPONDENTS OWNED MOBILE PHONES, INDICATING HIGH LEVELS OF TECHNICAL PROFICIENCY & POSSIBLY A GREATER WILLINGNESS TO ADOPT NEW INNOVATIONS.

Literacy clearly acts as a barrier to fully exploiting the potential of mobile phones, and 14% of respondents were not able to read SMS texts for themselves (n=26). However, all of these (n=25) had used a phone in the previous month, indicating that literacy does not stop people making some use of mobile phones.

Table 4 Type of phone most commonly used

		Frequency	Percent
Valid	Smart phone	75	38.9
	Feature phone	11	5.7
	Basic phone	89	46.1
	Total	175	90.7
Missing	System	18	9.3
Total		193	100.0

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 5 Frequency of use of mobile phone (in last month)

		Frequency	Percent
Valid	not used	12	6.2
	weekly	2	1.0
	once or twice a day	18	9.3
	several times a day	155	80.3
	Total	187	96.9
Missing	System	6	3.1
Total		193	100.0

HALF OF RESPONDENTS REGULARLY USE THE INTERNET & SOCIAL MEDIA PLATFORMS, INDICATING THAT SOCIAL MEDIA MARKETING STRATEGIES COULD BE EMPLOYED FOR ECOOK PRODUCTS/SERVICES, BUT WOULD LIKELY NEED TO BE COMPLIMENTED BY OTHER MEANS.

In terms of innovative services, Table 6 to Table 7 show that half of respondents used the internet and social media services (e.g. Facebook, Viber, WhatsApp). It is interesting to note that 51% (n=94) used Facebook or WhatsApp (at any time in the past) but 17% of these respondents (n=16) no longer use these services, leaving 78 current users. The vast majority of these (91%) use services daily.

Nearly one half of respondents used mobile money services and most use only infrequently – see Table 8.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 6 Frequency of use of internet (in last month)

		Frequency	Percent	Valid Percent
Valid	not aware of internet	23	11.9	12.3
	not used	86	44.6	46.0
	weekly	9	4.7	4.8
	once or twice a day	15	7.8	8.0
	several times a day	54	28.0	28.9
	Total	187	96.9	100.0
Missing	System	6	3.1	
Total		193	100.0	

MOBILE MONEY IS LIKELY TO BE A KEY ENABLER FOR ECOOK, AS IT CAN MAKE COLLECTING SMALL, BUT REGULAR REPLYMENTS MUCH EASIER. HOWEVER, THE MOBILE MONEY INDUSTRY IS STILL FINDING ITS FEET IN ZAMBIA & ONLY HALF OF RESPONDENTS REPORTED USING IT, MOST OF WHOM DO SO INFREQUENTLY.

Table 7 Frequency of use of social media

		Frequency	Percent	Valid Percent
Valid	no longer used	16	8.3	17.0
	weekly	7	3.6	7.4
	once or twice a day	18	9.3	19.1
	several times a day	53	27.5	56.4
	Total	94	48.7	100.0
Missing	System	99	51.3	
Total		193	100.0	

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 8 Frequency of use of mobile money

		Frequency	Percent	Valid Percent
Valid	not used	95	49.2	51.1
	1 or 2 times a month	71	36.8	38.2
	3 - 10 times a month	18	9.3	9.7
	daily	2	1.0	1.1
	Total	186	96.4	100.0
Missing	System	7	3.6	
Total		193	100.0	

A factor analysis has been conducted, and a single factor extracted based on the following variables:

- Frequency of use of mobile phone
- Type of mobile phone
- use of internet
- use of social media
- use of mobile money services

The sample has then been split into two roughly equal parts on the basis of this factor score (see Table 9).

Table 9 Composite technical proficiency classification

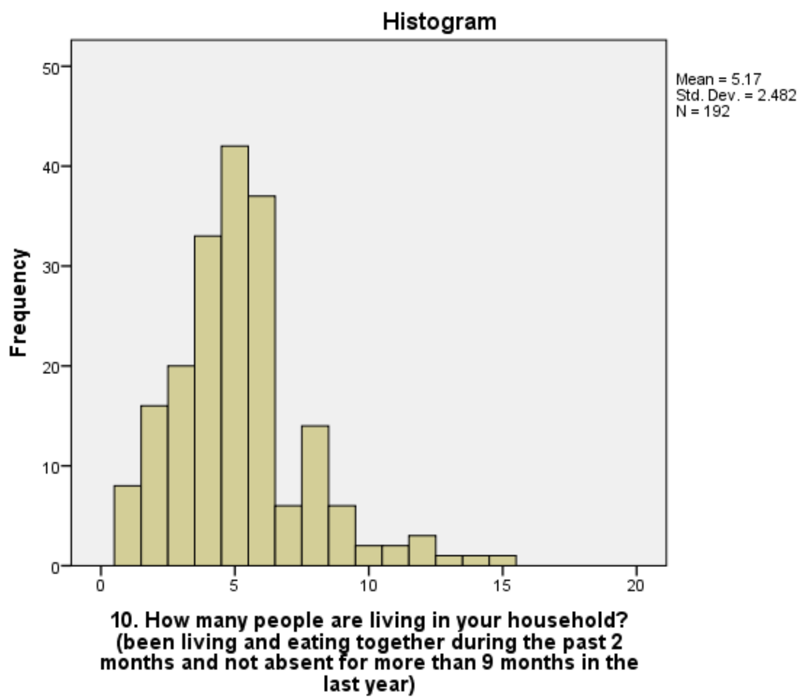
		Frequency	Percent
Valid	low	85	44.0
	high	88	45.6
	Total	173	89.6
Missing	System	20	10.4
Total		193	100.0

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

4.2.2 Household characteristics

The mean household size was 5.2 (including children). The distribution of household sizes is presented in Figure 5. 60% of households had at least one child under the age of 5 years.

Details of dwelling constructions are presented in Table 10 to Table 12. The households' main sources of drinking water are presented in Table 13.



THE MEAN HOUSEHOLD SIZE WAS FOUND TO BE 5.2 (INCLUDING CHILDREN).

Figure 5 Distribution of household size (adults + children)

Table 10 Dwelling construction - floor

		Deprived	Frequency	Percent
Valid	Dirt/Mud/Dung	X	14	7.3
	Cement screed		144	74.6
	Tiles		30	15.5
	Other	X	2	1.0
	Total		190	98.4
Missing	System		3	1.6
Total			193	100.0

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 11 Dwelling construction - walls

		Deprived	Frequency	Percent
Valid	Wood / mud / thatch	X	1	.5
	Mud bricks (traditional)	X	14	7.3
	Corrugated iron sheet	X	1	.5
	cement block (plastered or unplastered)		166	86.0
	Bricks (burnt)		6	3.1
	Other	X	2	1.0
	Total		190	98.4
Missing	System		3	1.6
Total			193	100.0

Table 12 Dwelling construction - roof

		Deprived	Frequency	Percent
Valid	Thatch/palm leaf	X	5	2.6
	Corrugated iron / cement sheet	X	162	83.9
	Cement		1	.5
	Tiles		6	3.1
	Other	X	16	8.3
	Total		190	98.4
Missing	System		3	1.6
Total			193	100.0

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 13 Main source of drinking water

		Deprived	Frequency	Percent
Valid	Piped into dwelling		7	3.6
	Piped into yard		69	35.8
	Public standpipe		41	21.2
	Tube well/borehole		63	32.6
	Protected dug well		7	3.6
	Protected spring		1	.5
	Unprotected spring	X	1	.5
	Rainwater		1	.5
	Surface (river/pond)	X	2	1.0
	Total		192	99.5
Missing	System		1	.5
Total			193	100.0

46% OF THE SAMPLE WERE DEPRIVED IN AT LEAST ONE OF THE INDICATORS RELATING TO EDUCATION, HOME CONSTRUCTION MATERIALS & SOURCE OF DRINKING WATER.

A poverty index has been created on the basis of the following variables:

- Level of education of respondent
- Dwelling construction materials (floor, walls and roof)
- Main source of drinking water.

Households have been classified as deprived as indicated in Table 10 to Table 13. They have been classified as deprived on the education indicator if the respondent had no education or primary education only. These five dichotomous indicators show poor internal consistency (Cronbach alpha = 0.391), indicating that these aspects of poverty do not appear to be related i.e. they are independent aspects of poverty. An index has been created by summing the number of aspects in which the household is deprived – see Table 14. For the purposes of the analysis, the sample has been split into two roughly equal parts: 54% non-deprived, and 46% that are deprived in at least one indicator.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 14 Composite Poverty index

		Frequency	Percent
Valid	0	104	53.9
	1	68	35.2
	2	15	7.8
	3	3	1.6
	4	2	1.0
	5	1	.5
	Total	193	100.0

4.3 Characteristics of household electricity supply

4.3.1 Sources of electricity

23% of respondents had no electricity. Only 4 respondents accessed electricity other than from the national grid (see Table 15). Only one respondent had an informal connection to the national grid, all the others had a direct connection.

ROUGHLY ¾ OF RESPONDENTS WERE CONNECTED TO THE NATIONAL GRID, WHILST ¼ WERE WITHOUT ACCESS TO ELECTRICITY.

Table 15 Sources of electricity

		Frequency	Percent
Valid	National Grid connection	144	74.6
	no electricity	45	23.3
	Other	1	.5
	Rechargeable Battery	1	.5
	Solar Home System	2	1.0
	Total	193	100.0

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

4.3.2 Household electrical appliances

Only those respondents who said they had electricity were asked which appliances they had – see Table 16.

Table 16 Household ownership of electrical appliances

Appliance	Frequency	Valid percent
Radio (battery powered)	92	63.4
Music system (mains powered)	71	49.0
Mobile phone	122	84.1
Non mobile phone	4	2.8
Television	128	88.3
refrigerator	113	77.9
Electric kettle	59	40.7
Electric water heater	21	14.5
fan	56	38.6
Air conditioner	2	1.4
Electric lights	87	60.0

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

4.3.3 Quality of supply

Respondents who accessed electricity via the national grid were asked about their experience of load shedding. Due to inconsistencies in the responses to different questions it is not clear exactly how many national grid users experienced load shedding, but it was around 10%. Although load shedding appears to take place throughout the year, Table 17 shows a clear seasonal trend, with more frequent load shedding taking place towards the end of the year (September to December).

There is a wide range of experience of blackouts. The frequency of blackouts ranges from once a month to twice a week (Table 18), and the duration of blackouts ranges from 30 minutes to 8 hours (Table 19).

Table 17 Months in which load shedding is experienced

	Frequency	Valid percent (n=140)
Jan	24	17.1
Feb	21	15.0
Mar	22	15.7
Apr	17	12.1
May	15	10.7
Jun	17	12.1
Jul	18	12.9
Aug	17	12.1
Sep	53	37.9
Oct	78	55.7

PARTICIPANTS REPORT THAT LOAD SHEDDING IS MOST FREQUENT FROM SEPTEMBER TO DECEMBER, WHICH TIES IN WITH SEASONAL RAINFALL PATTERNS, AS WHEN THE RAINS COME LATE, ZAMBIA'S HYDROPOWER-DOMINATED GRID IS UNABLE TO KEEP UP WITH DEMAND.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Nov	55	39.3
Dec	48	34.3

Table 18 Frequency of blackouts

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	once a month	17	8.8	11.8	11.8
	twice a month	41	21.2	28.5	40.3
	once a week	28	14.5	19.4	59.7
	twice a week	29	15.0	20.1	79.9
	every other day	7	3.6	4.9	84.7
	every day	3	1.6	2.1	86.8
	twice a day	1	.5	.7	87.5
	many times a day	5	2.6	3.5	91.0
	No load shedding	13	6.7	9.0	100.0
	Total	144	74.6	100.0	
Missing	System	49	25.4		
Total		193	100.0		

BLACKOUTS CAN BE CAUSED BY DEMAND EXCEEDING SUPLLY (LOAD SHEDDING) OR BY FAILURES (OR PLANNED MAINTENANCE) ON THE DISTRIBUTION INFRASTRUCTURE. BLACKOUTS CAUSED BY THE LATTER CAN OCCURE AT ANY TIME, HOWEVER THE SEVERITY OF LOAD SHEDDING VARIES SEASONALLY & ANNUALLY. IN 2017, WHEN THE SURVEY WAS CARRIED OUT, LOAD SHEDDING WAS NOT OCCURING, SO WHEN REPORTING ON THE FREQUENCY, SEVERITY PARTICPANTS WOULD HAVE BEEN REFERRING TO THEIR EXPERIENCE IN PREVIOUS YEARS. HOWEVER, THERE MAY ALSO HAVE BEEN CONFUSTION OVER WHICH TYPE OF BLACKOUTS WERE BEING REFERRED TO THROUGHOUT THE SURVEY.

Table 19 Duration of blackouts

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	under 5 minutes	1	.5	.7	.7
	10 mins	5	2.6	3.5	4.2
	30 mins	32	16.6	22.2	26.4
	1 hour	23	11.9	16.0	42.4
	2 hours	25	13.0	17.4	59.7
	4 hours	29	15.0	20.1	79.9
	8 hours	18	9.3	12.5	92.4
	1 day	1	.5	.7	93.1
	several days	1	.5	.7	93.8
	No load shedding	9	4.7	6.3	100.0
	Total	144	74.6	100.0	
Missing	System	49	25.4		
Total		193	100.0		

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Among respondents connected to the national grid, 43% had received some kind of information about a schedule (Table 20). Among those who did receive information (even if not accurate) (n=62), most got this information via radio and SMS (Table 21).

Table 20 Received information on load shedding schedule (all National grid users)

		Frequency	Percent
Valid	Yes	42	29.2
	Sometimes	20	13.9
	No	81	56.3
	Total	143	99.3
Missing	System	1	.7
Total		144	100.0

Table 21 Sources of information on load shedding schedules

	Frequency	Valid percent (n=61[3])
radio	58	95.1
Printed notice	0	0.0
newspapers	5	8.2
internet	1	1.6
SMS	51	83.6
neighbours	9	14.8
other	2	3.3

[3] Although 62 respondents said they got information, only 61 answered the question on sources of this information.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

4.4 Characteristics of cooking practice

4.4.1 Meals and timing

Table 22 shows that it is common practice to cook three meals per day[4]. A dichotomous variable was created to explore which households cooked fewer than three meals per day (category 1 = 1 or 2 meals/day; category 2 = 3 meals/day). Households cooking fewer than three meals per day tend to be smaller, and to have fewer children (MW U-test p = 0.006, and p = 0.004 respectively).

Table 22 Number of meals cooked (per day)

		Frequency	Percent
Valid	1	2	1.0
	2	25	13.0
	3	153	79.3
	4	6	3.1
	5	3	1.6
	Total	189	97.9
Missing	System	4	2.1
Total		193	100.0

80% OF RESPONDANTS REPORTED COOKING 3 MEALS A DAY.

92% OF PARTICIPANTS HEAT WATER FOR BATHING.

92% of respondents heated water for bathing (in addition to cooking food and boiling water for drinks).

The most common times to start cooking meals (modes) were:

- Breakfast: 9.00
- Lunch: 13.00
- Dinner: 19.00

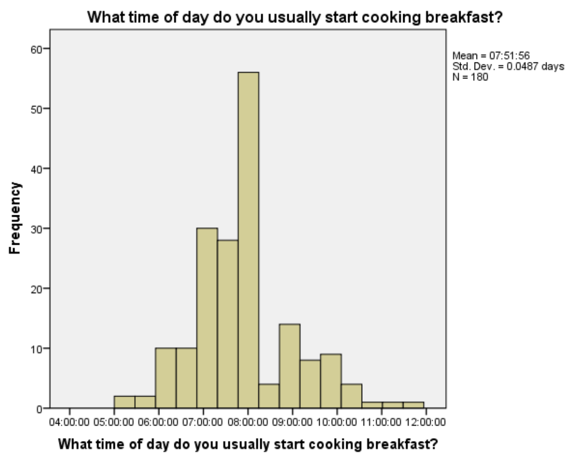
BREAKFAST IS TYPICALLY PREPARED AT 9:00, LUNCH AT 13:00 & DINNER AT 19:00.

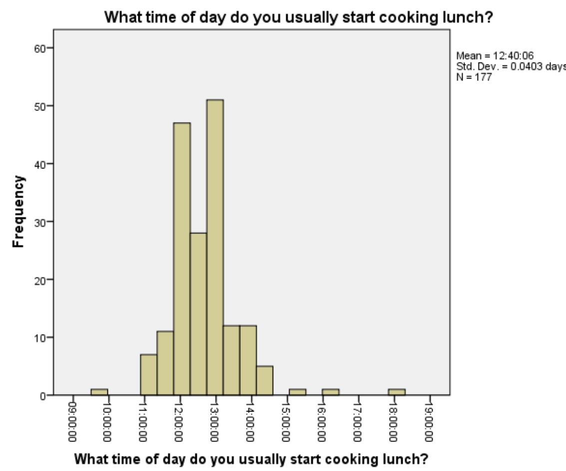
[4] No detail is available on which meals are omitted among households cooking only one or two meals per day.

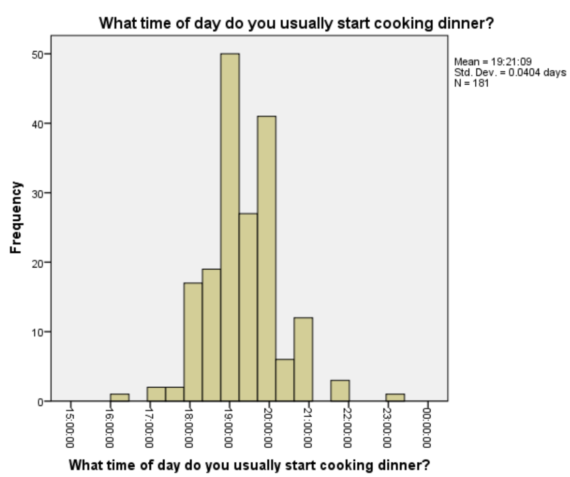
This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

The distributions of starting times are presented in Figure 6 and show that 90% of households start cooking:

- breakfast between 6.00 and 10.00
- lunch between 11.30 and 14.00
- dinner between 18.00 and 21.00.







RESPONDENTS SPEND AN AVERAGE OF 2.7 HOURS/DAY COOKING.

Figure 6 Distribution of times for starting to prepare meals

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Households spend an average of 2.7 hours/day cooking (median = 2.5 hours/day). Figure 7 shows that the mode is 2 hours/day. As might be expected, there is a correlation between time spent cooking and the number of meals cooked per day (r = 0.207, p = 0.006).

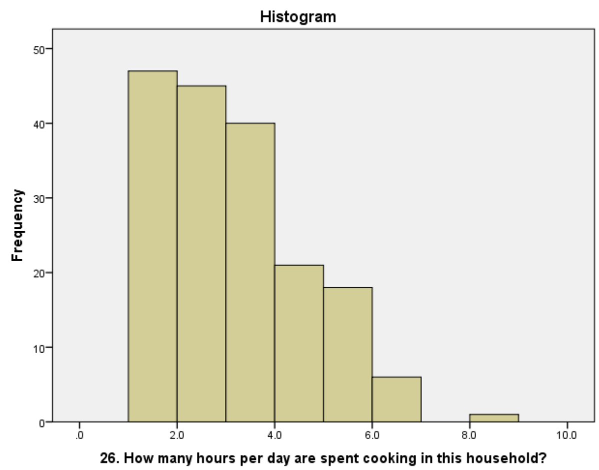


Figure 7 Distribution of time spent cooking (hours/day)

In 83% of households, it was a woman who did most of the cooking, and in 11% of households it was a man who did the majority of the cooking; only in 7% of households did men and women shared cooking. The norm was a female spouse of the head of the household or another female family member to do the majority of the cooking (see Table 23). N.B. no detail was gathered on who those family members were.

Table 23 Gender of persons who do the majority of cooking in the household[5]

Description	Gender			Total	Valid percent
	Male	Female	Both		
Head of household	7	14	1	22	11.8
Spouse of head	2	78	5	85	45.5

UNSURPRISINGLY, PARTICIPANTS REPORTED THAT WOMEN ARE USUALLY RESPONSIBLE FOR COOKING (83%), HOWEVER, IN 11% OF HOUSEHOLDS, MEN DO THE MAJORITY OF COOKING & IN 7% IT IS A SHARED RESPONSIBILITY, INDICATING THAT MARKETING ECOOK PRODUCTS & SERVICES TO MEN IS ALSO IMPORTANT. IN FACT, THE EVIDENCE FROM THE FOCUS GROUPS SUGGESTS THAT APPLIANCES SUCH AS ELECTRIC PRESSURE COOKERS (EPCS) CAN MAKE COOKING MUCH EASIER, WHICH MAY ENOCOURAGE MORE MEN TO COOK

[5] This was asked as multiple response question, so totals add up to more than 100%.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Other family member	4	52	4	60	32.1
Maid / cook	0	6	2	8	4.3
Other	7	15	3	25	13.4

4.4.2 Cooking fuels

Charcoal and electricity were the fuels most commonly used for cooking, followed by wood (Table 24). Most households used only a single fuel for cooking (Table 25). Of the 50% of respondents who did not use electricity for cooking, 82% had some prior experience of cooking with electricity. Electricity is clearly a part of cooking culture, given that over 90% of this sample had at least some experience of cooking with electricity.

Among households using only a single cooking fuel, charcoal was the clear favourite, with other users being split equally between electricity and wood (see Table 26). The pairing of cooking fuels among those households using two cooking fuels is presented in Table 27, along with the split of fuels regarded as the main cooking fuel. This shows that:

- Electricity and charcoal were most commonly used together; users were split equally among those using electricity and those using charcoal as their main cooking fuel.
- In a small number of cases charcoal was used in conjunction with wood as a backup fuel.

CHARCOAL & ELECTRICITY WERE THE MOST COMMON COOKING FUELS AMONG PARTICIPANTS, FOLLOWED BY WOOD. CHARCOAL WAS THE MOST POPULAR FUEL AMONG SINGLE FUEL USERS. HOWEVER, AMONG FUEL STACKERS, ELECTRCITY WAS EQUALLY LIKLEY TO BE USED AS A BACKUP FOR CHARCOAL, AS CHARCOAL WAS TO BACKUP ELECTRICITY.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 24 Cooking fuels

Fuel	Fuels used[6]		MAIN cooking fuel	
	Frequency	Valid Percent	Frequency	Valid Percent
Electricity	95	49.5	53	27.7
Charcoal	167	87.0	125	65.4
Wood	23	12.0	13	6.8
Total			191	100.0

THE VAST MAJORITY OF RESPONENTS ALREADY HAD SOME EXPERIENCE WITH COOKING WITH ELECTRICTY, HOWEVER IT IS UNCLEAR WHETHER THIS WAS A POSITIVE OR NEGATIVE EXPERIENCE.

Table 25 Number of cooking fuels used

		Frequency	Valid Percent
Valid	1	101	52.6
	2	89	46.4
	3	2	1.0
	Total	192	100.0
Missing	System	1	
Total		193	

[6] N.B. multiple response.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 26 Cooking fuel used - household uses single fuel only

		Frequency	Percent
Valid	Electricity	13	12.9
	Charcoal	76	75.2
	Wood	12	11.9
	Total	101	100.0

Table 27 Combinations of fuels used for cooking (and MAIN cooking fuel) - households using two cooking fuels

	Electricity	Charcoal	Wood
Electricity			
Charcoal	80 (elec 39, char 41)		
Wood	0	9 (char 7, wood 1)	

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

The cooking location within the household is split roughly equally between indoors and outdoors (Table 28). Cooking location preference for individual fuels is presented in Table 29 and confirm that both wood and charcoal are used indoors.

Table 28 Cooking location (within the household)

		Frequency	Valid Percent
Valid	Indoors	42	22.3
	Outdoors	47	25.0
	Both	99	52.7
	Total	188	100.0
Missing	System	5	
Total		193	

Table 29 Cooking location broken down by main cooking fuel – single cooking fuel only

Main cooking fuel	Cooking location			Total
	Indoors	Outdoors	Both	
Electricity	11	0	2	13
Charcoal	13	33	30	76
Wood	6	5	0	11
Total	30	38	32	100

4.4.3 Cooking devices

Among households in the sample, basic stoves are by far the most commonly used cooking device (Table 30). Electric devices are the next most common, particularly electric cookers. Note the relatively small number of households using improved stoves. Most households have one or two cooking devices (Table 31).

ELECTRICITY IS ALMOST EXCLUSIVELY USED INDOORS, WHILST WOOD AND CHARCOAL ARE USED BOTH INDOORS & OUTDOORS. THIS MAY SUGGEST THAT SOME HOUSEHOLDS ARE AWARE OF THE HEALTH IMPLICATIONS OF USING BIOMASS STOVES INDOORS, OR IT MAY SIMPLY BE THAT BIOMASS STOVE USERS, WHO ARE LIKELY TO BE POORER & THEREFORE HAVE SMALLER HOMES, HAVE LESS INDOOR SPACE TO COOK IN. UNLIKE DIRECT AC COOKING APPLIANCES, BATTERY-SUPPORTED STOVES CAN BE USED INDOORS OR OUTDOORS, SO THE COOK IS FREE TO CHOOSE WHERE THEY WANT TO COOK.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

There is an apparent anomaly in the data in that 12.9% of households using a single fuel used electricity (Table 26), yet only 6.5% of households with a single device used electric devices (Table 32). This can be explained by the finding that people who rely on electricity only for cooking have multiple electrical devices.

HALF THE PEOPLE WHO REPORTED COOKING WITH ELECTRICITY BUT DID NOT FUEL STACK WITH ANY OTHER FUEL WERE 'APPLIANCE STACKERS', I.E. THEY COOKED WITH MULTIPLE ELECTRIC APPLIANCES. THIS SHOWS THAT, JUST AS EACH FUEL HAS DESIRABLE & UNDESIRABLE CHARACTERISTICS THAT MAKE IT BETTER/WORSE FOR CERTAIN FOODS OR OCCASIONS, SO DOES EACH ELECTRIC APPLIANCE.

Table 30 Number of households owning cooking devices

Device	Frequency	Percent
3 stone fire	19	9.8%
Basic stove (wood, charcoal, dung etc.)	161	83.4%
Improved biomass cookstove	10	5.2%
single kerosene burner		
double kerosene burner		
Gas burner (portable) - single		
Gas burner (portable) - double		
Gas cooker (rings and oven)		
Gas oven		
Induction stove		
Electric hotplate - 1 hob	1	0.5%
Electric hotplate - 2 hob	32	16.6%
Electric hotplate - more than 2 hob	26	13.5%
Electric Cooker (rings and oven)	41	21.2%
Electric oven	22	11.4%

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Electric water heater	14	7.3%
Microwave	21	10.9%
Toaster -	25	13.0%
Rice cooker	14	7.3%
Electric slow/multicooker (pressure cooker)	10	5.2%
Other	2	1.0%

JUST OVER HALF THE SAMPLE (57%) REPORTED USING MULTIPLE COOKING DEVICES, WITH SOME HOUSEHOLDS REPORTING OWNING UP TO 8 DIFFERENT COOKING DEVICES!

Table 31 Number of cooking devices in the household

		Frequency	Valid Percent
Valid	1	77	43.0
	2	52	29.1
	3	19	10.6
	4	10	5.6
	5	11	6.1
	6	6	3.4
	7	3	1.7
	8	1	.6
	Total	179	100.0
Missing	System	14	
Total		193	

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 32 Number of households owning cooking devices – households with single device

Device	Frequency	Percent (n=77)
3 stone fire	8	10.4%
Basic stove (wood, charcoal, dung etc.)	64	83.1%
Improved biomass cookstove	3	3.9%
Electric hotplate - 2 hob	1	1.3%
Electric hotplate - more than 2 hob	1	1.3%

FOR HOUSEHOLDS WITH A SINGLE COOKING DEVICE, THE BASIC BIOMASS STOVE WAS BY FAR THE MOST POPULAR (83%).

The survey also asked about non-cooking electrical appliances; 40% of households had fridges (n=77), and 20% had freezers (n=38) but most freezer owners had fridges, so these probably represent fridge-freezers i.e. 44% of households had either a refrigerator, freezer or fridge-freezer (n=84).

4.5 Fuel consumptions and costs

4.5.1 Electricity

Of 144 households that had a grid connection, all but one had a direct connection. Among those with direct connections, monthly was the most common period for topping up electricity, followed by twice monthly (see Table 33). People most commonly top up with 100 ZMK, then 150, or 200 ZMK (Table 34). These two sets of figures have been combined to calculate the monthly cost of electricity (Figure 8). The mean expenditure was 206 ZMK/month. Monthly electrical energy consumptions have then been calculated from monthly electricity costs on the basis of the Metered residential tariffs (prepaid) published by ZESCO[7]:

- 0-200 kWh 0.15 ZMK/kWh
- > 200 kWh 0.51 ZMK/kWh

[7] http://www.zesco.co.zm/customerCare/tariffs

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 33 Frequency of topping up electricity meter

Days		Frequency	Valid Percent
Valid	0	2	2.2
	3	2	2.2
	5	2	2.2
	7	6	6.5
	12	1	1.1
	14	6	6.5
	15	1	1.1
	18	2	2.2
	21	14	15.1
	26	4	4.3
	27	1	1.1
	28	8	8.6
	30	41	44.1
	31	1	1.1
	60	2	2.2
	Total	93	100.0
Missing	System	50	
Total		143	

IT IS IN POSSIBLE TO TOP UP YOUR ELECTRICITY METER WITH JUST ENOUGH UNITS TO COOK A SINGLE MEAL, I.E. IN THE SAME WAY THAT MANY PEOPLE PAY FOR CHARCOAL. HOWEVER, ONLY 2 PARTICIPANTS REPORTED DOING THIS.

MOST RESPONDENTS (59%) REPORTED TOPPING UP THEIR ELECTRICITY METER EVERY 3-4 WEEKS. THIS MEANS THERE IS LIKELY TO BE A DISCONNECT BETWEEN WHAT PEOPLE SPEND ON ELECTRICITY & THEIR COOKING PRACTICES, AS CHANGING THE WAY YOU COOK WON'T HAVE AN EFFECT ON HOW MUCH YOU ARE SPENDING FOR SEVERAL WEEKS.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 34 Amounts paid when topping up electricity meter

		Frequency	Valid Percent
Valid	0	2	2.2
	20	1	1.1
	40	1	1.1
	50	10	10.8
	60	1	1.1
	70	5	5.4
	80	1	1.1
	90	1	1.1
	100	27	29.0
	110	1	1.1
	130	1	1.1
	150	16	17.2
	200	15	16.1
	220	1	1.1
	250	2	2.2
	300	2	2.2
	358	1	1.1
	360	1	1.1
	400	1	1.1
	500	1	1.1
	700	1	1.1
	2000	1	1.1
	Total	93	100.0
Missing	System	50	
Total		143	

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

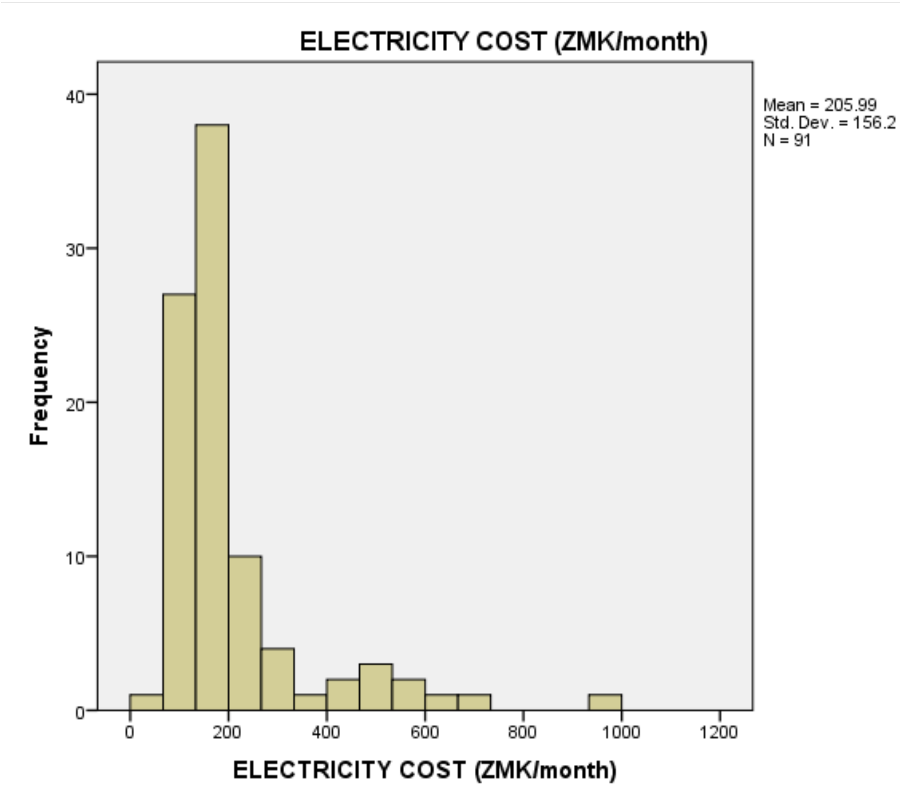


Figure 8 Monthly cost of electricity (ZMK/month)

THE MEAN MONTHLY EXPENDITURE ON ELECTRICTY (FOR COOKING & OTHER PURPOSES) WAS ROUGHLY 200 ZMK (15 USD). THIS WORKS OUT AT 360 KWH/MONTH, OR 12 KWH/DAY, WHICH IS VERY HIGH, HOWEVER ZAMBIA HAS ONE OF THE LOWEST TARIFFS IN SUB-SAHARAN AFRICA, WHICH DOES NOT ENCOURAGE ENERGY EFFICIENCY.

"Electricity tariffs in Zambia remain among the lowest in Sub-Saharan Africa."[8]

4.5.2 Charcoal

Only those respondents who used charcoal for cooking were asked for details of their consumption of charcoal. Charcoal consumption is difficult to assess because people buy it in a wide variety of measures e.g. bag, bucket, sack. Many respondents have estimated the amount of charcoal in kg, and others have described the measure used; estimated capacities of these measures are given in Table 35.

[8] http://documents.worldbank.org/curated/en/571041495102306927/pdf/ITM00194-P162760-05-18-2017-1495102304619.pdf

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 35 Estimated capacity of charcoal measures

	kg
Small plastic bag	2.5
Plastic bag	5
Medium sized bag	25
Medium sized bag (with charcoal over edge)	50
Large bag (sack)	90

Nearly half of charcoal users buy charcoal on a monthly basis, but most buy more frequently - 20% buy small amounts every day or every other day (Table 36). Charcoal is most commonly bought in 25 kg, 50 kg, and 90 kg sacks (Table 37). Again, over 10% of charcoal users usually buy charcoal in small amounts (2.5 kg and less).

ALMOST HALF OF THE CHARCOAL USERS BUY MONTHLY, HOWEVER 20% BUY IN SMALL QUANTITIES ON A DAILY BASIS. ECOOK SYSTEMS WITH MONTHLY REPAYMENT PLANS ARE LIKELY TO BE ATTRACTIVE TO THE FORMER, HOWEVER MORE FREQUENT REPAYMENT OPTIONS WILL BE NECESSARY TO REACH THE LATTER, WHO ARE LIKELY TO BE THE POORER HOUSEHOLDS.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 36 Frequency of purchasing charcoal (days)

		Frequency	Valid Percent
Valid	1	24	15.1
	2	8	5.0
	3	2	1.3
	4	2	1.3
	7	6	3.8
	9	1	.6
	10	1	.6
	14	17	10.7
	15	1	.6
	21	12	7.5
	25	1	.6
	28	6	3.8
	30	71	44.7
	40	1	.6
	44	1	.6
	60	5	3.1
	Total	159	100.0
Missing	System	34	
Total		193	

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 37 Amounts of charcoal bought (kg)

		Frequency	Valid Percent
Valid	.7	1	.8
	2.0	2	1.5
	2.5	11	8.3
	5.0	4	3.0
	10.0	8	6.1
	12.5	1	.8
	15.0	1	.8
	20.0	1	.8
	25.0	33	25.0
	40.0	1	.8
	45.0	1	.8
	50.0	27	20.5
	75.0	1	.8
	90.0	31	23.5
	100.0	6	4.5
	130.0	2	1.5
	240.0	1	.8
	Total	132	100.0
Missing	System	61	
Total		193	

There are only modest differences in the prices paid for charcoal between rural and urban areas (see Table 38). Amounts paid and how long purchases last have been combined to give figures for monthly expenditure on charcoal (see Figure 9). Urban respondents paid on average 40% more for charcoal: mean expenditure of 136 ZMK/month (n=113) compared to a mean of 97 ZMK/month among rural respondents (n=43).

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 38 Specific charcoal prices

	Mean (ZMK/kg)	Median (ZMK /kg)	Std.dev.	25% quartile (ZMK /kg)	75% quartile (ZMK /kg)
Rural	1.77	1.73	1.21	1.19	2.00
Urban	1.82	2.00	0.54	1.40	2.00

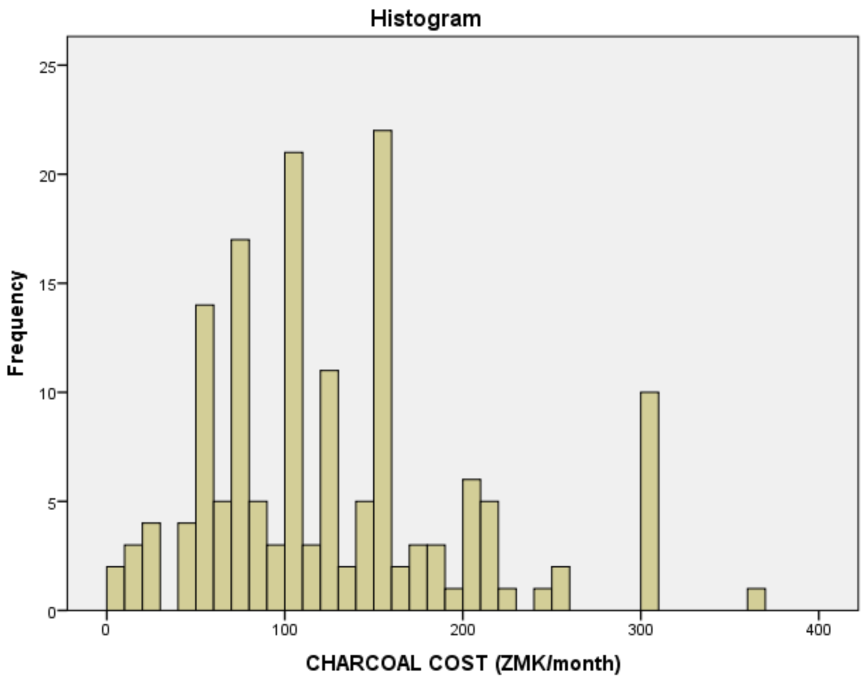


Figure 9 Monthly cost of charcoal (ZMK/month)

URBAN PARTICIPANTS REPORTED SPENDING AROUND 40% MORE ON CHARCOAL PER MONTH THAN RURAL PARTICIPANTS: 136 VERSUS 97 ZMK./MONTH 10 VERSUS 7 USD/MONTH. INTERNATIONALLY, THESE EXPENDITURES ARE QUITE LOW, HOWEVER GRID TARIFFS IN ZAMBIA ARE ALSO VERY LOW.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

4.5.3 Wood

23 respondents used wood for cooking, of which 13 used it as their main cooking fuel (Table 24). Only 18 respondents provided information on purchasing wood. Most of these are from rural areas (n=10). Interestingly, rural respondents also paid for wood – see Table 39.

Table 39 Amounts spent on wood (irrespective of amount of wood purchased)

		SETTLEMENT (rural/urban)		Total
		rural	urban	
83. How much did you spend last time you bought wood? (ZMK)	0	4	1	5
	5	0	1	1
	20	2	0	2
	30	1	0	1
	50	6	0	6
	120	1	0	1
	300	2	0	2
Total		16	2	18

There was not enough data on the amount of wood consumed to deduce the mass of wood represented by the various units of wood use e.g. bundles, wheelbarrows. The most commonly paid price was 50 ZMK (Table 39), and most people purchased wood on a monthly basis (Table 40). Only 4 respondents bought wood several times a week.

INTERESTINGLY, MANY RURAL FIREWOOD USERS ALSO REPORTED PAYING FOR IT. THE MEAN EXPENDITURE FOR THE WHOLE SAMPLE WAS 79 ZMK/MONTH OR 6 USD/MONTH. THIS IS LOWER THAN THE ANTICIPATED COSTS OF PV-ECOOK SYSTEMS, HOWEVER, IF THE TREND OF DECREASED ACCESS TO THE BUSH DUE TO INCREASED URBANISATION CONTINUES, THESE PRICES MAY WELL RISE & CHARCOAL MAY WELL BECOME EVEN MORE WIDELY USED, AS IT CAN BE TRANSPORTED FROM FURTHER AWAY.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 40 Frequency of purchasing wood

Days		Frequency	Valid Percent
Valid	1	1	5.6
	3	1	5.6
	14	2	11.1
	21	3	16.7
	30	10	55.6
	90	1	5.6
	Total	18	100.0
Missing	System	175	
Total		193	

Amounts paid and how long purchases last have been combined to give figures for monthly expenditure on wood (see Figure 10). The mean expenditure was 79 ZMK/month. Only one rural respondent paid for wood.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

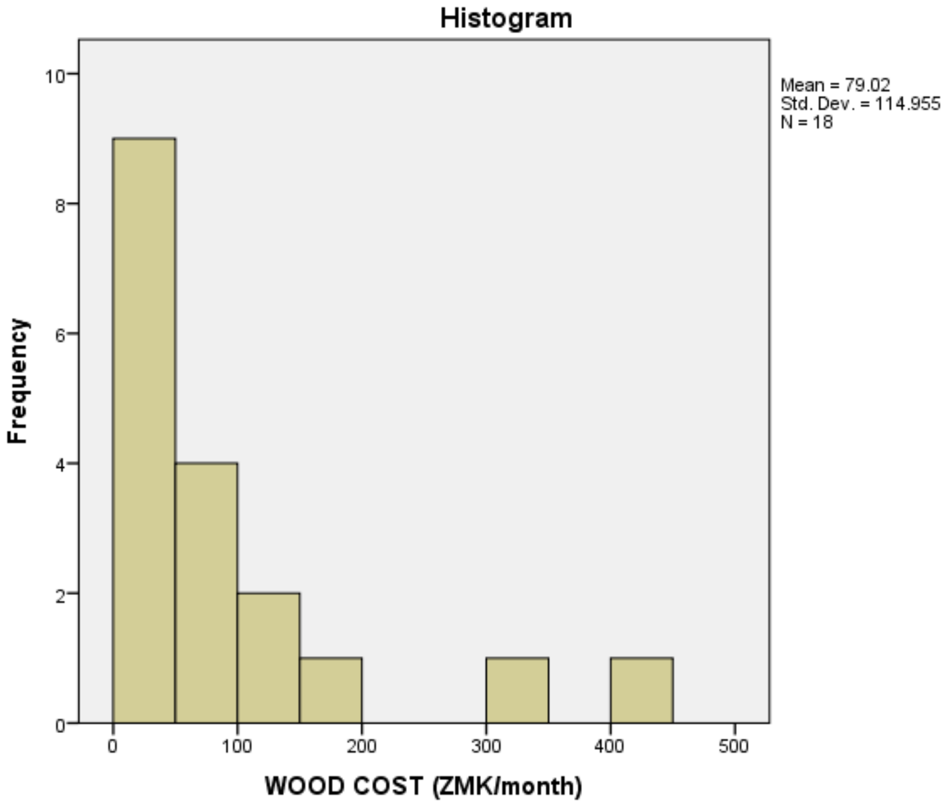


Figure 10 Monthly cost of wood (ZMK/month)

4.5.4 Energy consumptions

Energy consumptions have been based on the calorific values given in Table 41.

Table 41 Calorific values and conversion efficiencies[9]

Fuel	Calorific value
Wood	15.9 MJ/kg
Charcoal	29.9 MJ/kg
Kerosene	34.9 MJ/ltr
LPG	44.8 MJ/kg
Electricity	3.6 MJ/kWh

[9] Source: World Bank (BLG14 Cooking Costs by Fuel Type.xlsx)

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Figure 11 presents the total energy consumed in a month by all respondents in each settlement grouping (i.e. the urban sample is roughly two and a half times the size of the rural sample). This shows that in both rural and urban areas, the energy content of charcoal consumed is higher than the energy content of electricity consumed.

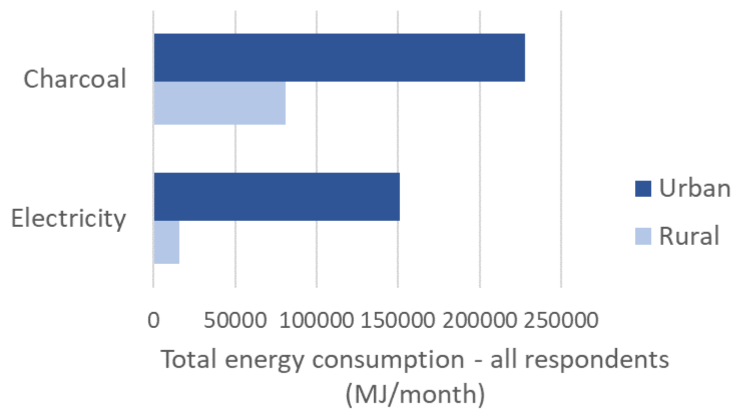


Figure 11 Energy consumptions (sum).

Energy consumptions have been divided by the number of household members to arrive at estimates of per capita energy consumptions for each fuel. Results in Figure 12 shows that specific consumptions of electricity and charcoal were similar among urban respondents, and specific consumptions of both fuels were also similar among rural respondents. However, rural users used less energy for both fuels. N.B. these figures include respondents who used multiple fuels.

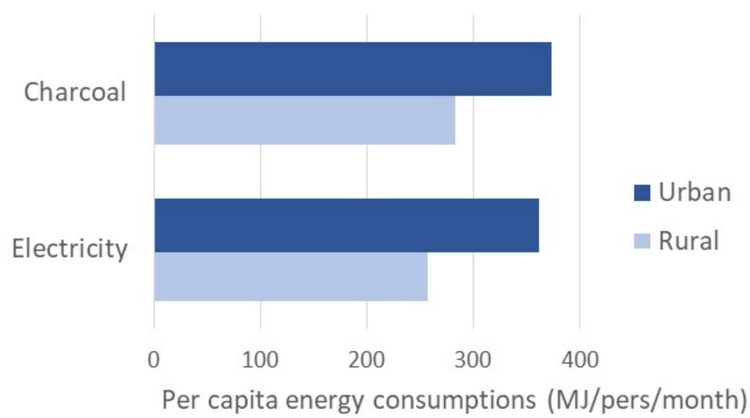


Figure 12 Per capita energy consumptions (valid users)

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

The analysis in Figure 12 simply considers differences between different fuels, and takes no account of fuel stacking – use of multiple fuels in a household. The main sources of energy used for cooking, including combinations of fuels, are presented in Table 42 (N.B. only 2% of households use combinations of energy not included in this typology). Household energy consumptions have been calculated only for those households where valid energy consumption data is available for all sources of energy used for cooking.

Table 42 Most common combinations of fuels used for cooking

		Frequency	Percent
Valid	Electricity only	13	6.7
	Charcoal only	76	39.4
	Wood only	12	6.2
	Electricity & charcoal	80	41.5
	Charcoal & wood	9	4.7
	Total	190	98.4
Missing	System	3	1.6
Total		193	100.0

ELECTRICITY & CHARCOAL/FIREWOOD ARE USEFUL FOR OTHER THINGS TOO. ALMOST ALL PARTICIPANTS WHO COOKED WITH ELECTICITY REPORTED USING IT FOR LIGHTING & REFRIGERATION, WHILST HALF REPORTED USING IT FOR WATER HEATING. IN CONTRAST, CHARCOAL WAS ALMOST UNIVERSALLY ALSO USED FOR WATER HEATING & BY ABOUT A THIRD FOR SPACE HEATING.

The finding in Figure 12 that per capita electrical energy consumption is similar to the per capita consumption of charcoal energy is counterintuitive – given that the conversion efficiency of electricity to heat is much higher than that for charcoal, one would expect the specific consumption figures for electricity to be much lower. Table 43 shows that electricity is used for more than cooking, but so is charcoal, so parity of specific energy consumptions cannot be explained by non-cooking uses of electricity. It is not possible to determine cooking energy consumptions from these data.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 43 Additional uses of fuels used for cooking

	Electricity (n=93) Frequency (valid percent)	Charcoal (n=156) Frequency (valid percent)	Wood (n=21) Frequency (valid percent)
lighting	93 (100%)		
refrigeration	85 (91%)		
Water heating	51 (55%)	151 (97%)	18 (86%)
Space heating	11 (12%)	59 (38%)	10 (48%)
other	23 (25%)	28 (18%)	4 (19%)

4.5.5 Cooking times

Results in Table 44 indicate that it takes longer to cook with electricity and cooking with wood is fastest (note that this finding is significant at only a 94% confidence level). This cannot be explained by the number of meals cooked per day (no difference across main cooking fuel choices), nor by the size of the household, which actually acts In the opposite sense, given that households using electricity are smaller (see Table 44).

INTERESTINGLY, RESPONDENTS WHO COOK WITH ELECTRICITY REPORTED SPENDING MORE TIME COOKING (3.1 HRS/DAY) THAN CHARCOAL (2.7 HRS/DAY) OR WOOD (2.2 HRS/DAY). THIS COULD BE BECAUSE THE ELECTRIC APPLIANES IN USE ARE QUITE INEFFICIENT & SLOW. IN WHICH CASE, THERE MAY BE AN OPPORTUNITY FOR ECOOKING DEVICES SUCH AS THE ELECTRIC PRESURE COOKER (EPC) THAT CAN COOK MUCH FASTER.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 44 Time spent cooking by choice of main cooking fuel

Means	Electricity (n)	Charcoal (n)	Wood (n)	KW test (p value)
Time spent cooking (hour/day)	3.1 (50)	2.7 (114)	2.2 (13)	0.058
Number of people in household	4.4 (53)	5.4 (124)	6.4 (13)	0.003

4.6 Beliefs and attitudes

4.6.1 Perceptions on fuels

THE LPG MARKET IN ZAMBIA IS NASCENT, SO MOST RESPONDENTS DID NOT HAVE OPINIONS ON IT. HOWEVER, OF THOSE THAT DID THOUGHT IT WAS DIFFICULT TO ACCESS, UNSAFE & EXPENSIVE.

Figure 13 and Figure 14 indicate that respondents had little understanding of coal and LPG as cooking fuels (most respondents had no opinion). Charcoal was clearly the only fuel regarded as easy to access, and the only fuel generally regarded as safe (N.B. electricity was not included in these questions). A further set of questions on various aspects of different fuels provide further insights (see Figure 15):

- While most respondents regarded smoke as a problem, opinion was split on the positive aspects of smoke in controlling insects and flavouring food.
- Firewood was regarded as inconvenient, while charcoal was regarded as convenient.
- Most respondents were aware that firewood is harmful to health, but they were less likely to feel that charcoal is harmful to health.
- Respondents were more likely to agree that electricity, rather than firewood, was expensive for cooking.
- Most respondents were unaware of the cost of LPG.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

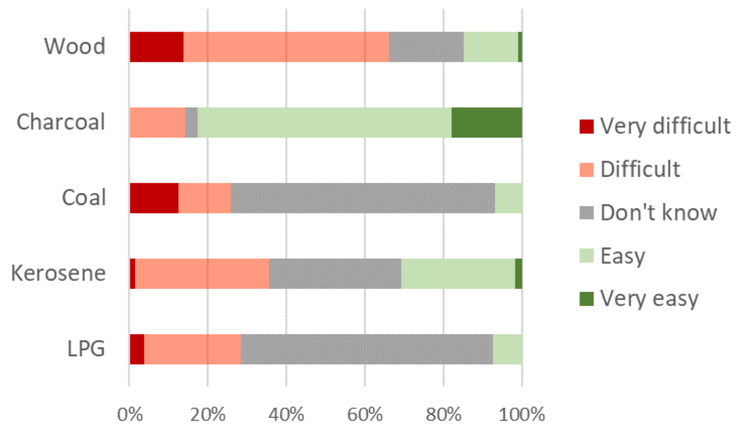


Figure 13 Ease of access to fuels

EASE OF ACCESS ACTS AS A BARRIER TO WOOD USE, BUT NOT FOR CHARCOAL, SUGGESTING THAT CHARCOAL IS MORE READILY AVAILABLE.

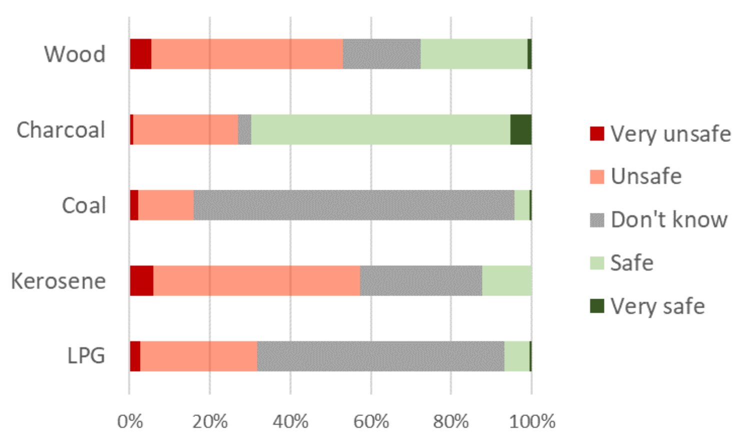


Figure 14 Safety of fuels

CHARCOAL IS REGARDED AS THE SAFEST FUEL ACROSS ALL GROUPS OF USERS (N.B. ELECTRICITY WAS NOT INCLUDED IN THESE QUESTIONS) AND IS NOT, THEREFORE, INFLUENTIAL IN CHOICE OF FUELS. PERCEPTIONS REGARDING THE SAFETY OF WOOD, ON THE OTHER HAND, ARE LINKED TO THE CHOICE OF WOOD FOR COOKING.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

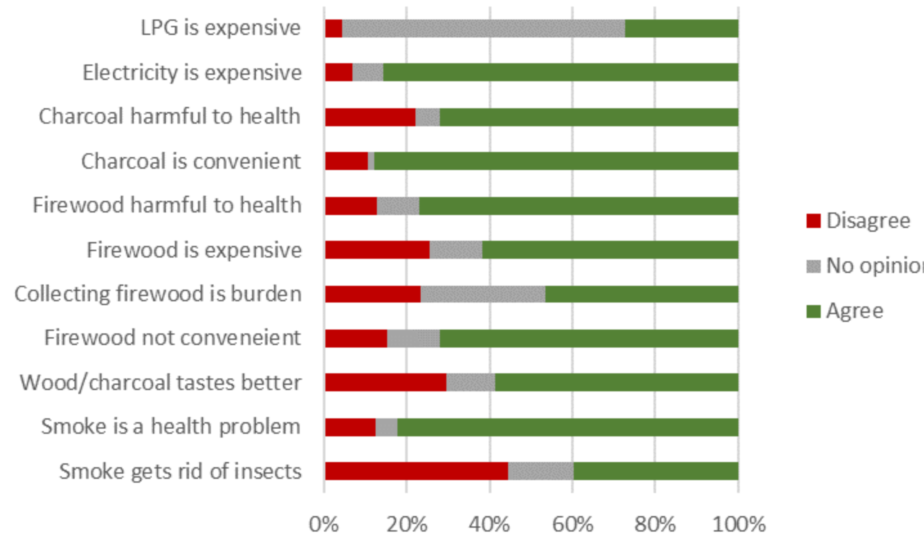


Figure 15 Perceptions of fuels

SMOKE IS REGARDED AS A HEALTH HAZARD AMONG ALL GROUPS, SO DOES NOT PLAY A ROLE IN CHOICE OF FUELS. HOWEVER, BELIEFS IN POSITIVE ASPECTS OF SMOKE (AS AN INSECT REPELLENT AND IN FLAVOURING FOOD) ACT AS BARRIERS FOR ELECTRICITY USE I.E. CHARCOAL & WOOD USERS HELD MORE POSITIVE VIEWS ON THESE BELIEFS.

Mean attitude scores have been calculated for groups of respondents that use each fuel as their main cooking fuel (Table 45). The following relationships can be seen:

- People who choose electricity and charcoal find it difficult to access wood
- People who choose electricity and charcoal regard wood as unsafe
- Charcoal is regarded as the safest fuel across all groups of users (N.B. electricity was not included in these questions)
- Electricity users do not believe that smoke is an effective insect repellent
- Charcoal and wood users are more likely to feel that these fuels make food taste better
- Wood users are less likely to feel that wood is expensive and that collection is a burden
- The belief that electricity is expensive appears to act as a driver for use of charcoal.

COST IS CLEARLY AN IMPORTANT ISSUE. THE BELIEF THAT ELECTRICITY IS EXPENSIVE APPEARS TO ACT AS A DRIVER FOR USE OF CHARCOAL. THE BELIEF THAT WOOD IS EXPENSIVE ACTS AS A BARRIER TO THE USE OF WOOD.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 45 Attitudes by choice of main cooking fuel (mean values)

	Range	33. What is your MAIN cooking fuel?			K-W P value
		Electricity	Charcoal	Wood	
N		53	125	13	
How easy is it to access LPG?	-2 to +2	-0.06	-0.33	-0.23	**0.016**
How easy is it to access kerosene?	-2 to +2	0.3	-0.19	-0.15	**0.002**
How easy is it to access coal?	-2 to +2	-0.55	-0.23	-0.15	**0.046**
How easy is it to access charcoal?	-2 to +2	1.09	0.8	0.54	**0.034**
How easy is it to access wood?	-2 to +2	-0.7	-0.76	0.69	**0**
How safe is LPG?	-2 to +2	-0.11	-0.35	-0.15	**0.039**
How safe is kerosene?	-2 to +2	-0.46	-0.55	-0.31	0.441
How safe is coal?	-2 to +2	-0.19	-0.11	-0.08	0.766
How safe is charcoal?	-2 to +2	0.43	0.45	0.85	0.533
How safe is wood?	-2 to +2	-0.19	-0.42	0.38	**0.013**
Smoke from stove is good at chasing insects away.	-1 to +1	-0.34	0.06	0.15	**0.025**
Smoke from cooking fuels is a big health problem.	-1 to +1	0.57	0.74	0.85	0.28
food tastes better when cooked with charcoal/wood	-1 to +1	0.04	0.38	0.54	**0.036**
Cooking with firewood is not convenient.	-1 to +1	0.64	0.58	0.15	0.093
Collecting/preparing firewood is a family burden	-1 to +1	0.06	0.37	-0.31	**0.002**
Firewood is expensive for cooking.	-1 to +1	0.49	0.39	-0.46	**0.001**
Cooking with firewood is harmful to health.	-1 to +1	0.72	0.65	0.31	0.119
Charcoal is convenient to use for cooking.	-1 to +1	0.65	0.84	0.62	0.147
Cooking with charcoal is harmful to health.	-1 to +1	0.6	0.46	0.42	0.608
Electricity is expensive for cooking.	-1 to +1	0.58	0.89	0.58	**0.007**
LPG is expensive for cooking.	-1 to +1	0.06	0.3	0.23	**0.017**

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

4.6.2 Purchasing preferences

When it comes to purchasing substantial household items, most respondents said they would make decisions jointly (Table 46). The head female of the household was more likely to be involved in purchasing a cooker than in purchasing a solar panel, but not by much.

Table 46 Main decision maker for hypothetical household purchases

	Cooking device		Solar panel	
	Frequency	Percent	Frequency	Percent
male head of house	35	18.1	50	25.9
female head of house	32	16.6	20	10.4
joint decision	114	59.1	111	57.5
another relative			1	.5
Other	7	3.6	6	3.1
Total	188	97.4	188	97.4
System missing	5	2.6	5	2.6
Total	193	100.0	193	100.0

RESPONES SUGGEST THAT PURCHASING DECISIONS ARE GENERALLY MADE TOGETHER, BOTH FOR COOKING & POWER GENERATION EQUIPMENT.

Respondents were split more or less equally on whether or not people would like to rent equipment rather than buy it – see **Error! Reference source not found.**. Having said that, 97% said they would prefer to pay for high value purchases by monthly instalments rather than paying the total cost up front. These potentially contradictory findings indicate that some kind of finance that eliminates the need for a large single payment is important to people, and that they like to end up owning the asset (rather than renting indefinitely). The vast majority of respondents (80%) opted for monthly payments, with the remainder preferring quarterly payments (every 3 months).

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 47 How would people in your neighbourhood feel about the idea of renting equipment?

		Frequency	Percent
Valid	Very opposed	22	11.4
	Opposed	53	27.5
	No opinion	17	8.8
	Positive	92	47.7
	Very positive	4	2.1
	Total	188	97.4
Missing	System	5	2.6
Total		193	100.0

ALMOST ALL RESPONDENTS INDICATED A PREFERENCE FOR PAYING FOR HIGH VALUE ITEMS IN INSTALLMENTS. 80% INDICATED THAT MONTHLY REPAYMENTS WERE PREFERABLE TO QUARTERLY, HOWEVER THE SURVEY DID NOT INCLUDE MORE FREQUENT REPAYMENT OPTIONS, WHICH MAY WELL HAVE BEEN MORE ATTRACTIVE TO THE 20% OF CHARCOAL USERS WHO BUY FUEL ON A DAILY BASIS.

4.6.3 Cooking device preferences

Overall, there appears to be a strong appetite for cooking with some form of modern energy (see Table 48).

Table 48 How many people would switch to modern energy (gas/electric) if fuels cost were the same?

		Frequency	Percent
Valid	none	6	3.1
	a few people	20	10.4
	some people	25	13.0
	many people	117	60.6
	don't know	20	10.4
	Total	188	97.4
Missing	System	5	2.6
Total		193	100.0

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

On details of any proposed design, 91% felt that it would need to take very large pots as well as medium sized ones. There was a clear preference for a square design (72% voted for design A, 13% for design B, and 15% for deign C in Figure 16). Overall, respondents were supportive of the idea of using a device provided by the electricity utility company, ZESCO (see Table 49).

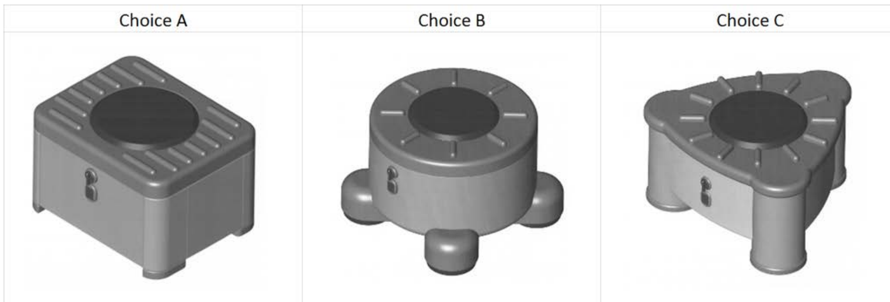


Figure 16 Hypothetical cooking device design options

Table 49 How would you feel about using a cooker provided by ZESCO?

		Frequency	Percent
Valid	Very opposed	2	1.0
	Opposed	16	8.3
	No opinion	22	11.4
	Positive	138	71.5
	Very positive	10	5.2
	Total	188	97.4
Missing	System	5	2.6
Total		193	100.0

When asked about the hypothetical situation of using firewood, a sizable minority (17%) said they would prefer to use a three stone fire rather

60% OF PARTICINTS THOUGHT THAT PRICE WAS THE MAJOR DECIDING FACTOR FOR HOUSEHOLDS CONSIDERING TRANSITIONING TO MODERN ENERGY FOR COOKING, WHICH SUGGESTS THAT THERE ARE OTHER IMPORTANT CONSIDERATIONS TO TAKE INTO ACCOUNT, SUCH AS ACCESS, RELIABILITY & CULTURAL PREFERENCES.

70% OF RESPONDENTS FELT POSITIVELY ABOUT USING A COOKER PROVIDED BY ZESCO, WHICH SLIGHTLY CONTRADICTS THE EARLIER FINDING THAT OPINION ON RENTING EQUIPMENT WAS DIVIDED, AS EVERYTHING PROVIDED TO HOUSEHOLDS BY ZESCO IS RENTED BY THE USER.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

than a cookstove, suggesting that there remains some resistance to change from traditional cooking practices.

4.7 Consumer preferences

4.7.1 Interpreting the results

Discrete choice modelling was used as a means of exploring the key characteristics (or parameters) that cooking devices should have in order to find ready acceptance with consumers. Choice models are set up using choice cards, based on the key parameters identified, each of which has a limited number of 'levels'. The respondent must then choose one of the two cards presented. Discrete choice models predict the probability that an individual will choose an option, based on the levels of each parameter given in the option.

Three sets of choices were posed to respondents, representing different aspects of cooking device design:

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

The two main figures to look for in the results tables in the following sections are the beta coefficients (B), which reflect the strength of preference for each attribute, and whether each coefficient is significant in the model (Sig). If a variable is significant (Sig<0.05), then the larger the B value (positive or negative), the more important it is in the making a choice.

Other statistics presented include the standard error (S.E.), which is a measure of how precise the beta value is likely to be – a large standard error means that that the actual beta value may lie within a wider range. The odds ratio (Exp(B)) is the change in odds resulting from a unit change in the predictor variable and is another measure of the influence the variable has on people's choice, as is the Wald statistic. As all variables have been separated out into dichotomous dummy variables, the degrees of freedom (df) for all variables is 1.

Where the cost variable is significant in a model, a measure of willingness to pay (also known as implicit price) can be derived for each attribute from the ratio of the coefficients (Hanley, Mourato and Wright, 2001):

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

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

where:

β_x = coefficient of any parameter

β_c = coefficient of cost parameter

4.7.2 Discrete choice modelling results

4.7.2.1 Cooking processes

The variables used in the analysis are:

Cooking:

0 = boil only

1 = boil & fry

SpeedMed

0 = slow

1 = normal

Speedfast

0 = slow

1 = fast

Flavour

0 = no smoky flavour

1 = smoky flavour

Potlid

0 = no lid

1 = pot with lid

Pot sealed

0 = no lid

1 = sealed pot

2 hob:

0 = 1 hob

1 = 2 hob

4 hob:

0 = 1 hob

1 = 4 hob

THE COOKING PROCESS DESIGN FEATURES THAT APPEAR TO BE MOST IMPORTANT TO CONSUMERS ARE:

- LID – PEOPLE HAVE A STRONG PREFERENCE FOR A LID, BUT NOT FOR A SEALED POT
- COOKING – PREFER TO BE ABLE TO BOTH BOIL AND FRY
- HOBS – PEOPLE PREFER MULTIPLE HOBS, BUT INTERESTINGLY PEOPLE SEEM ALMOST AS KEEN TO HAVE FOUR HOBS AS TWO.
- COST.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Results from the binary logistic regression are presented in Table 50.

Table 50 Binary logistic regression – cooking processes

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	PRCooking(1)	1.138	.123	85.923	1	.000	3.122
	PRSpeedMed(1)	.224	.140	2.558	1	.110	1.252
	PRSpeedFast(1)	.155	.151	1.049	1	.306	1.168
	PRFlavour(1)	-.201	.136	2.176	1	.140	.818
	PRPotLid(1)	1.409	.185	58.225	1	.000	4.090
	PRPotSealed(1)	.143	.158	.818	1	.366	1.153
	PR2hob(1)	.558	.140	15.922	1	.000	1.747
	PR4hob(1)	.502	.166	9.185	1	.002	1.652
	PRCOSTC	-.413	.083	24.684	1	**.000**	.662
	Constant	-1.416	.209	46.052	1	**.000**	.243

a. Variable(s) entered on step 1: PRCooking, PRSpeedMed, PRSpeedFast, PRFlavour, PRPotLid, PRPotSealed, PR2hob, PR4hob, PRCOSTC.

Note: Compared against a constant only model, the model was significant (χ^2 = 643, $p < 0.001$, with df = 9); Nagelkerke R^2 = 0.268. Prediction success = 72.7%.

Those design features that appear to be most important to consumers are (see Table 51 for estimates of willingness to pay):

- Lid – people have a strong preference for a lid, but not for a sealed pot
- Cooking – prefer to be able to both boil and fry
- Hobs – people prefer multiple hobs, but interestingly people seem almost as keen to have four hobs as two.
- Cost.

COOKING WITH A LID ON THE POT IS MORE ENERGY-EFFICIENT, SO WILL REDUCE THE SIZE OF THE BATTERY & MAKE ECOOK SYSTEMS MORE AFFORDABLE. HOWEVER, A SEALED & PRESSURISED POT IS EVEN MORE EFFICIENT, SO SOME COMPROMISES MATY HAVE TO BE MADE FOR THE LOWEST COST SYSTEMS.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the

Table 51 Willingness to pay for priority characteristics - cooking process

Feature	Willingness to pay (ZMK)
pot with lid	341
boil & fry	276
2 hob	135
4 hob	122

DISCHARGE RATE IS A KEY DETERMINANT OF BATTERY LIFE. FRYING GENERALLY REQUIRES HIGHER POWER THAN BOILING & 2 HOBS REQUIRE TWICE AS MUCH POWER AS ONE. AGAIN, SYSTEM DESIGNERS MAY HAVE TO CHOOSE TO TRADE OFF USABILITY FOR COST IN BUDGET MODELS.

4.7.2.2 Stove

The variables used in the analysis are:

STPeople6:

0 = cooks for 4 people

1 = cooks for 6 people

STPeople8:

0 = cooks for 4 people

1 = cooks for 8 people

STSupplementSometimes

0 = always need to use with other stove

1 = sometimes need to use with other stove

STSupplementAll

0 = always need to use with other stove

1 = you can do all your cooking on it

STWoodSmoke

0 = no smoke

1 = gives same smoke as wood fire

STCharcoalSmoke

0 = no smoke

1 = gives same smoke as charcoal fire

STPortable

0 = cannot be moved (too heavy)

1 = can be carried in/out of the house

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

STLooks

0 = looks plain

1 = Looks good

Results from the binary logistic regression are presented in Table 52.

Table 52 Binary logistic regression – stove design

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	STPeople6(1)	.468	.141	11.089	1	.001	1.597
	STPeople8(1)	.930	.122	58.364	1	.000	2.534
	STSupplement Sometimes(1)	-.378	.148	6.513	1	**.011**	.685
	STSupplement All(1)	-.033	.140	.055	1	.814	.968
	STWoodSmok e(1)	-1.303	.140	86.465	1	.000	.272
	STCharcoalSm oke(1)	-.210	.137	2.357	1	.125	.810
	STPortable(1)	.417	.112	13.736	1	.000	1.517
	STLooks(1)	.178	.108	2.700	1	.100	1.194
	STCOSTC	-.454	.073	38.482	1	**.000**	.635
	Constant	.348	.204	2.906	1	.088	1.417

a. Variable(s) entered on step 1: STPeople6, STPeople8, STSupplementSometimes, STSupplementAll, STWoodSmoke, STCharcoalSmoke, STPortable, STLooks, STCOSTC.

PEOPLE'S STRONGEST PREFERENCE IS FOR A DEVICE THAT AVOIDS THE KIND OF SMOKE GENERATED BY A WOOD FIRE. INTERESTINGLY, PEOPLE DO NOT REGISTER A PREFERENCE FOR NO SMOKE OVER CHARCOAL SMOKE. WOOD SMOKE IS MUCH THICKER THAN CHARCOAL SMOKE THROUGHOUT THE ENTIRE DURATION OF COOKING. HOWEVER, CHARCOAL SMOKE CONTAINS MUCH HIGHER LEVELS OF THE SILENT KILLER: CARBON MONOXIDE.

Note: Compared against a constant only model, the model was significant (χ^2 = 416, p < 0.001, with df = 9); Nagelkerke R^2 = 0.182. Prediction success = 67.0%.

Those design features that appear to be most important to consumers are (see Table 53 for estimates of willingness to pay):

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

- Smoke – people strongest preference is for a device that avoids the kind of smoke generated by a wood fire. Interestingly, people do not register a preference for no smoke over charcoal smoke.
- Capacity – people want to be able to cook for larger numbers of people; top preference is to be able to cook for 8 people, then 6 people.
- Portable – people would like a device that can be carried in/out of the house
- Cost.

Table 53 Willingness to pay for priority characteristics – stove design

Feature	Willingness to pay (ZMK)
Gives same smoke as wood fire	-287
Can cook for 8 people	205
Can cook for 6 people	103
Can be carried in/out of the house	92
Always need to use with other stove	-83

THE MOST IMPORTANT STOVE FEATURES ARE:

- SMOKE –AVOIDING THE KIND OF SMOKE GENERATED BY A WOOD FIRE.
- CAPACITY – PEOPLE WANT TO BE ABLE TO COOK FOR LARGER NUMBERS OF PEOPLE.
- PORTABLE – PEOPLE WOULD LIKE A DEVICE THAT CAN BE CARRIED IN/OUT OF THE HOUSE
- COST.

4.7.2.3 Device Functionality

The variables used in the analysis are:

FULED

0 = 2 hobs

1 = 2 hobs + 3 LED lights

FUMob

0 = 2 hobs

1 = 2 hobs + charge mobile phone

FUTV

0 = 2 hobs

1 = 2 hobs + television

FUAvailabe

0 = only works on sunny days

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

1 = works on sunny and rainy days

FU6yr

0 = pay each month (utility)

1 = lease over 6 years

FU3yr

0 = pay each month (utility)

1 = lease over 3 years

FUCleaning

0 = awkward to clean

1 = easy to clean

Results from the binary logistic regression are presented in Table 54.

Table 54 Binary logistic regression – device functionality

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	FULED(1)	.345	.165	4.396	1	.036	1.412
	FUMob(1)	.523	.172	9.255	1	.002	1.688
	FUTV(1)	.716	.174	17.012	1	.000	2.047
	FUAvailabe(1)	1.111	.114	95.478	1	.000	3.037
	FU6yr(1)	1.152	.148	60.574	1	.000	3.164
	FU3yr(1)	1.282	.128	100.445	1	.000	3.604
	FUCleaning(1)	.257	.117	4.875	1	**.027**	1.293
	FUCOSTC	-.509	.073	49.037	1	**.000**	.601
	Constant	-.636	.203	9.840	1	**.002**	.529

ALL FUNCTIONALITY FEATURES EXPLORED IN THE MODEL WERE SIGNIFICANT. IN ORDER OF PREFERENCE:

- FINANCE – STRONG PREFERENCE FOR LEASE-TO-OWN MODELS IF REPAYMENT SIZES WERE COMPARABLE.
- AVAILABILITY – STRONG PREFERENCE FOR A SYSTEM THAT COULD COOK RELIABLY REGARDLESS OF THE WEATHER.
- ADDITIONAL APPLIANCES - TV, PHONE CHARGEING, THEN LIGHTING.
- EASY TO CLEAN.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

a. Variable(s) entered on step 1: FULED, FUMob, FUTV, FUAvailabe, FU6yr, FU3yr, FUCleaning, FUCOSTC.

Note: Compared against a constant only model, the model was significant (χ^2 = 607, $p < 0.001$, with df = 8); Nagelkerke R^2 = 0.257. Prediction success = 72.1%.

All design features explored in the model were significant (see Table 53 for estimates of willingness to pay):

- Finance – people have a strong preference for leasing models over simply making regular monthly payments (for as long as they used the system). There was a preference for a 3 year lease period over a 6 year period. These findings are potentially difficult to interpret, as people were not given any detail on the relative magnitudes of payments.
- Availability – people had a strong preference for a system that could cook reliably regardless of the weather.
- In terms of appliances (additional to the cooking device), highest priority was TV, followed by the ability to charge a phone, and then lighting.
- Having a device that was easy to clean was of lowest importance (but still significant).

PEOPLE HAVE A STRONG PREFERENCE LEASE-TO-OWN OVER UTILITY MODELS, WITH AS SHORT A REPAYMENT PERIOD AS POSSIBLE. HOWEVER, PRODUCT/SERVICE DESIGNERS MAY AGAIN HAVE TO COMPROMISE TO REACH THE BOTTOM OF THE PYRAMID, AS UTILITY MODELS ARE LIKELY TO HAVE THE LOWEST MONTHLY COSTS, AS THEY HAVE THE LONGEST FINANCING HORIZON.

Table 55 Willingness to pay for priority characteristics – device functionality

Feature	Willingness to pay (ZMK)
lease over 3 years	252
lease over 6 years	226
works on sunny and rainy days	218
2 hobs + television	141
2 hobs + charge mobile phone	103
2 hobs + 3 LED lights	68
easy to clean	50

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

4.7.3 Disaggregating choices

Further analysis was conducted to explore differences in preferences between different groups of respondents. The effects of five demographic variables were investigated:

- Gender
- Settlement (rural/urban)
- Choice of main cooking fuel
- Size of household
- Age of respondent

This analysis simply looked for relationships between these variables and each of the modelling variables among the cards that were chosen by respondents i.e. those sets of choice parameters that were 'preferred' by respondents.

INTERESTINGLY THERE WAS VERY LITTLE DIFFERENCE BETWEEN THE REPSONSES GIVEN BY RURAL & URBAN PARTICIPANTS. THIS COULD BE BECAUSE THE RURAL AREAS SURVEYED WERE CLOSE TO LUSAKA, SO CULTURALLY VERY SIMILAR. FURTHER RESEARCH IS NEEDED IN DIFFERENT AREAS OF THE COUNRTRY TO SEE IF PREFERENCES VARY. IF NOT, PRODUCTS/SERVCICES DESIGNED FOR LUSAKA COULD EASILY SCALE ACROSS THE WHOLE COUNTRY.

4.7.3.1 Cooking Processes

Results in Table 56 indicate that the ability to boil and fry was more important to women, as was having two hobs. Table 52 indicates that there were only marginal differences in preferences expressed by urban and rural respondents.

Table 56 Cooking variables disaggregated by gender

Variable	Male (n=601)	Female (n=832)	
Dichotomous variables			Chi-square p value
PRCooking(1)	85%	92%	**<0.001**
PRSpeedMed(1)	12%	9%	0.059
PRSpeedFast(1)	10%	9%	0.856

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

PRFlavour(1)	14%	13%	0.696
PRPotLid(1)	77%	81%	0.088
PRPotSealed(1)	14%	11%	0.074
PR2hob(1)	77%	82%	**0.016**
PR4hob(1)	8%	8%	0.620
Continuous variables (means)			MW U-test p value
PRCOST	189	193	0.092

Table 57 Cooking variables disaggregated by settlement

Variable	Rural (n=427)	Urban (n=1006)	
Dichotomous variables			Chi-square p value
PRCooking(1)	90%	89%	0.310
PRSpeedMed(1)	9%	10%	0.383
PRSpeedFast(1)	8%	10%	0.167
PRFlavour(1)	11%	15%	0.052
PRPotLid(1)	82%	78%	0.066

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

PRPotSealed(1)	12%	13%	0.930
PR2hob(1)	83%	79%	**0.043**
PR4hob(1)	6%	9%	0.069
Continuous variables (means)			MW U-test p value
PRCOST	193	190	0.263

Comparing choices made by respondents using different fuels as their main coking fuel suggests that people using electricity were more likely to select options that included a smoky flavour, and charcoal users were more likely to prefer a pot with a lid (rather than a pot with no lid), and to prefer two hobs. The preference for a pot with a lid may reflect the tendency for food to stick on the bottom of a pan due to the high temperatures and lack of control associated with burning charcoal.

Table 58 Cooking variables disaggregated by main cooking fuel

Variable	Electricity (n=401)	Charcoal (n=937)	Wood (n=95)	
Dichotomous variables				Chi-square p value
PRCooking(1)	89%	89%	87%	0.768
PRSpeedMed(1)	12%	9%	14%	0.066
PRSpeedFast(1)	9%	10%	11%	0.801
PRFlavour(1)	19%	12%	10%	**0.003**

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

PRPotLid(1)	75%	81%	75%	**0.030**
PRPotSealed(1)	14%	11%	17%	0.125
PR2hob(1)	76%	82%	76%	**0.014**
PR4hob(1)	10%	7%	11%	0.121
Continuous variables (means)				KW U-test p value
PRCOST	191	192	186	0.451

The only link found between preferences and household size was that respondents who preferred the smoky flavour in food came from smaller households (Table 59).

Age of respondent was found to have no effect on preferences.

Table 59 Number of persons in household by cooking variable responses

Parameter variable	Number of persons in household (mean)		
	0	1	MW U-test p value
PRCooking(1)			0.362
PRSpeedMed(1)			0.342
PRSpeedFast(1)			0.408
PRFlavour(1)	5.2	4.7	**0.009**

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

PRPotLid(1)			0.125
PRPotSealed(1)			0.331
PR2hob(1)			0.290
PR4hob(1)			0.755

4.7.3.2 Stove Design

Choice variables disaggregated by gender in Table 60 highlight differences in attitudes towards smoke held by men and women. Men were more likely to feel that wood smoked was acceptable whereas women were less willing to put up with wood smoke, preferring to live with charcoal smoke. Settlement (rural or urban) was not found to have any effect on preferences.

WOMEN WERE FOUND TO VALUE THE ABILITY TO FRY AS WELL AS BOIL, HAVING 2 HOBS INSTEAD OF 1 & AVOIDING THE SMOKE FROM WOOD FIRES MORE THAN MEN. THIS COULD WELL BE BECAUSE AS PRINCIPAL COOKS IN MOST HOUSEHOLDS, THEY ARE MORE IN TOUCH WITH THE PRACTICALITIES OF COOKING, RATHER THAN SIMPLY BEING A CONSUMER OF THE FINISHED PRODUCT, TASTY FOOD.

Table 60 Stove design variables disaggregated by gender

Variable	Male (n=588)	Female (n=826)	
Dichotomous variables			Chi-square p value
STPeople6(1)	10%	11%	0.484
STPeople8(1)	71%	75%	0.144
STSupplementSometimes(1)	10%	8%	0.182
STSupplementAll(1)	12%	10%	0.438
STWoodSmoke(1)	16%	11%	**0.006**

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

STCharcoalSmoke(1)	69%	75%	**0.008**
STPortable(1)	81%	84%	0.286
STLooks(1)	22%	21%	0.644
Continuous variables (means)			MW U-test p value
STCOST	181	184	0.250

Current fuel choices were reflected in preferences (see Table 61). Respondents currently using wood as their main cooking fuel were more likely to tolerate wood smoke in their preferences, while charcoal users would not accept wood smoke, preferring to settle for charcoal smoke. Charcoal users had a stronger preference for a high capacity device that would be able to cook for eight people. This is consistent with the finding that household size was higher among charcoal users (although it was highest among the small sub-sample of wood users) – see Table 62.

Table 61 Stove design variables disaggregated by main cooking fuel

Variable	Electricity (n=390)	Charcoal (n=925)	Wood (n=99)	
Dichotomous variables				Chi-square p value
STPeople6(1)	12%	10%	16%	0.104
STPeople8(1)	68%	76%	71%	**0.013**
STSupplementSometimes(1)	9%	8%	12%	0.440

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

STSupplementAll(1)	13%	10%	10%	0.212
STWoodSmoke(1)	15%	11%	19%	**0.024**
STCharcoalSmoke(1)	69%	75%	68%	**0.029**
STPortable(1)	81%	84%	81%	0.420
STLooks(1)	24%	20%	23%	0.143
Continuous variables (means)				KW U-test p value
STCOST	180	183	191	0.132

Table 62 Household size by choice of main cooking fuel

33. What is your MAIN cooking fuel?	Mean	N
Electricity	4.42	53
Charcoal	5.35	124
Wood	6.38	13
Total	5.16	190

Table 63 indicates that respondents preferring a high capacity device that can cook for eight people come from larger households, as might be expected. Portability also appears to be more important to respondents from larger households. On the other hand, an attractive appearance is less important to people from larger households. Respondents who were prepared to accept charcoal smoke came from larger households, which again is consistent with findings in Table 62.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 63 Number of persons in household by stove design variable responses

Parameter variable	Number of persons in household (mean)		
	0	1	MW U-test p value
STPeople6(1)			0.107
STPeople8(1)	4.7	5.4	**< 0.001**
STSupplementSometimes(1)			0.541
STSupplementAll(1)			0.075
STWoodSmoke(1)			0.521
STCharcoalSmoke(1)	4.9	5.3	**0.012**
STPortable(1)	4.8	5.3	**0.007**
STLooks(1)	5.3	4.9	**0.046**

Exploring the mean age of respondents who made particular choices shows that older respondents preferred a higher capacity device, and one that was portable (see Table 64). On the other hand, looks tended to be important to slightly younger respondents.

Table 64 Age of respondents by stove design variable responses

Parameter variable	Age of respondent (mean)

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

	0	1	MW U-test p value
STPeople6(1)			0.204
STPeople8(1)	31.8	33.8	**0.005**
STSupplementSometimes(1)			0.596
STSupplementAll(1)			0.158
STWoodSmoke(1)			0.658
STCharcoalSmoke(1)			0.113
STPortable(1)	31.9	33.5	**0.036**
STLooks(1)	33.6	31.9	**0.050**

4.7.3.3 Device Functionality

None of the choice parameter variables were sensitive to gender. Table 65 indicates that preferences are largely similar across the rural/urban divide as well, although urban respondents had a stronger preference for a device that could provide lighting as well as cooking.

Table 65 Device functionality variables disaggregated by settlement

Variable	Rural (n=427)	Urban (n=993)	
Dichotomous variables			Chi-square p value

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

FULED	41%	49%	**0.008**
FUMob	20%	18%	0.300
FUTV	21%	19%	0.308
FUAvailabe	44%	39%	0.077
FU6yr	22%	19%	0.275
FU3yr	42%	37%	0.075
FUCleaning	64%	68%	0.126
Continuous variables (means)			MW U-test p value
FUCOST	120	126	0.077

RESPONDENTS THAT USE ELECTRICITY AS THEIR MAIN COOKING FUEL ARE MORE TOLERANT OF A LOWER STORAGE CAPACITY DEVICE THAT FUNCTIONS ONLY ON SUNNY DAYS. THIS COULD BE BECAUSE THEY ARE ALREADY USED TO FUEL STACKING WHEN ELECTRICITY IS NOT AVAILABLE AT MEALTIMES DUE TO LOAD SHEDDING.

Table 66 indicates that respondents that use electricity as their main cooking fuel are more tolerant of a lower storage capacity device that functions only on sunny days and had a stronger preference for a device that can provide lighting as well as cooking.

Table 66 Device functionality variables disaggregated by main cooking fuel

Variable	Electricity (n=401)	Charcoal (n=923)	Wood (n=96)	
Dichotomous variables				Chi-square p value

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

FULED	51%	44%	50%	**0.048**
FUMob	19%	19%	14%	0.390
FUTV	17%	21%	18%	0.263
FUAvailabe	36%	42%	48%	**0.029**
FU6yr	20%	20%	17%	0.739
FU3yr	34%	41%	39%	0.072
FUCleaning	70%	65%	65%	0.185
Continuous variables (means)				KW U-test p value
FUCost	125	124	125	0.933

There is no evidence that preferences are dependent on the number of people living in the household or the age of the respondent.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

5 Conclusion

The study has highlighted several opportunities and challenges for future eCook product/service designers. Urban Zambians tend to fuel stack electricity and charcoal, both of which are available at very low cost compared to other countries. Wood smoke is seen as highly undesirable by most, however most are indifferent to charcoal smoke, which is less visible but also has severe health implications. Most participants cooked 3 meals a day, but electricity users reported spending longest in the kitchen, likely due to the inefficient appliances currently in use. If monthly repayments were on a par, respondents prefer lease-to-own business models, as they would eventually own the equipment. However most saw an energy service model, where the cookers are rented for a service fee (in the same way that power generation, transmission & distribution infrastructure currently is) by the national utility, ZESCO, as a favourable option.

The findings from this study will be combined with those from the other activities that have been carried under the eCook Zambia Market Assessment. Together they will build a more complete picture of the opportunities and challenges that await this emerging concept. Further outputs will be available from https://elstove.com/innovate-reports/ and www.MECS.org.uk.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

6 References

Batchelor, S. (2013) *Is it time for Solar electric cooking for Africa?* Gamos Concept Note, May 2013, Reading, UK.

Batchelor, S. (2015a) *Africa Cooking with Electricity (ACE)*. Reading. Gamos Working Paper (Draft as at August 2015). Available at: https://www.researchgate.net/publication/298722923_Africa_cooking_with_electricity_ACE.

Batchelor, S. (2015b) *Solar Electric Cooking in Africa in 2020: A synthesis of the possibilities*. Evidence on Demand (prepared at the request of the UK Department for International Development). doi: 10.12774/eod_cr.december2015.batchelors.

Batchelor, S. and Scott, N. (2016) *Market Research Studies (Kenya)*. Available at: http://www.gamos.org.uk/images/documents/LCTsurveyreportv7.pdf.

Brown, E. and Sumanik-Leary, J. (2015) *A review of the behavioural change challenges facing a proposed solar and battery electric cooking concept*. Evidence on Demand (prepared at the request of the UK Department for International Development). doi: 10.12774/eod_cr.browneetal.

ESMAP and GACC (2015) *State of the clean and improved cooking sector in Africa*. Washington DC, USA.

Hanley, N., Mourato, S. and Wright, R. E. (2001) 'Choice Modelling Approaches : a Superior Alternative for Environmental Valuation ?', *Journal of Economic Surveys*, 15(3), pp. 435–462. doi: 10.1111/1467-6419.00145.

IEG World Bank Group (2015) *World Bank Group Support to Electricity Access, FY2000-2014 - An Independent Evaluation*. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/22953/96812revd.pdf?sequence=9&isAllowed=y.

Leach, M. and Oduro, R. (2015) *Preliminary design and analysis of a proposed solar and battery electric cooking concept : costs and pricing*. Evidence on Demand (prepared at the request of the UK Department for International Development). doi: 10.12774/eod_cr.november2015.leachm.

Leary, J. *et al.* (2018) *eCook Global Market Assessment Where will the transition take place first ?* Implemented by Gamos, Loughborough University, University of Surrey. Funded by DfID, Innovate UK, Gamos. doi: 10.13140/RG.2.2.22612.30082.

Slade, R. (2015) *Key Assumptions and Concepts on Potential for Solar Electric Cooking: Batteries capable of operating suitably in 'harsh'' conditions in the developing world'*. Prepared at the request of the UK Department for International Development. doi: 10.12774/eod_cr.november2015.slader.

World Bank (2014) *Clean and improved cooking in sub-Saharan Africa: A landscape report, Africa Clean Cooking Energy Solutions Initiative*. Washington, D.C. Available at: http://documents.worldbank.org/curated/en/879201468188354386/pdf/98667-WP-P146621-PUBLIC-Box393179B.pdf.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

7 Appendix

7.1 Appendix A: Problem statement and background to Innovate eCook project

7.1.1 Beyond business as usual

The use of biomass and solid fuels for cooking is the everyday experience of nearly 3 Billion people. This pervasive use of solid fuels—including wood, coal, straw, and dung—and traditional cookstoves results in high levels of household air pollution, extensive daily drudgery required to collect fuels, and serious health impacts. It is well known that open fires and primitive stoves are inefficient ways of converting energy into heat for cooking. The average amount of biomass cooking fuel used by a typical family can be as high as two tons per year. Indoor biomass cooking smoke also is associated with a number of diseases, including acute respiratory illnesses, cataracts, heart disease and even cancer. Women and children in particular are exposed to indoor cooking smoke in the form of small particulates up to 20 times higher than the maximum recommended levels of the World Health Organization. It is estimated that smoke from cooking fuels accounts for nearly 4 million premature deaths annually worldwide – more than the deaths from malaria and tuberculosis combined.

While there has been considerable investment in improving the use of energy for cooking, the emphasis so far has been on improving the energy conversion efficiency of biomass. Indeed in a recent overview of the state of the art in Improved Cookstoves (ICS), ESMAP & GACC (2015), World Bank (2014), note that the use of biomass for cooking is likely to continue to dominate through to 2030.

"Consider, for a moment, the simple act of cooking. Imagine if we could change the way nearly five hundred million families cook their food each day. It could slow climate change, drive gender equality, and reduce poverty. The health benefits would be enormous." ESMAP & GACC (2015)

The main report goes on to say that "The "business-as-usual" scenario for the sector is encouraging but will fall far short of potential." (ibid,) It notes that without major new interventions, over 180 million households globally will gain access to, at least, minimally improved[10] cooking solutions by the end of the decade. However, they state that this business-as-usual scenario will still leave over one- half (57%) of the developing world's population without access to clean cooking in 2020, and 38% without even

[10] A minimally improved stove does not significantly change the health impacts of kitchen emissions. "For biomass cooking, pending further evidence from the field, significant health benefits are possible only with the highest quality fan gasifier stoves; more moderate health impacts may be realized with natural draft gasifiers and vented intermediate ICS" (ibid)

minimally improved cooking solutions. The report also states that 'cleaner' stoves are barely affecting the health issues, and that only those with forced gasification make a significant improvement to health. Against this backdrop, there is a need for a different approach aimed at accelerating the uptake of truly 'clean' cooking.

Even though improved cooking solutions are expected to reach an increasing proportion of the poor, the absolute numbers of people without access to even 'cleaner' energy, let alone 'clean' energy, will increase due to population growth. The new Sustainable Development Goal 7 calls for the world to "ensure access to affordable, reliable, sustainable and modern energy for all". Modern energy (electricity or LPG) would indeed be 'clean' energy for cooking, with virtually no kitchen emissions (other than those from the pot). However, in the past, modern energy has tended to mean access to electricity (mainly light) and cooking was often left off the agenda for sustainable energy for all.

Even in relation to electricity access, key papers emphasise the need for a step change in investment finance, a change from 'business as usual'. IEG World Bank Group (2015) note that 22 countries in the Africa Region have less than 25 percent access, and of those, 7 have less than 10 percent access. Their tone is pessimistic in line with much of the recent literature on access to modern energy, albeit in contrast to the stated SDG7. They discuss how population growth is likely to outstrip new supplies and they argue that "unless there is a big break from recent trends the population without electricity access in Sub-Saharan Africa is projected to increase by 58 percent, from 591 million in 2010 to 935 million in 2030." They lament that about 40% of Sub-Saharan Africa's population is under 14 years old and conclude that if the current level of investment in access continues, yet another generation of children will be denied the benefits of modern service delivery facilitated by the provision of electricity (IEG World Bank Group, 2015).

> "Achieving universal access within 15 years for the low-access countries (those with under 50 percent coverage) requires a quantum leap from their present pace of 1.6 million connections per year to 14.6 million per year until 2030." (ibid)

Once again, the language is a call for a something other than business as usual. The World Bank conceives of this as a step change in investment. It estimates that the investment needed to really address global electricity access targets would be about \$37 billion per year, including erasing generation deficits and additional electrical infrastructure to meet demand from economic growth. "By comparison, in recent years, low-access countries received an average of \$3.6 billion per year for their electricity sectors from public and private sources" (ibid). The document calls for the Bank Group's

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

energy practice to adopt a new and transformative strategy to help country clients orchestrate a national, sustained, sector-level engagement for universal access.

In the following paragraphs, we explore how increasing access to electricity could include the use of solar electric cooking systems, meeting the needs of both supplying electricity and clean cooking to a number of households in developing countries with sufficient income.

7.1.2 Building on previous research

Gamos first noted the trends in PV and battery prices in May 2013. We asked ourselves the question, is it now cost effective to cook with solar photovoltaics? The answer in 2013 was 'no', but the trends suggested that by 2020 the answer would be yes. We published a concept note and started to present the idea to industry and government. Considerable interest was shown but uncertainty about the cost model held back significant support. Gamos has since used its own funds to undertake many of the activities, as well as IP protection (a defensive patent application has been made for the battery/cooker combination) with the intention is to make all learning and technology developed in this project open access, and awareness raising amongst the electrification and clean cooking communities (e.g. creation of the infographic shown in Figure 17 to communicate the concept quickly to busy research and policy actors).

Gamos has made a number of strategic alliances, in particular with the University of Surrey (the Centre for Environmental Strategy) and Loughborough University Department of Geography and seat of the Low Carbon Energy for Development Network). In October 2015, DFID commissioned these actors to explore assumptions surrounding solar electric cooking[11] (Batchelor, 2015b; Brown and Sumanik-Leary, 2015; Leach and Oduro, 2015; Slade, 2015). The commission arose from discussions between consortium members, DFID, and a number of other entities with an interest in technological options for cleaner cooking e.g. Shell Foundation and the Global Alliance for Clean Cookstoves.

Drawing on evidence from the literature, the papers show that the concept is technically feasible and could increase household access to a clean and reliable modern source of energy. Using a bespoke economic model, the Leach and Oduro paper also confirm that by 2020 a solar based cooking system could be comparable in terms of monthly repayments to the most common alternative fuels, charcoal and LPG. Drawing on published and grey literatures, many variables were considered (e.g. cooking energy needs, technology performance, component costs). There is uncertainty in many of the

[11] The project has been commissioned through the PEAKS framework agreement held by DAI Europe Ltd.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

parameter values, including in the assumptions about future cost reductions for PV and batteries, but the cost ranges for the solar system and for the alternatives overlap considerably. The model includes both a conservative 5% discount rate representing government and donor involvement, and a 25% discount rate representing a private sector led initiative with a viable return. In both cases, the solar system shows cost effectiveness in 2020.

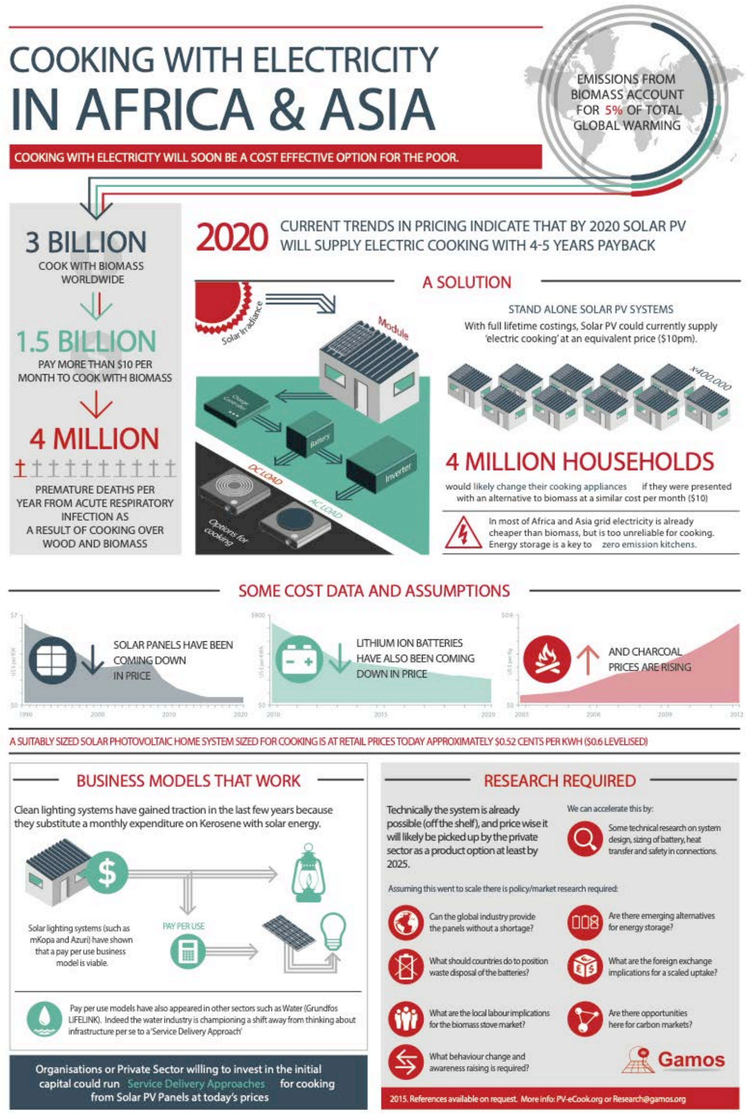


Figure 17 Infographic summarising the concept in order to lobby research and policy actors.

The Brown and Sumanik-Leary paper in the series examines the lessons learned from four transitions – the uptake of electric cooking in South Africa, the roll out of Improved Cookstoves (ICS), the use of LPG and the uptake of Solar Home Systems (SHS). They present many behavioural concerns, none of which

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

preclude the proposition as such, but all of which suggest that any action to create a scaled use of solar electric cooking would need in depth market analysis; products that are modular and paired with locally appropriate appliances; the creation of new, or upgrading of existing, service networks; consumer awareness raising; and room for participatory development of the products and associated equipment.

A synthesis paper summarising the above concludes by emphasising that the proposition is not a single product – it is a new genre of action and is potentially transformative. Whether solar energy is utilised within household systems or as part of a mini, micro or nano grid, linking descending solar PV and battery costs with the role of cooking in African households (and the Global South more broadly) creates a significant potential contribution to SDG7. Cooking is a major expenditure of 500 million households. It is a major consumer of time and health. Where households pay for their fuelwood and charcoal (approximately 300 Million) this is a significant cash expense. Solar electric cooking holds the potential to turn this (fuelwood and charcoal) cash into investment in modern energy. This "consumer expenditure" is of an order of magnitude more than current investment in modern energy in Africa and to harness it might fulfil the calls for a step change in investment in electrical infrastructure.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

7.1.3 Summary of related projects

A series of inter-related projects have led to and will follow on from the research presented in this report:

- Gamos Ltd.'s early conceptual work on eCook (Batchelor, 2013).
    - The key **CONCEPT NOTE** can be found here.
    - An early infographic and a 2018 infographic can be found here.
- Initial technical, economic and behavioural feasibility studies on eCook commissioned by DfID (UK Aid) through the CEIL-PEAKS Evidence on Demand service and implemented by Gamos Ltd., Loughborough University and University of Surrey.
    - The key **FINAL REPORTS** can be found here.
- Conceptual development, stakeholder engagement & prototyping in Kenya & Bangladesh during the "*Low cost energy-efficient products for the bottom of the pyramid*" project from the USES programme funded by DfID (UK Aid), EPSRC & DECC (now part of BEIS) & implemented by University of Sussex, Gamos Ltd., ACTS (Kenya), ITT & UIU (Bangladesh).
    - The key **PRELIMINARY RESULTS** (Q1 2019) can be found here.
- A series of global & local market assessments in Myanmar, Zambia and Tanzania under the "*eCook - a transformational household solar battery-electric cooker for poverty alleviation*" project funded by DfID (UK Aid) & Gamos Ltd. through Innovate UK's Energy Catalyst Round 4, implemented by Loughborough University, University of Surrey, Gamos Ltd., REAM (Myanmar), CEEEZ (Zambia) & TaTEDO (Tanzania).
    - The key **PRELIMINARY RESULTS** (Q1 2019) can be found here.
- At time of publication (Q1 2019), a new DfID (UK Aid) funded research programme '*Modern Energy Cooking Services*' (MECS) lead by Prof. Ed Brown at Loughborough University is just beginning and will take forward these ideas & collaborations.

This data and material have been funded by UK AID from the UK government; however, the views expressed do not necessarily reflect the UK government's official policies.

7.1.4 About the Modern Energy Cooking Services (MECS) Programme.

Sparking a cooking revolution: catalysing Africa's transition to clean electric/gas cooking.

www.mecs.org.uk | mecs@lboro.ac.uk

Modern Energy Cooking Services (MECS) is a five-year research and innovation programme funded by UK Aid (DFID). MECS hopes to leverage investment in renewable energies (both grid and off-grid) to address the clean cooking challenge by integrating modern energy cooking services into the planning for access to affordable, reliable and sustainable electricity.

Existing strategies are struggling to solve the problem of unsustainable, unhealthy but enduring cooking practices which place a particular burden on women. After decades of investments in improving biomass cooking, focused largely on increasing the efficiency of biomass use in domestic stoves, the technologies developed are said to have had limited impact on development outcomes. The Modern Energy Cooking Services (MECS) programme aims to break out of this "business-as-usual" cycle by investigating how to rapidly accelerate a transition from biomass to genuinely 'clean' cooking (i.e. with electricity or gas).

Worldwide, nearly three billion people rely on traditional solid fuels (such as wood or coal) and technologies for cooking and heating[12]. This has severe implications for health, gender relations, economic livelihoods, environmental quality and global and local climates. According to the World Health Organization (WHO), household air pollution from cooking with traditional solid fuels causes to 3.8 million premature deaths every year – more than HIV, malaria and tuberculosis combined[13]. Women and children are disproportionally affected by health impacts and bear much of the burden of collecting firewood or other traditional fuels.

Greenhouse gas emissions from non-renewable wood fuels alone total a gigaton of CO_2e per year (1.9-2.3% of global emissions)[14]. The short-lived climate pollutant black carbon, which results from incomplete combustion, is estimated to contribute the equivalent of 25 to 50 percent of carbon dioxide

[12] http://www.who.int/indoorair/health_impacts/he_database/en/

[13] https://www.who.int/en/news-room/fact-sheets/detail/household-air-pollution-and-health https://www.who.int/gho/hiv/epidemic_status/deaths_text/en/, https://www.who.int/en/news-room/fact-sheets/detail/malaria, https://www.who.int/en/news-room/fact-sheets/detail/tuberculosis

[14] Nature Climate Change 5, 266–272 (2015) doi:10.1038/nclimate2491

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

warming globally – residential solid fuel burning accounts for up to 25 percent of global black carbon emissions[15]. Up to 34% of woodfuel harvested is unsustainable, contributing to climate change and local forest degradation. In addition, approximately 275 million people live in woodfuel depletion 'hotspots' – concentrated in South Asia and East Africa – where most demand is unsustainable[16].

Africa's cities are growing – another Nigeria will be added to the continent's total urban population by 2025[17] which is set to double in size over the next 25 years, reaching 1 billion people by 2040. Within urban and peri-urban locations, much of Sub Saharan Africa continues to use purchased traditional biomass and kerosene for their cooking. Liquid Petroleum Gas (LPG) has achieved some penetration within urban conurbations, however, the supply chain is often weak resulting in strategies of fuel stacking with traditional fuels. Even where electricity is used for lighting and other amenities, it is rarely used for cooking (with the exception of South Africa). The same is true for parts of Asia and Latin America. Global commitments to rapidly increasing access to reliable and quality modern energy need to much more explicitly include cooking services or else household and localized pollution will continue to significantly erode the well-being of communities.

Where traditional biomass fuels are used, either collected in rural areas or purchased in peri urban and urban conurbations, they are a significant economic burden on households either in the form of time or expenditure. The McKinsey Global Institute outlines that much of women's unpaid work hours are spent on fuel collection and cooking[18]. The report shows that if the global gender gap embodied in such activities were to be closed, as much as $28 trillion, or 26 percent, could be added to the global annual GDP in 2025. Access to modern energy services for cooking could redress some of this imbalance by releasing women's time into the labour market.

[15] http://cleancookstoves.org/impact-areas/environment/

[16] Nature Climate Change 5, 266–272 (2015) doi:10.1038/nclimate2491

[17] https://openknowledge.worldbank.org/handle/10986/25896

[18] McKinsey Global Institute. *The Power of Parity: How Advancing Women's Equality can add $12 Trillion to Global Growth*; McKinsey Global Institute: New York, NY, USA, 2015.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

To address this global issue and increase access to clean cooking services on a large scale, investment needs are estimated to be at least US$4.4 billion annually[19]. Despite some improvements in recent years, this cross-cutting sector continues to struggle to reach scale and remains the least likely SE4All target to be achieved by 2030[20], hindering the achievement of the UN's Sustainable Development Goal (SDG) 7 on access to affordable, reliable, sustainable and modern energy for all.

Against this backdrop, MECS draws on the UK's world-leading universities and innovators with the aim of sparking a revolution in this sector. A key driver is the cost trajectories that show that cooking with (clean, renewable) electricity has the potential to reach a price point of affordability with associated reliability and sustainability within a few years, which will open completely new possibilities and markets. Beyond the technologies, by engaging with the World Bank (ESMAP), MECS will also identify and generate evidence on other drivers for transition including understanding and optimisation of multi-fuel use (fuel stacking); cooking demand and behaviour change; and establishing the evidence base to support policy enabling environments that can underpin a pathway to scale and support well understood markets and enterprises.

The five-year programme combines creating a stronger evidence base for transitions to modern energy cooking services in DFID priority countries with socio-economic technological innovations that will drive the transition forward. It is managed as an integrated whole; however, the programme is contracted via two complementary workstream arrangements as follows:

- An Accountable Grant with Loughborough University (LU) as leader of the UK University Partnership.
- An amendment to the existing Administrative Arrangement underlying DFID's contribution to the ESMAP Trust Fund managed by the World Bank.

The intended outcome of MECS is a market-ready range of innovations (technology and business models) which lead to improved choice of affordable and reliable modern energy cooking services for

---

[19] The SE4ALL Global Tracking Report shows that the investment needed for universal access to modern cooking (not including heating) by 2030 is about $4.4 billion annually. In 2012 investment was in cooking was just $0.1 billion. Progress toward Sustainable Energy: Global Tracking Report 2015, World Bank.

[20] The 2017 SE4All Global Tracking Framework Report laments that, "Relative to electricity, only a small handful of countries are showing encouraging progress on access to clean cooking, most notably Indonesia, as well as Peru and Vietnam."

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

consumers. Figure 18 shows how the key components of the programme fit together. We will seek to have the MECS principles adopted in the SDG 7.1 global tracking framework and hope that participating countries will incorporate modern energy cooking services in energy policies and planning.

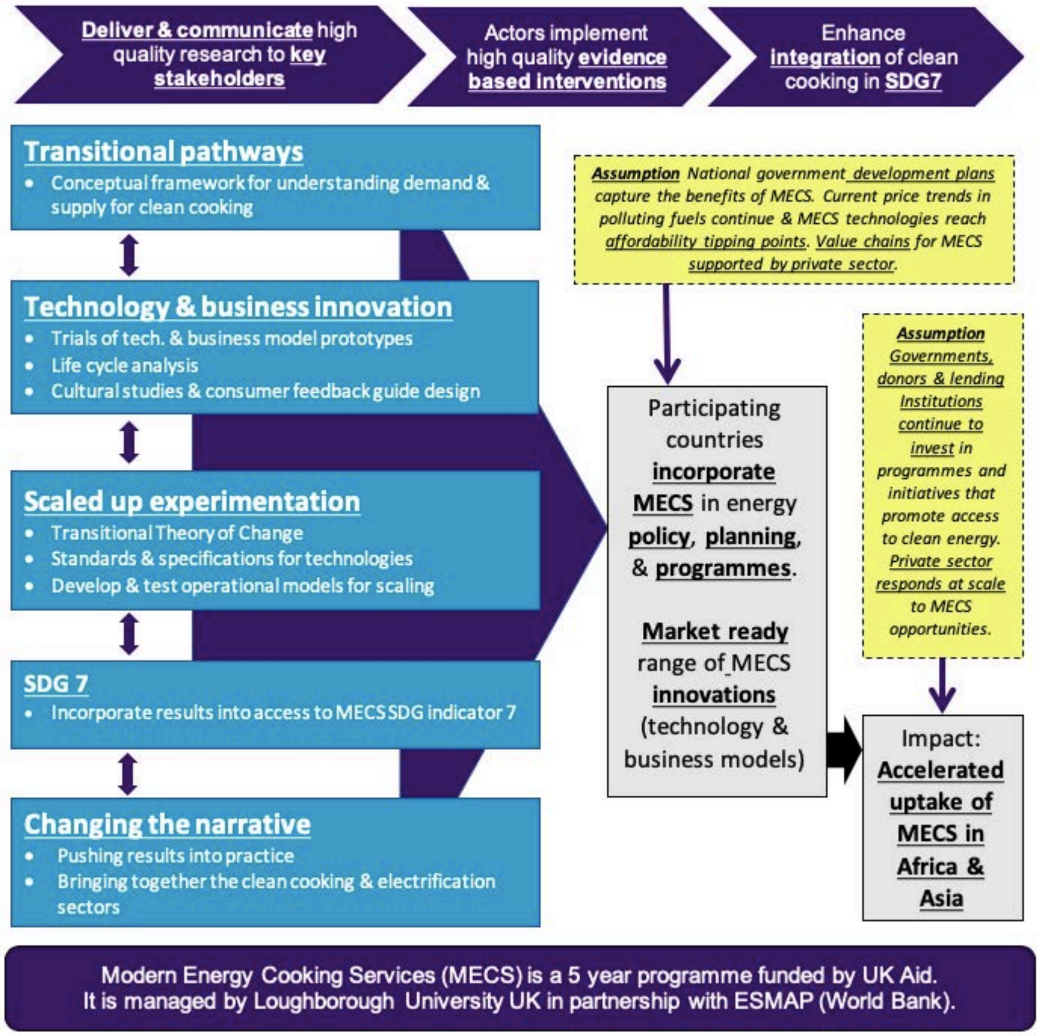


Figure 18: Overview of the MECS programme.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.