eCook Tanzania Country Report

Opportunities and Challenges in Tanzania

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1 Executive Summary

This country report captures preliminary findings and analysis of an indepth assessment of Tanzania as a potential market for eCook. eCook is a potentially transformative battery electric cooking concept designed to offer clean cooking and access to electricity to poorer households currently cooking on charcoal or other polluting fuels (Batchelor 2013; Batchelor 2015a; Batchelor 2015b). This research was funded under Energy Catalyst Round 4 of Innovate UK. It utilized funding from DFID UK Aid through the Innovate system with partially matching funds from Gamos Ltd. The report is rich with detail and is intended to provide decision makers and researchers with new knowledge and evidence.

PV-eCook and Grid-eCook have very different target markets. **PV-eCook is targeted at regions where no grid infrastructure exists** (nor is it likely to in the near future), i.e. rural off-grid HHs. From a system-level perspective, **Grid-eCook** offers the ability to rebalance and reinforce weak grid infrastructure. As a result, the **key target market segments are expected to be those living at the fringes of the grid**, where the infrastructure is weakest, i.e. urban slums or rural grid-connected HHs .

Tanzania had been identified as a country of interest through the Global Market Study (Leary and Batchelor 2018). **The aim of this Tanzania study is** to support a strategic long term mix of interventions that seek to pre-position research and knowledge such that when the pricing of components and systems reaches viability, donors, investors, private sector and civil society can take rapidly eCook to scale. The objectives of the study are to locate, quantify and characterise the market for eCook in Tanzania.

To achieve this, the programme of research includes the following key methodologies:

- Cooking diaries – asking households to record exactly what they cook, when and how for 6 weeks. The first two weeks cooking as they would normally do, and then asking them to transition to cooking with electricity for the remaining duration of the trial.
- Choice modelling surveys – asking potential future eCook users which design features they would value most in a future eCook device.
- Focus groups – offering a deeper qualitative exploration of how people currently cook, how they would like to cook in the future and the compatibility of these cooking practices with the strengths and weaknesses of cooking on battery-supported electrical appliances.
- Techno-economic modelling – refining Leach & Oduro's (2015) model and adapting it to reflect the unique market conditions in each national context.

- Prototyping – using the data from the above methodologies to shape the next generation of eCook prototypes in a participatory design process involving local entrepreneurs and future end users of eCook devices.
- Stakeholder engagement – bringing together key policy, private sector, NGO, research and community actors to explore the opportunities and challenges that await eCook in each unique national context

There are clear indications particularly from the diaries and focus group exercises, that households would adopt electricity for cooking – if the price and other conditions were 'right'. There were a number of comments particularly about the multicooker about how clean it was (and they meant cleanliness in terms of sweat and clothing rather than the development communities use meaning clean as emitting now emissions). These features whereby one can set up a meal and do other things, plus that one does not 'sweat' over hot coals, and one's dress remains clean, are possibly very powerful arguments when marketing eCook in the future.

However, there are some reservations. Cost is a major factor, but (the lack of) reliability and availability were obviously at the forefront of people's experience. If PV-eCook is fully implemented then such factors are all mitigated – eCook offering a reliable offering that can be made available even where there is no grid electricity at the moment. Even where the grid is available, Grid-eCook offers greater reliability and availability.

However the cost is not yet there. The cost of building the demonstration prototype shows the current situation – a shortage of components of the right size on the market (batteries, inverters, cookers), and a high cost for the available components (batteries at $520/kWh). This comes as no surprise to us. Our premise since 2013 has been that components will become cheaper and more available as learning rates kick in to Lithium Batteries, and by 2020 system will be affordable.

Behaviour change is as important as we had originally thought, but our understanding of how people cook and the compatibility with different electrical appliances has improved. We can now see that the motivations to change behaviour to adopt an aspirational product that offers more than what a charcoal stove can (or even LPG) are an alternative and seemingly more viable pathway than creating something that mimics as closely as possible the slow and inefficient nature of charcoal stoves. **This work in Tanzania has shown that perhaps a move directly to multicookers could be possible.**

The policy review and the stakeholders meetings confirm that there is a hunger within the Government and other decision makers for a solution to the enduring problem of biomass cooking. Policies tend to support eCook, and certainly targets seem to enshrine a solution like eCook. It will be important to raise awareness of the solution and co-construct with the Tanzanian Government the emerging solutions. This will not be a quick process, and a vision of 5 to 10 years should be held rather than expecting short returns with a cheap but inadequate eCook solution.

Acknowledgements

We would like to thank all those that participated in this study. In particular, the staff of TaTEDO, both those named as authors, but also the supporting staff who facilitated the meetings with the people and who offered their own insights. We would like to thank all participants of the cooking diaries, who dedicated and focused to record what they were cooking, to the respondents in the choice survey and the attendees at the stakeholder meeting. We also thank the Tanzanian government, the Ministry of Energy for attending the stakeholder meeting and facilitating our study in the country.

We thank the donors DFID via Innovate for partial funding, and the directors and shareholders of Gamos who matched the funding for the benefit and public good of Tanzania.

This is version 1 of this report, dated August 2018. We expect some additional data to be gathered and a version 2 to be available in November 2018.

Table of Contents

2 Introduction

This report presents the detailed in country research to explore the market for eCook in Tanzania. 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 and researchers with new knowledge and evidence.

2.1 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—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. The enduring problem of biomass cooking is discussed further in Annex 1. The Annex not only describes the scale of the problem, but describes how changes in renewable energy technology and energy storage open up new possibilities for addressing the problem. The annex describes some key background research.

2.2 Context of the Innovate project

The research was funded under Energy Catalyst Round 4 of Innovate UK. It utilized funding from DFID UK Aid through the Innovate system with partially matching funds from Gamos Ltd. Annex 1 also describes the overall aims of the Innovate project. It follows on from a series of initial feasibility studies (described below) funded by DfID UK AID under the PEAKS mechanism (available from https://elstove.com/dfid-uk-aid-reports/).

2.3 Introducing 'eCook'

eCook is a potentially transformative battery electric cooking concept designed to offer clean cooking and access to electricity to poorer HouseHolds (HHs) currently cooking on charcoal or other polluting fuels (Batchelor 2013; Batchelor 2015a; Batchelor 2015b). Slade (2015)investigated the technical viability of the proposition, highlighting the need to 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. The study concluded 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 and charge controller in a comparable configuration to the popular Solar Home System (SHS) and is best matched with rural, off-grid contexts.
- Grid-eCook uses an AC battery charger 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.

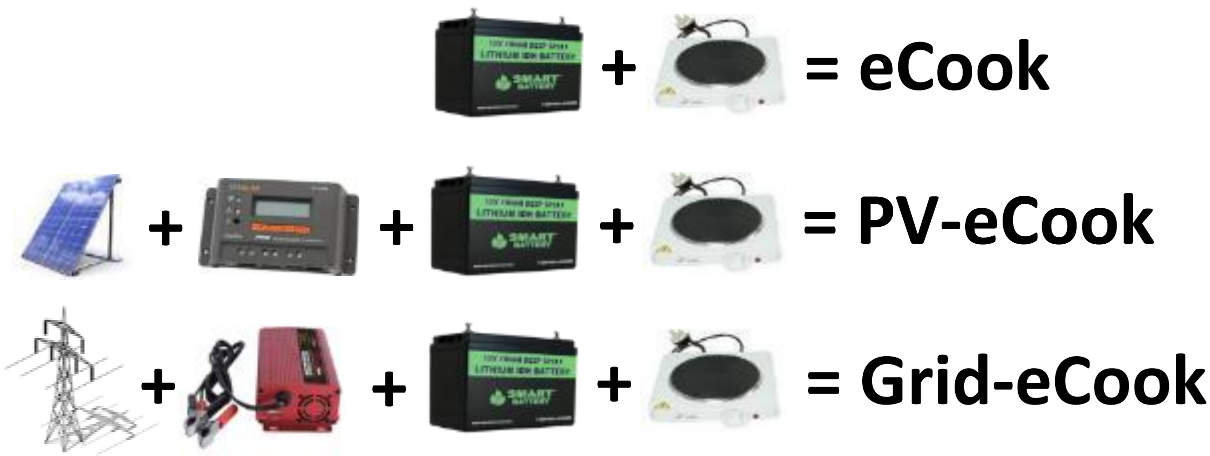

Figure 1: Pictorial definitions of 'eCook' terminology used in this report.

Hundreds of millions of households still rely on polluting fuels; that harm the health of the household, that degrade the local environment and that are a drain on household finances. Where households seek to use 'clean' fuels, their use of electricity is often hampered by unreliability and grid capacity, and the availability and price of LPG (in addition to the broader sustainability challenges associated with fossil fuels). Enabling affordable electric cooking sourced from renewable energy technologies, could provide households with sustainable, reliable, modern energy.

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.

The global market assessment (Leary & Batchelor 2018) has shown that there are considerable opportunities for eCook in its various forms, in a great many countries. The viability scores vary according to the convergence of the different factors, and no single country presents the ideal market conditions for eCook across all sectors of its society. Instead, each country has its own unique market dynamics and understanding these is absolutely vital in order to tailor prototype designs and marketing strategies to that particular context.

Figure 2 shows that PV-eCook is most viable in Africa, particularly in East and Southern Africa.

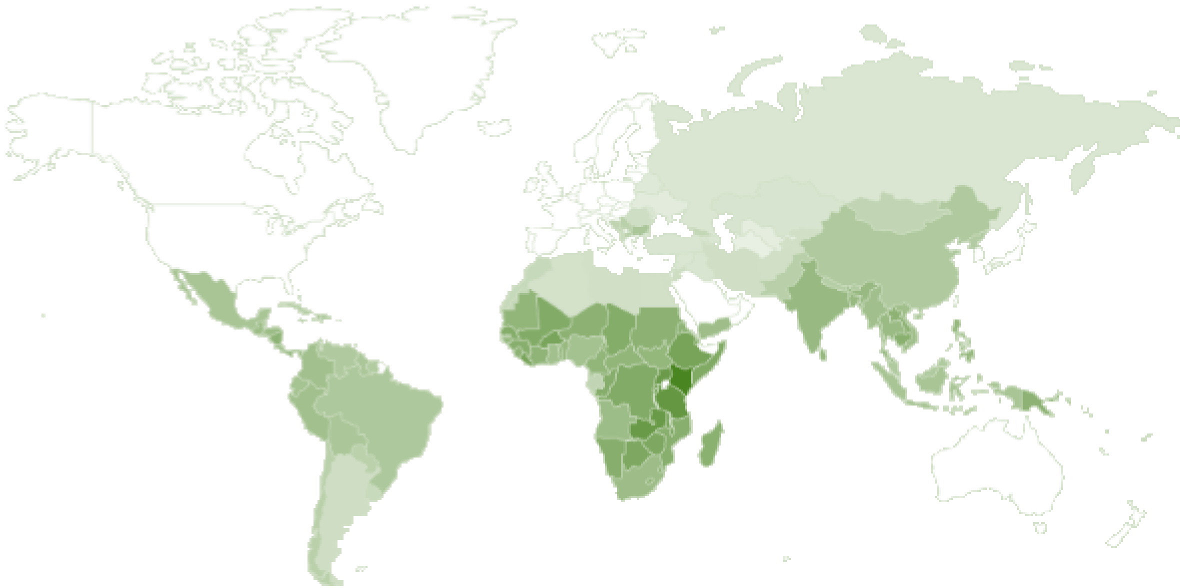

Figure 2Choropleth plots showing viability scores for PV-eCook. The shading of the Green indicates most viable.

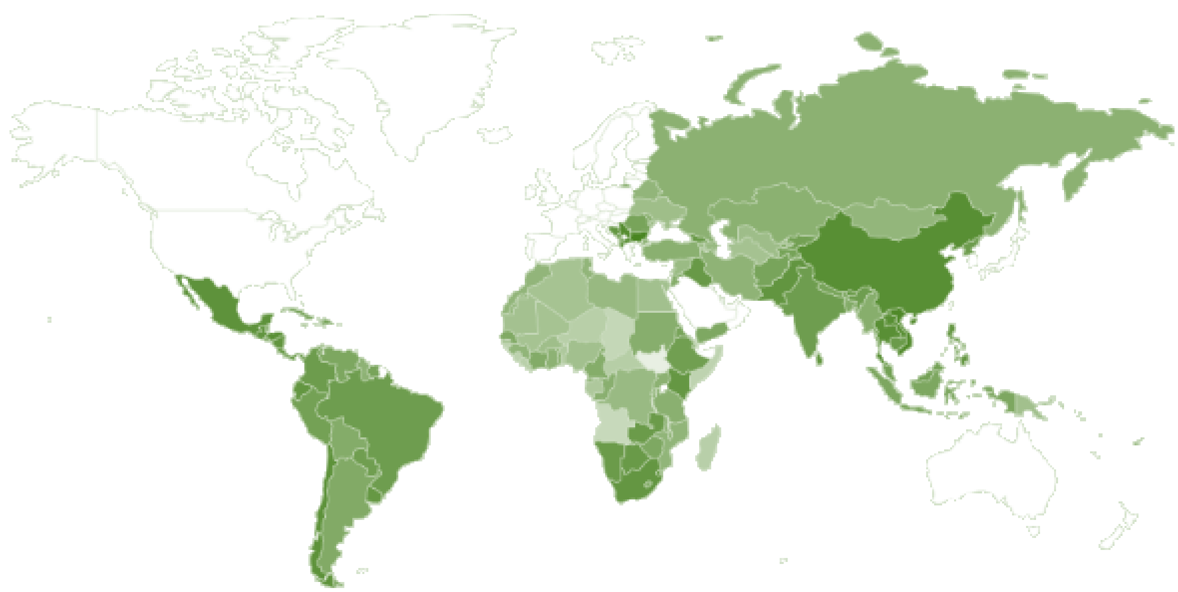

Figure 3Choropleth plots showing viability scores for Grid-eCook. The shading of the Green indicates most viable

Figure 3 shows that Grid-eCook is viable in much of Africa, particularly in East and Southern Africa, but more so in Asia and Latin America.

Since the Global study was based on national statistics of varying quality, the next step was to undertake deeper in country work in a number of promising countries. The choice of countries was based on the data described in the Global Market Assessment, plus took into consideration the existing and possible in-country partners, and whether the countries represented a wider cluster of countries. For example, understanding the Zambian market is likely to shed light on the dynamics of other countries with a significant number of charcoal users looking to foster an emerging electric cooking market based on cheap grid electricity.

In particular, three countries stood out and were selected for further study:

1. In Zambia over 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.
2. The liberalisation of Myanmar opens the door to a significant charcoal market, with a small percentage of users already cooking on electricity, paving the way for eCook.
3. Tanzania has a strong SHS industry and is one of the world's biggest charcoal markets, creating several global deforestation hotspots.

This report presents the detailed in country research for Tanzania.

3 Aims, objectives and methodology

The aim of this Tanzania study is to support a strategic long term mix of interventions that seek to pre-position research and knowledge such that when the pricing of components and systems reaches viability, donors, investors, private sector and civil society can take rapidly eCook to scale.

The objectives of the study are to locate, quantify and characterise the market for eCook in Tanzania.

To achieve this, the programme of research includes the following key methodologies:

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4 From Global markets to Tanzania

4.1 Target market segments

PV-eCook and Grid-eCook have very different target markets. **PV-eCook is targeted at regions where no grid infrastructure exists** (nor is it likely to in the near future), i.e. rural off-grid HHs. From a system-level perspective, **Grid-eCook** offers the ability to rebalance and reinforce weak grid infrastructure. As a result, the **key target market segments are expected to be those living at the fringes of the grid**, where the infrastructure is weakest, i.e. urban slums or rural grid-connected HHs . However, in reality these markets will clearly overlap, with some users of particularly unreliable grids with high unit costs potentially opting for PV-eCook over Grid-eCook and as national grids continue to expand, newly connected PV-eCook users may wish to sell their PV panels and buy an AC charger to convert to Grid-eCook.

eCook is fundamentally predicated upon the premise that monthly/weekly/daily repayments on a battery electric cooker could be comparable to current expenditures HH cooking fuels. Firewood, dung and crop waste are usually collected and therefore there is no existing expenditure, making users of these fuels harder to reach. In contrast in most contexts, LPG, kerosene, charcoal and coal are commercialised. As a result this overall research seeks to determine **how many people are using these fuels**, **where they are located** and **how much they are paying for them**.

Most fundamentally, **as a renewable energy technology, solar PV requires upfront investment**. Whilst ICS have struggled to find an appropriate business model, pay-as-you-go solutions for solar lighting have facilitated rapid uptake. Pay-as-you-go for eCook would enable direct substitution of daily/weekly/monthly charcoal expenditure and a reframing of the concept not as an ICS but as a repurposing of household expenditure to support the roll out of electrical infrastructure (whether national grid, mini-grid or off-grid PV), which could therefore attract private and government investment in a way that ICS have not. As a result, this paper **includes how the political and private sector landscape of electrification, electrification, local prices for fuelwood/charcoal/LPG and cultural preferences** for specific foods might affect the proposition.

4.2 Variables used

Brown & Sumanik-Leary (2015) carried out a review of the behavioural change challenges that are likely to enable and constrain the uptake of eCook. The global study (Leary & Batchelor 2018) compared actual country contexts with Brown & Sumanik-Leary (2015) generic typology to evaluate the viability of eCook in each place. Table 1 shows how each of Brown & Sumanik-Leary (2015) factors are represented by an indicator. Indicators are grouped into sub-categories, which themselves are grouped into categories. In brief it was hypothesized that the market for eCook may be influenced by:-

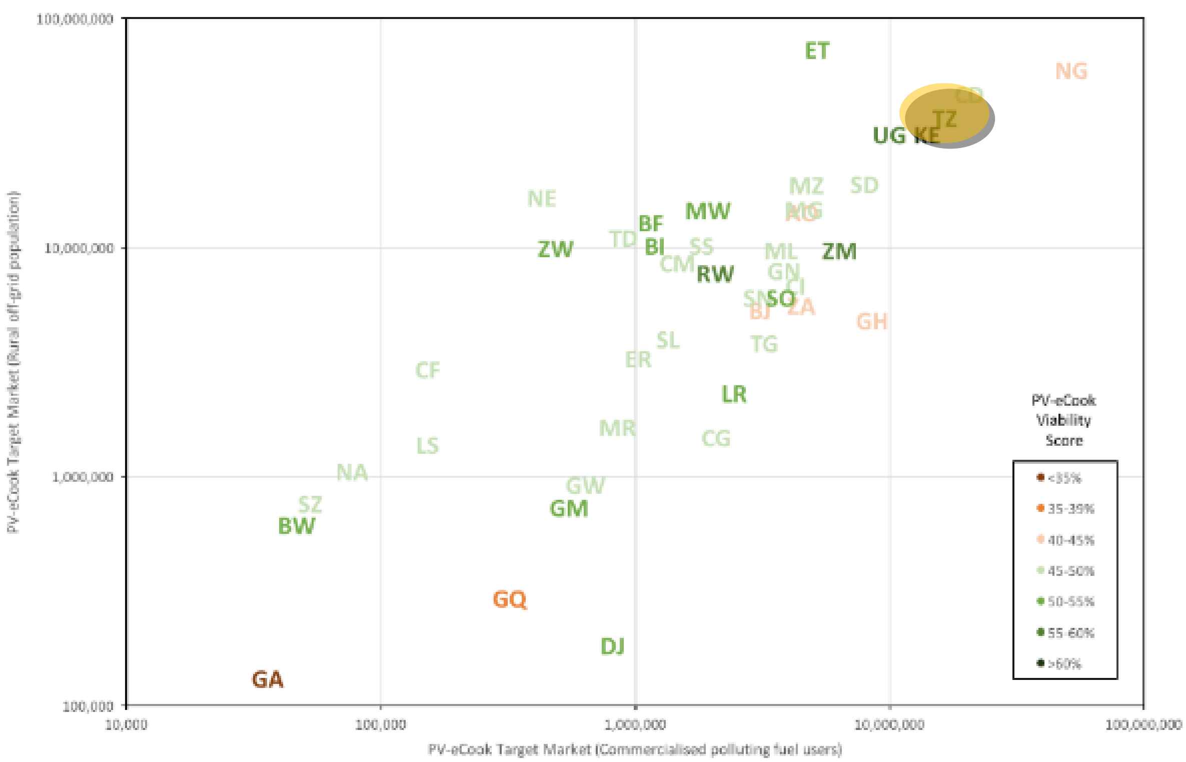
- The alternative fuel options – that includes the availability and cost of electricity, and the attractiveness of alternatives such as kerosene and LPG.
- The finance available to consumers – both in terms of incomes, repayment mechnisms (i.e. presence of mobile money) and ability to (and cost of) borrow the upfront capital.
- The solar resource and ambient temperatures - which affect energy generation/storage options.
- Governance – the markets will be strongly affected by the rule of law.
- Skills and capacity availability –is the institutional environment in place to train technicians?

- The size of the market - both in proportional terms and absolute numbers.
- Ease of doing business – will it be possible for private sector to set up new markets?
- Policy environment – is it favourable towards renewable energy technologies?
- The national grid – how many people it reaches, affordability and the quality of the supply.

For the in country studies, several activities were identified which we hoped would capture these contextual, behavioural and human factors.

4.3 Africa

Kenya, **Tanzania** and Uganda all represent large markets that are likely to transition quickly (dark green colour on Figure 4 indicates high viability score). Nigeria represents the largest market, however its viability score is one of the lowest (indicated by orange colour), indicating that although a transition to PV-eCook could have a big impact, it is not likely to occur very quickly. Ethiopia has a large rural population, however the fact that it sits to the left of the origin to top right diagonal indicates that it is likely that a smaller proportion of these people purchase their fuel. Zambia, Rwanda, Malawi and Somalia also represent significant populations that fit into our target market segments and would be relatively easy to reach (i.e. high viability scores).

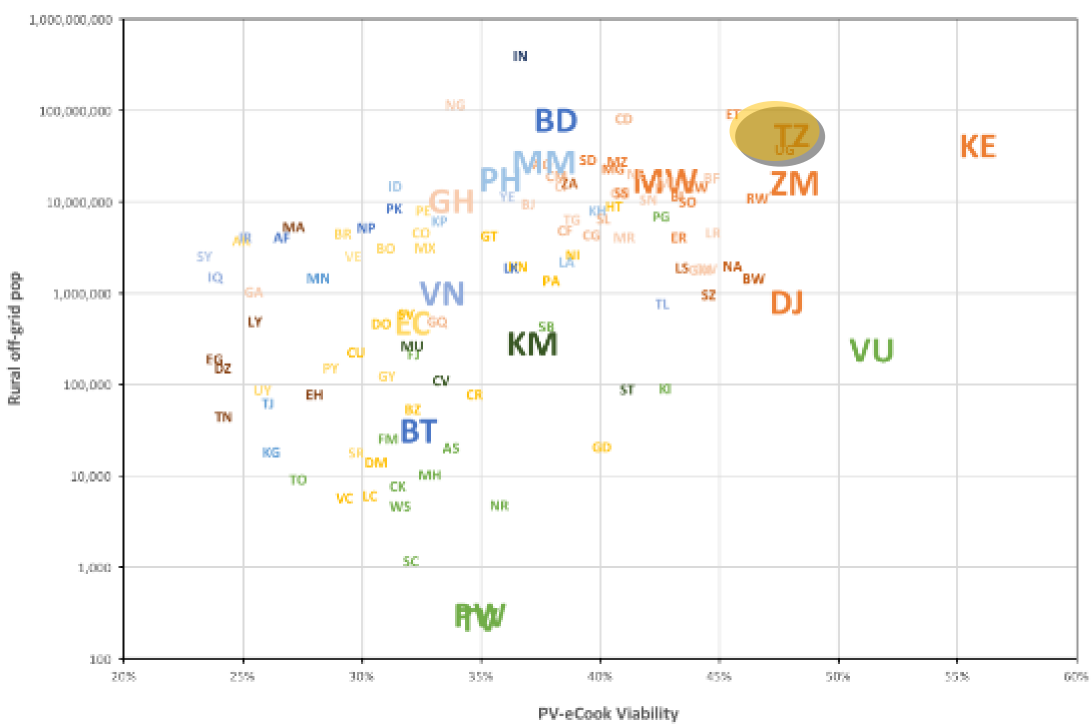


AO	Angola	CD	DRC	LR	Liberia	SL	Sierra Leone
BJ	Benin	GQ	Equatorial Guinea	MG	Madagascar	SO	Somalia
BW	Botswana	ER	Eritrea	MW	Malawi	ZA	South Africa
BF	Burkina Faso	ET	Ethiopia	ML	Mali	SS	South Sudan
BI	Burundi	GA	Gabon	MR	Mauritania	SD	Sudan
CM	Cameroon	GM	Gambia	MZ	Mozambique	SZ	Swaziland
CF	Central African Rep.	GH	Ghana	NA	Namibia	TZ	Tanzania
TD	Chad	GN	Guinea	NE	Niger	TG	Togo
CG	Congo	GW	Guinea-Bissau	NG	Nigeria	UG	Uganda
CI	Côte d'Ivoire	KE	Kenya	RW	Rwanda	ZM	Zambia
DJ	Djibouti	LS	Lesotho	SN	Senegal	ZW	Zimbabwe

Figure 4: Target market segments and viability for PV-eCook in Sub-Saharan Africa.

4.4 Electrification and demographics

The urban/rural divide and the current levels of access to electricity allow us to separate the two distinct markets for Grid-eCook (at the fringes of the grid) and PV-eCook (off-grid). The picture is clear for PV-eCook, as Kenya is both the easiest market to enter and has one of the biggest target market segments. It is closely followed by a number of East African countries (shown in orange on Figure 5), such as **Tanzania**, Zambia and Uganda.



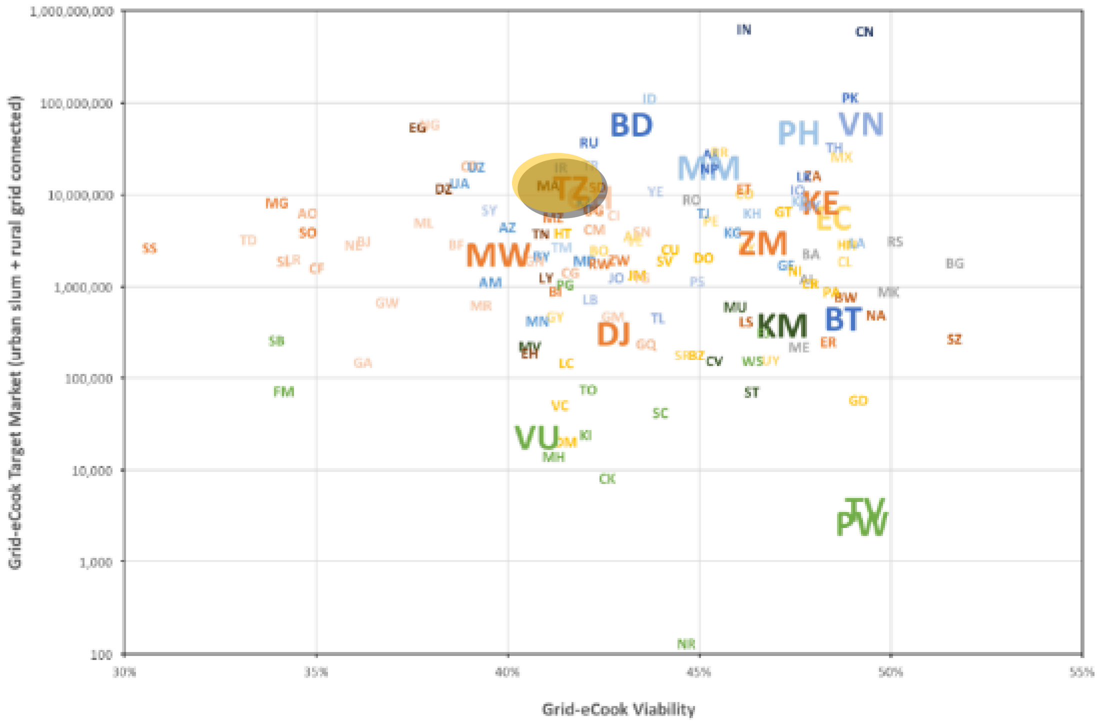


Figure 5: Comparison of size of PV-eCook (top) and Grid-eCook (bottom) target market segments by electrification and demographic status with ease of reaching these market segments.

Countries coloured by region: AIMS, Central Africa, Central America & Caribbean, Central Asia & North Korea, East Africa, Europe, India & China, Middle East , North Africa, Pacific Islands & PNG, South America & Mexico, South Asia (excl. India), Southeast Asia, Southern Africa and West Africa. Two-letter country codes listed in ***Error! Reference source not ound.****.*

4.5 Commercialised polluting fuels

The use of solid fuels (charcoal, coal, firewood, dung and crop waste) has long been recognised as a leading cause of premature deaths due to the negative effects of the indoor air pollution they generate on respiratory health. However, recent evidence on the negative health effects of kerosene use has lead the WHO to create a new classification of 'polluting fuels' (WHO 2014), which also includes kerosene. The global study focused on three of these kerosene, charcoal and coal, as these three commercialised polluting fuels present the greatest opportunity to divert an existing expenditure to increase quality of life.

Figure 6offers a complementary market segmentation, comparing the number of commercialised polluting fuel (kerosene, coal or charcoal) users with the viability of both PV- and Grid-eCook. Kenya and the rest of East Africa clearly show the greatest potential for eCook, with significant populations relying on charcoal and kerosene for their HH cooking needs.

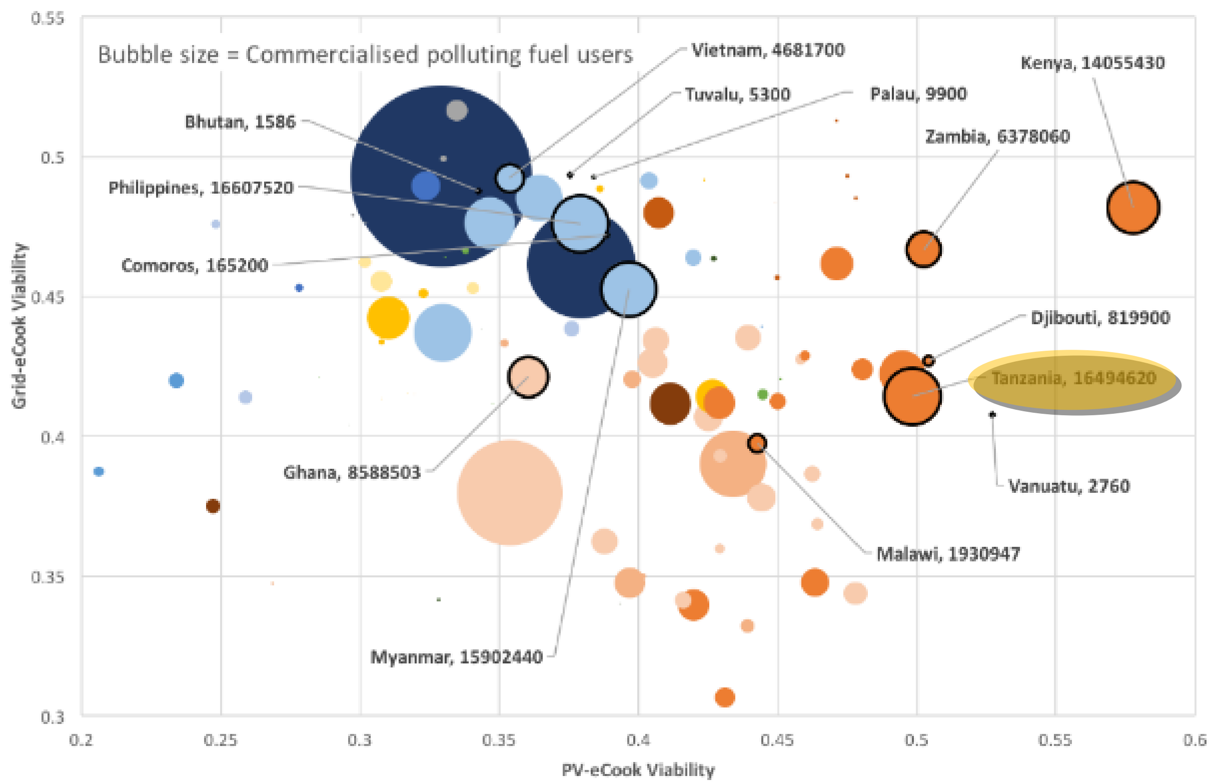


Figure 6Size of commercialized polluting fuel (kerosene, charcoal, coal) users market segments and ease of reaching them with Grid-eCook or PV-eCook solutions.

Countries coloured by region: AIMS, Central Africa, Central America & Caribbean, Central Asia & North Korea, East Africa, Europe, India & China, Middle East , North Africa, Pacific Islands & PNG, South America & Mexico, South Asia (excl. India), Southeast Asia, Southern Africa and *West Africa*.

4.6 Introduction to the opportunity for eCook in Tanzania

Like its East African neighbour, Kenya, Tanzania has enormous potential for PV-eCook. 68% of Tanzanians (38 million) live in rural areas, 96% of whom (37 million) are not connected to the grid. The Tanzanian off-grid industry is growing rapidly in order to meet the needs of this huge market segment, with 185,000 SHS and pico-solar products sold in the second half of 2016 (GOGLA et al. 2016). What is more, the climatic conditions are very favourable, offering a strong and stable solar resource (monthly averages ranging from 4.5-5.4kWh/m2/day) and comfortable temperature range (monthly averages ranging from 20-24). However, it should be noted that like Kenya, significant regional variation in climatic conditions is likely across this large country.

15 million Tanzanians (27%) use charcoal as their primary household cooking fuel – making it the fourth largest domestic charcoal market in the world after DRC, Myanmar and the Philippines have a higher number of users. 5 experts from the GACC database responded to the charcoal price survey, indicating that prices in Tanzania are currently only at moderate levels (0.45USD/kg in major cities). However,

although Drigo et al. (2014) estimate that only 15% of biomass harvested for household wood fuel in Tanzania is non-renewable, this nationally averaged figure masks some important trends. 70% of the charcoal produced in Tanzania is transported to Dar es Salaam, creating a hotspot of rapid tree felling in the surrounding area (see Figure 7). However, Prof. JumanneMaghembe, Natural Resources and Tourism Minister, estimates that less than 30% is actually consumed in the city, with the remainder "exported to Asia through Zanzibar and porous Indian Ocean illegal ports" (Daily News 2017).

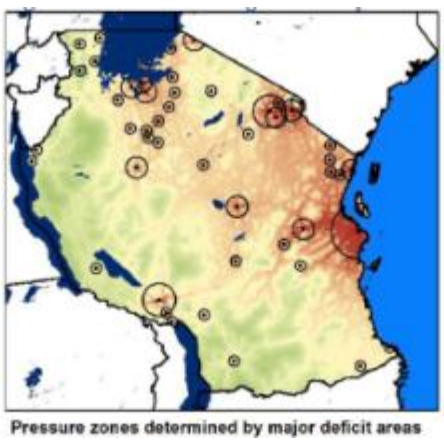


Figure 7Pressure on Tanzanian woodsheds from the harvesting of wood fuels for HH energy in urban centres.

As a result, earlier this year, the Government of Tanzania banned both the export of charcoal and its transportation between districts (The Citizen 2017b), with the intention that charcoal consumers will transition to cleaner fuels, specifically LPG. However, Tanzania has a long history of banning charcoal, often with unintended consequences. Havnevik (1993)describe the impact of the charcoal ban in 1979. It had little effect on deforestation, as the same quantity of charcoal was produced and either sold at much higher prices on the black market or stored until the ban was lifted a month later. There has been considerable public opposition to the proposition of another outright ban, pointing out that alternatives that are "accessible, available and affordable all the time" need to be in place first (The Citizen 2017a). As a result, a gradual tightening of restrictions in order to reduce the availability of charcoal, push up the price and invoke a gradual transition, seems most likely (The East African 2017). At the time of writing this seems to have little effect on prices or availability of charcoal.

Nevertheless this presents a considerable opportunity for eCook, as although LPG is being targeted as the primary fuel to enable a transition away from charcoal, there is considerable interest in electricity. Low access rates appear to be the major barrier for electricity, as a low tariff of 0.13USD/kWh is supplemented by an attractive lifeline tariff of 0.06 USD/kWh for the first 75kWh. Currently only 16% of Tanzanians (9 million) have access to the national grid, however only 1% (600,000) use electricity as their primary cooking fuel. With an average of 7 blackouts per month, reliability may also be a barrier, as this is likely to be an upper bound. 9 million Tanzanians live in urban slums, 11 million urban Tanzanians are not yet connected to the grid, and 16 million with charcoal or kerosene. It is likely that these three market segments overlap considerably, creating an opportunity for Grid-eCook to leverage existing expenditures on polluting fuels to offer both access to clean cooking facilities and electricity to millions of people who are currently well within reach of the grid, but not yet connected to it.

5 Cooking diaries

5.1 Introduction and Method

Somewhat to our surprise, despite decades of work on improving the efficiencies of biomass stoves, there seems to be little available data on 'how' people cook.

This becomes important because electricity presents as a more controllable fuel. So for instance, to fry on a charcoal stove requires lighting, undertaking the frying, and either putting out the charcoal or waiting for it to burn out. With LPG or electricity, the process is not only more instant, but uses significantly less energy because surplus combustion of the cooking fuels due to preparation and finalisation is not required.

Therefore, it seems important to us to know whether people are spending a lot of time frying or boiling or something else?

The cooking diary study was designed to explore deeper into the unique cooking practices of individual households. 22 households were selected to participate in the study, based upon the fuels they cooked with and their willingness to record high quality data for the duration of the study. The study began with a registration survey designed to capture basic information on who they are cooking for, the appliances they use and why. For the first 2 weeks of the study, baseline data was captured on how households currently cooked. Before cooking, the cook would record the time and an energy reading by weighing the fuels they planned to use. After cooking, they would again record time and energy, plus details of what they cooked and how they cooked it. Data was recorded on paper forms and collected by the enumerators and digitised in Excel. Subsequent analysis was performed in SPSS.

In the second part of the experiment, the households were asked to transition to using solely electricity for cooking. As part of the study, they were invited to choose any 2 of the following appliances: induction stove, rice cooker, electric pressure cooker, kettle, thermo-pot or a 2 plate hotplate. They were also able to continue using any electrical appliances that they already owned. Data was recorded for a further 4 weeks, allowing participants time to adapt their cooking practices around the new appliances.

The survey finished with an exit survey, asking about their experience with cooking with electricity. Participants were also invited to share their energy-efficient cooking practices by participating in the Rice and Ugali Cooking Challenge. A prize was offered to the participant who could cook rice and ugali using the least energy possible, whilst the enumerators observed and recorded their cooking practices.

5.2 Overview of data

Paper records kept by participants were transcribed into digital form using an Excel worksheet. Data from each heating event was entered into a separate column. Although each record related to distinct times of the day, they could cover multiple heating events e.g. an early morning record could include breakfast, preparing food for a baby, and heating water (3 events).

Water heating is often forgotten as a 'cooking energy' need although ironically most stoves are tested for their efficiency for boiling water.

In the choice modelling a larger sample of people offer insights into how much is boiled for bathing, and how much for tea and purification.

Heating water is the most common single heating event (Table 1). The number of main meals captured is similar, although breakfast appears to be the most commonly cooked meal by a small margin.

Table 1 Number of heating events[1]

Heating event	Frequency	Percent
Breakfast	855	29.4
Lunch	784	27.0
Dinner	815	28.0
Snack	34	1.2
Baby food	445	15.3
Heat water	1143	39.3
Other	45	1.5

The majority of missing cases in the data are instances in which no food was prepared by the household – see Table 2. This leaves a small number of cases for which data was gathered, but the meal prepared was not recorded.

Table 2 Zero energy meals

	Frequency	Percent
Forgot to fill in a form	36	1.2
Bought food	76	2.6
Ate food prepared earlier without reheating	43	1.5
Ate at a friend/family member's place	48	1.7
Did not eat	84	2.8
Total	287	9.9

[1] N.B. multiple heating events in each record means that total sums to more than 100%.

Energy consumption is directly proportional to the number of people being cooked for. Overall, the mean number of adults per heating event was 3.8, and the mean number of children was 1.6. If children are weighted the same as adults, then the mean number of persons per heating event was 4.6. one anomaly was an unexpectedly low number of records when a meal was prepared for five adults – see Figure 8. It was assumed that this was simply a random effect.

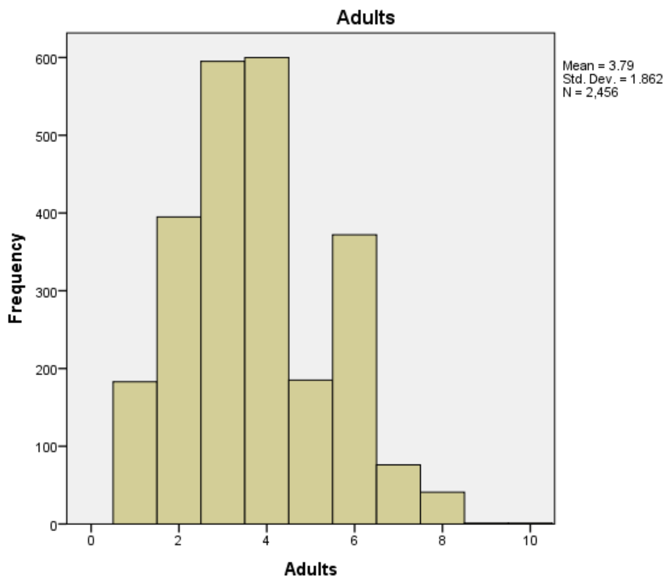


Figure 8 Distribution of adults per heating event

5.3 Energy consumptions

For each of the five dominant fuels, energy consumptions have been calculated from deduced fuel consumptions (based on the before and after readings e.g. weight of wood (kg)) and the calorific values given in Table 3.

Table 3 Calorific values and conversion efficiencies[2]

Fuel	Calorific value	Density
Wood	15.9 MJ/kg	
Charcoal	29.9 MJ/kg	
Kerosene	34.9 MJ/ltr	0.8 kg/ltr
LPG	44.8 MJ/kg	
Electricity	3.6 MJ/kWh	

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

5.3.1 Phase 1 and Phase 2

The energy consumption for each fuel was plotted against dates for each participant in turn in. The date that each participant shifted from using their 'normal' fuels (Phase 1) to using electricity (Phase 2) could clearly be seen. The number of Phase 1 and Phase 2 records are presented in the data document. For most participants, around 40% of records are in phase 1. In this section, energy consumptions in the two phases are compared, so one person's data has been omitted as it contained no Phase 2 records.

Not all records have valid energy consumption data. Mean total energy consumption indicate that energy consumption data was available for 84% of phase 1 records and 82% of Phase 2 records. These figures also indicate that, across all participants, **the mean energy used during Phase 2 was only 31% of the energy used during Phase 1**. This headline figure will hide all sorts of nuances in the numbers of heating events, the numbers of people cooked for, the types of food cooked, and so on. The following sections seek to unpack energy consumptions in more detail.

The distribution of energy consumptions (per event) is presented in Figure 9. This includes some very high figures, but the maximum (271 MJ) was a Sunday lunchtime event at which the household cooked 10 chickens for 33 people, so although it appears to be an outlier, it does appear to be valid and cannot be omitted. The next highest figure (216 MJ) was a dinner event when the household cooked dinner for 6 but he also heated a full, big pot of hot bathing water for over an hour. This might account for up to half of the energy consumed (based on estimates of volume of water, temperature reached, and efficiency of conversion), so it is possible that the energy consumption is erroneous, but it is not obviously wrong.

At the other end of the scale, there are 4 records where foods have been cooked but beginning and end fuels readings are the same, assumed to be in error, so consumption figures have been deleted.

Because of this wide variation in consumption figures, including high figures that may represent exceptional events, median energy consumption figures have been used in the analysis to represent 'normal' heating events.

Discussing the total energy used is perhaps not that helpful as pointed out in the text. Energy conversion efficiencies for charcoal are less than half that for LPG. So while charcoal looks like the dominant energy source in Phase 1, its not. Of more interest is the 'useful' energy at the pot, and this is where the focus needs to be.

Nevertheless the graphs show how the transition to electricity for Phase 2 was generally successful.

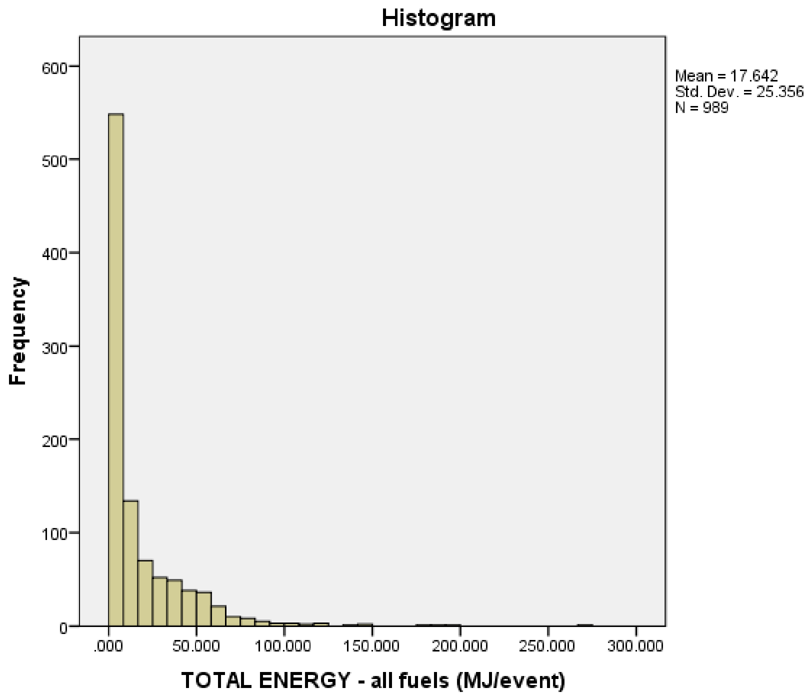


Figure 9 Distribution of total energy consumption (MJ/event)

5.3.2 Mix of fuels

The mix of fuels used in Phase 1 is presented in Figure 10. This shows that charcoal accounts for the majority of energy consumed (59%). This does not mean that charcoal is the most commonly used fuel, as the conversion efficiency of charcoal will be less than that of LPG, for example. During Phase 2, electricity was the dominant fuel used for all heating events, as was intended in the design of the experiment (see Figure 11). Note that only 58% of the total energy consumed during phase 2 was electrical energy. Charcoal accounted for 19% of all energy used in Phase 2. Participants' observations indicated that in many cases charcoal was used because of power cuts.

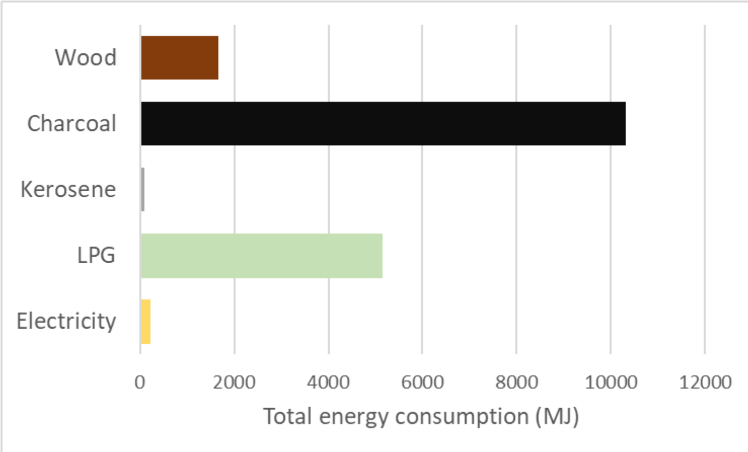


Figure 10 Energy content of fuels used in Phase 1

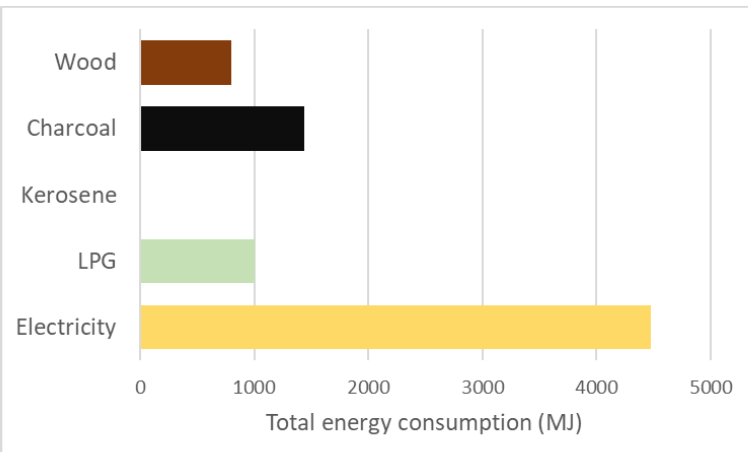


Figure 11 Energy content of fuels used in Phase 2

The data shows that participants used multiple fuels in 14% of heating events in Phase 1, but in only 2% of heating events in Phase 2. It also shows that almost all participants used both LPG and charcoal.

5.3.3 Per capita consumptions

It has already been pointed out that energy consumption depends on the number of people being cooked for. Per capita energy consumptions have been calculated simply by dividing the energy consumption for the heating event by the number of people that the meal was cooked for. Note that adults and children have been given an equal weighting when calculating per capita consumptions.

During Phase 1, different participants used different fuels, so per capita energy consumption values will depend on the fuel being used. A single fuel was used in most heating events, so per capita consumptions for heating events using the main fuels only have been calculated. **Totals indicate that cooking with charcoal uses 5.5 times as much energy as cooking with LPG, and ten times as much energy as cooking with electricity (in Phase 2).**

Table 4 Per capita energy consumptions and number of people cooked for – single fuels only

	Phase 1						Phase 2		
	LPG			Charcoal			Electricity		
	Median	People (mean)	N	Median	People (mean)	N	Median	People (mean)	N
A1	1.0	4.3	33	5.4	4.5	8	0.6	4.3	84
A2				7.0	3.4	13	0.6	2.5	56
A3	2.4	2.5	36	27.1	1.8	6	1.3	2.2	58
C1	1.5	4.1	26	9.3	4.0	7	0.6	3.9	39
D1	0.4	3.4	30				0.5	4.5	37
E1	1.3	4.7	44				0.8	5.0	53
E2	1.1	6.0	23	2.7	5.7	6	0.6	4.5	46
E3	0.9	5.1	13	5.0	6.3	44	0.4	5.7	57
E3	1.0	4.3	26				0.5	3.1	82
H1	1.3	3.6	25	8.6	2.7	6	0.8	3.8	78
J1	1.3	7.1	17	3.6	7.5	16			
J2	0.9	4.0	31				0.4	3.5	66
L1	0.7	5.7	21				1.7	4.7	59
M1	1.2	4.2	50				0.8	4.0	52
N1	1.3	1.0	19				0.7	1.8	27
N2	1.2	7.9	10	4.1	8.6	31	0.4	7.1	82
R1	0.7	6.8	30	9.5	7.3	6	0.4	7.1	61
S1							0.8	2.6	90
S2							0.5	5.3	84
T1	1.5	3.0	19				0.7	3.8	59
U1	1.4	5.9	53				1.1	5.9	66
V1				8.7	5.7	27	0.4	5.8	85
Total	1.2	4.5	511	6.0	6.0	190	0.6	4.4	1321

* results shown only for participants with 5 or more cases.

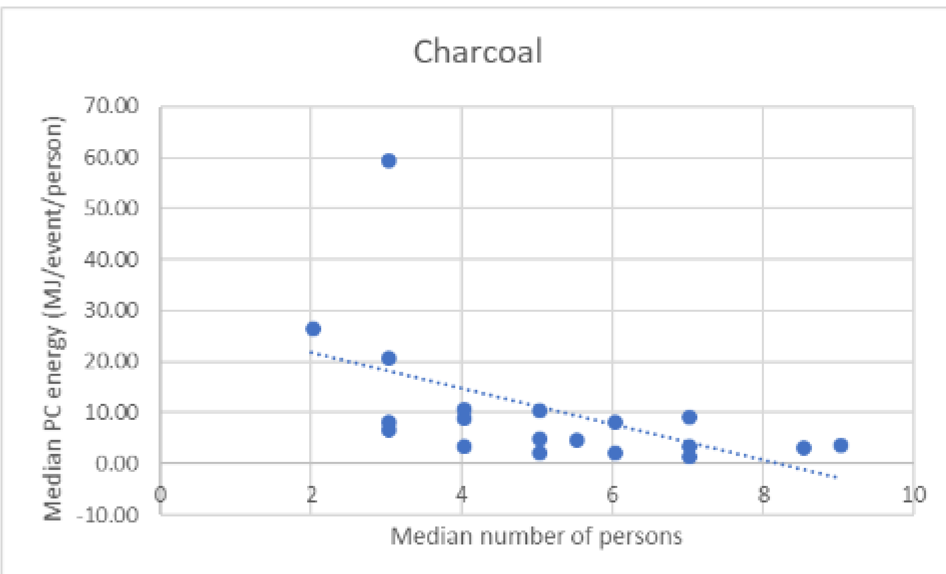
Plotting per capita consumption against number of people the data shows that, apart from a few participants with high per capita consumptions, there is a good deal of consistency in the

Totals indicate that cooking with charcoal uses 5.5 times as much energy as cooking with LPG, and ten times as much energy as cooking with electricity (in Phase 2).

Cool headline!

median values among most participants (Phase 1). Whilst this may suggest that per capita consumption does not depend on the total number of persons cooked for, any effect is probably masked by differences in conversion efficiencies of different fuels. These effects have been explored by separating out heating events using only a single fuel. The main fuels used were charcoal, LPG, and wood (see Figure 10), so each has been considered in turn. Figure 12 presents median per capita energy used for heating events where only a single fuel was used:

- Charcoal. **When the single outlier (T1) is removed, there is a negative relationship between per capita energy consumption and number of persons** ($B = -1.540$, $p < 0.001$).
- LPG. When the two high values (A3 and S2) are removed, there is no significant relationship between per capita energy consumption and number of persons.
- Wood. Only two participants used wood (D1 and R1), and only four heating events meet the criteria for the analysis, so it was not possible to reach any realistic conclusions.



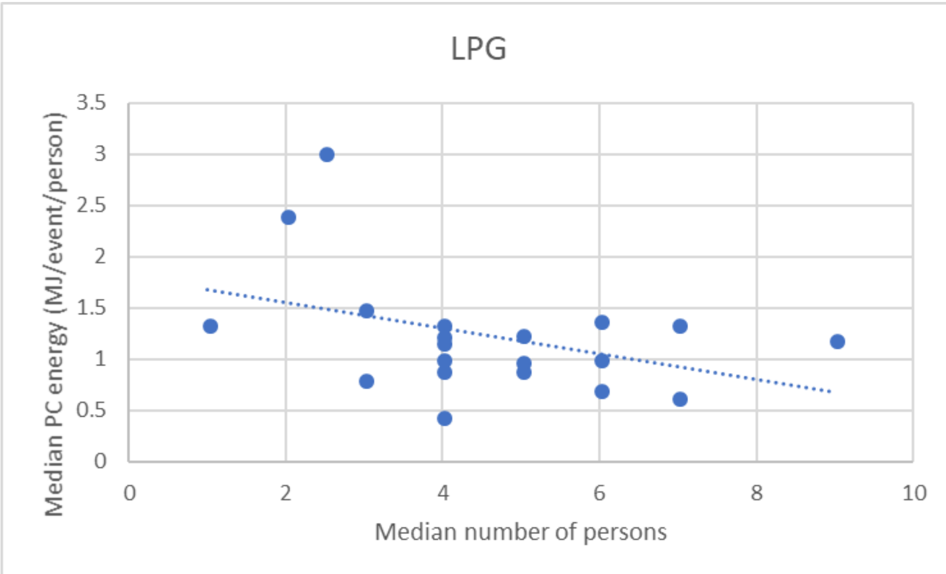


Figure 12 Relationship between per capita energy consumption and number of people – Phase 1 Charcoal and LPG

Figure 13 presents median data for Phase 2, but only those heating events where only electricity was used. When one outlier is omitted (L1), a regression analysis shows that there is no significant relationship between per capita energy consumption and number of persons.

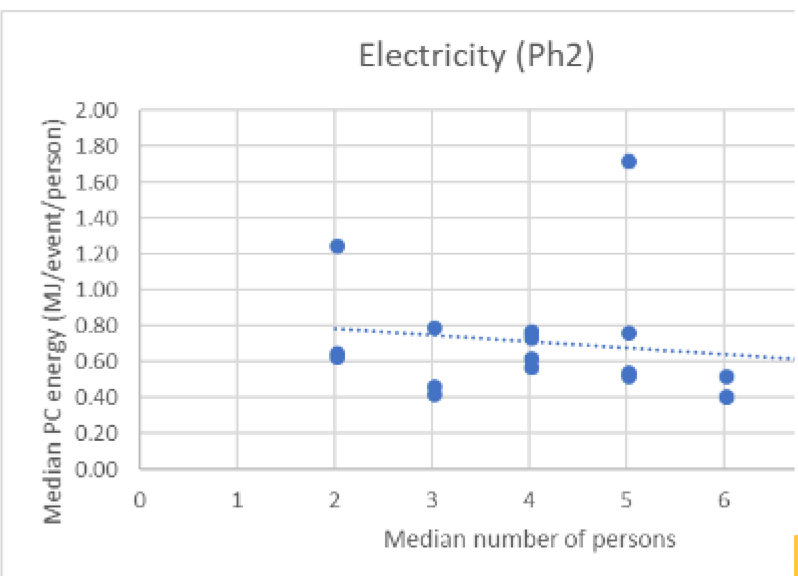


Figure 13 Relationship between per capita energy consumption and number of people – Phase 2

The more direct relationship between number being cooked for and the controllability of electricity is something we have always surmised, but its great to see it in data.

If you light a charcoal stove to make tea for one person, it will be almost the same as making tea for 5 people. But with electricity, assuming you don't overfill the kettle, then one cup of tea 'costs' a lot less energy than 5 cups of tea.

These findings indicate that economies of scale can be achieved when using high thermal mass fuels that are not

readily controllable i.e. charcoal. LPG and electricity, in contrast, can be turned down and switched off instantly, and these exhibit less economies of scale.

5.3.4 Energy consumption by heating event

Summing the energy consumed in all Phase 1 records shows that dinners and water heating consumed the most energy, closely followed by lunches. The median per capita energy consumptions for each type of heating event illustrate differences in the overall conversion efficiencies associated with different fuels (Figure 14). Data shows that for all fuels, preparing food for babies was the most energy intensive heating event (on a per capita basis). The next most energy intensive event was lunch (electricity and charcoal) and dinner (LPG). Note that per capita energy consumptions for breakfast and heating water were similar.

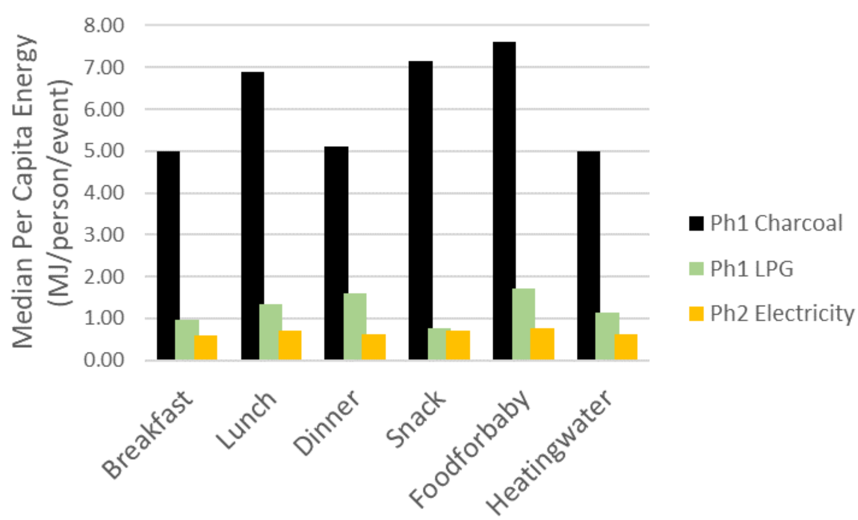


Figure 14 Per capita energy consumptions for different heating events

The mix of fuels used for different events in Phase 1 is illustrated in Figure 15. Note that this chart presents the number of occasions (or cases) in which fuels were used – it does not reflect the amount of energy used. It shows that biomass was most commonly used for dinners and lunches.

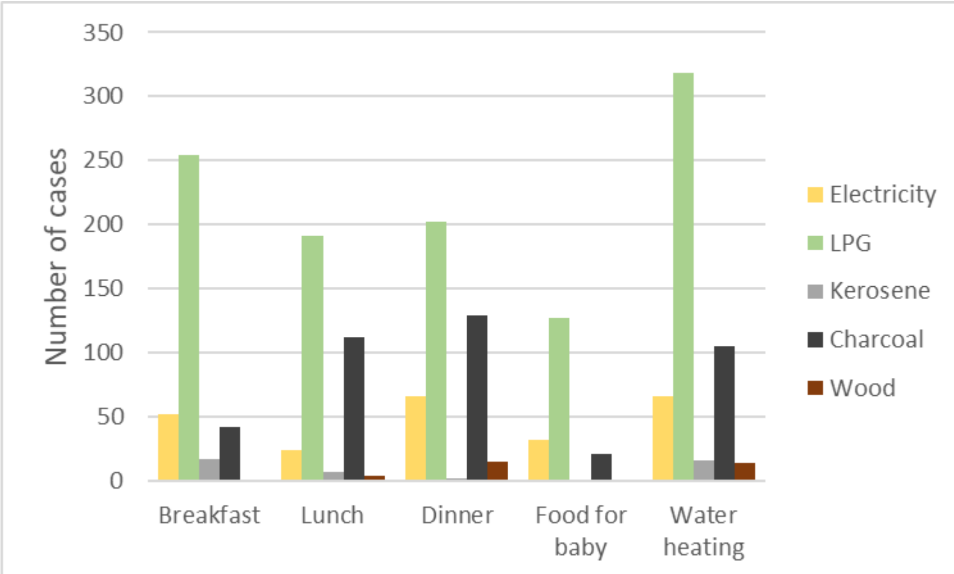


Figure 15 Choice of fuels for heating events (Phase 1)

5.3.5 Energy consumption per day

Daily energy consumption across the sample is complex. Even when households are in phase 2, mainly using electricity, the daily energy consumption can be skewed by the few days when they have to revert back to charcoal because of no power. While the main data report shows the daily energy consumption, this summary discusses the daily energy consumptions for three participants in particular. These three have been chosen as they represent a range of cooking efficiencies:

- J2 uses 0.9 MJ/capita/event (median) for a mean of 4.5 persons/event, when she uses LPG. However, when she uses charcoal she uses 2.6 MJ/capita/event (median) and 0.4MJ/capita/event (median) when she uses electricity.
- U1 uses 1.4 MJ/capita/event (median) for a mean of 5.9 persons/event when using LPG, and 1.1 MJ/capita/event (median) for electricity.
- R2 uses 0.7 MJ/capita/event (median) for a mean of 7.9 persons/event for LPG, 9.5 MJ/capita/event (median) for charcoal and 0.4 MJ/capita/event (median) for electricity;

N.B. on 1st April, R2 cooked for 33 people and the energy consumption for that day was 420 MJ.

The main data report shows a set of charts for Phase 2 (N.B. these charts include all fuels used; fuels other than electricity were used during power cuts).

Much of the data suggests consistent daily energy consumption, with odd anomalies (or spikes), representing special occasions of some sort. An analysis of mean energy consumption by day of the week shows little consistency either between the three example participants, or between the two

> The daily energy consumption is complex because people are using mixtures of charcoal, LPG and electricity. The example energy consumption shown above is based on the energy content of the fuel – ie kgs of charcoal and LPG are assigned an energy content, kWh consumption at the meter is measured. So the above are Gross energy consumptions inclusive of conversion efficiencies and process efficiencies.
>
> However, in Leach and Oduro (2015), they quote two sources who attempted to measure cooking in real household situations. "Ravindranath and Ramakrishna (1997) conducted empirical measurement of the efficiency of various cooking appliances …..with housewives cooking a meal for 6 people **under controlled conditions**, based on rice and sauce." Leach and Oduro then work the consumption figures into useful energy, and build them back up into gross energy for the household by assuming a 70% efficiency. "The results range from 0.6 to 1.3 MJ per meal per capita, (0.18 to 0.37 kWh), with a mean of 0.9 MJ/capita per meal (0.24 kWh). This equates to 0.72 to 1.48 kWh per meal for a family of four." They also note that "As part of an EU-funded project in South Africa, Cowan (2008) conducted similar tests of the energy used by different cooking appliances, both in the laboratory but mainly under real cooking conditions. He explored the cooking energy for a wide range of types of meal."
>
> Based on these sources, Leach and Oduro created 'low cook' and 'high cook' scenarios for their early economic modelling of the eCook proposition with 0.68 Gross MJ/capita/event and 1.85 Gross MJ/capita/event respectively.
>
> **The data here suggests that J2 and R2 are firmly in the low cook scenario while U1 is more than low cook but still a lot less than high cook.**

phases. Note that these figures typically represent the means of only 2 to 5 readings.

5.4 Meals cooked

5.4.1 Food types cooked

Separating out foods cooked for breakfast, lunch or dinner only, Table 5 shows that when asked to cook with electricity, participants **were less likely** to cook ugali, and seem to have substituted it with rice (which is easier to cook). Most of the other dishes were less frequently cooked in Phase 2, but it is not clear what has been cooked in their place as 'other' is the only dish that was cooked more often in Phase 2. Table 6 shows that participants were less likely to prepare complex meals with multiple dishes in Phase 2 (36% of meals in Phase 2 comprised a single dish only, compared with 27% in Phase 1).

It is interesting that overall people were 'less likely' to cook ugali on electric cookers, and changed their eating habits to accommodate our trial.

Rice is a 'low energy' food, it requires less energy to cook than the equivalent weight of ugali flour. Would this be a strategy people would adopt during the rainy season if a Solar Home System that cooked wasn't quite performing to fit all their needs, or was this a temporary strategy for the trial to keep the experimenters happy?

N.B. food information was not submitted in all records. 88% of breakfast/lunch/dinner records in both Phase 1 and Phase 2 contained food information (N=912 and N=1249 respectively).

Table 5 Number of meals containing food types (Breakfast, lunch and dinner heating events only)

	Phase 1		Phase 2	
	N = 1036		N = 1415	
	Frequency	Percent	Frequency	Percent
Ugali	228	22.0%	246	17.4%
Chapati	42	4.1%	34	2.4%
Rice	243	23.5%	385	27.2%
Eggs	46	4.4%	46	3.3%
Bananas	169	16.3%	225	15.9%
Pilau	57	5.5%	59	4.2%
Chips	24	2.3%	20	1.4%
Makande	29	2.8%	20	1.4%
Stew	298	28.8%	363	25.7%
Other meat/fish	78	7.5%	37	2.6%
Other veg	136	13.1%	137	9.7%
Beans	216	20.8%	261	18.4%
Other	329	31.8%	537	38.0%

Table 6 Number of foods included in a heating event (Breakfast, lunch and dinner heating events only)

It is not clear from Table 7 that any particular foods lend themselves to being eaten on their own (i.e. as single dish meals), although something included in 'other' is most commonly eaten on its own, mostly 'porridge'.

Table 7 Occurrence of foods in meals by number of foods in the meal (all heating events, Phase 1 and 2)

	1	2	3	4	Total
Ugali	27	207	219	22	475
Chapati	27	35	15		77
Rice	79	313	223	20	635
Eggs	23	54	15	2	94
Bananas	73	152	155	23	403
Pilau	36	46	27	9	118
Chips	7	20	15	2	44
Makande	21	17	10	1	49
Stew	28	308	298	32	666
Other meat/fish	4	45	60	8	117
Other veg	3	75	178	19	275
Beans	19	198	239	24	480
Other	416	284	196	26	922

5.4.2 Reheating food

In 18% of all records, some food was precooked. Where multiple heating events are recorded on one case, it is not possible to determine which of the events the food has been reheated for. Therefore, the analysis considers only those records that related to a single heating event. Comparing the number of each type of event with Table 1 indicates that breakfasts are mostly commonly combined with other events. The data shows that lunches are most commonly reheated and shows that combinations of rice, ugali, and stews are most commonly reheated. Note that where some food was precooked and the meal comprises multiple foods, it is not possible to determine which food was reheated.

Reheating pre-cooked food has a number of effects on the energy demand. In the UK, where modern energy is common, 79 million 'ready meals' are eaten each week. A ready meal is effectively a pre-cooked meal (prepared by the producer).

5.4.3 Energy to cook food types

The data report identifies the energy required to cook various food types and meal combinations. In Phase 1 participants may have used multiple fuels. In order to meaningfully compare the specific energy used to cook different foods and combinations, only records using a single fuel have been included. Furthermore, records in which food was reheated have been omitted from the results.

Electrical energy consumption is broken down further where the efficiency of different electrical devices is discussed.

5.5 Cooking appliances

5.5.1 Detail on how participants cook

Participants were asked to record the following information on how they cooked:

- Cooking appliance used i.e. what type of stove.
- Type of cooking pot / utensil.
- How they used the lid.
- Cooking process used e.g. fry, boil, bake etc.

The cooking appliances used to cook individual foods are presented in Table 8. Note that any single record (or meal) can contain information on up to four foods, so the table includes each separate food–appliance combination. This shows that 9% of foods were cooked with electricity in Phase 1. Table 9 shows that boiling is by far the most commonly used cooking process. Note that participants did less frying when using only electricity in Phase 2; this can also be seen in the lower use of frying pans in Table 10. Voltage dips or brown outs were an issue for some participants, meaning that frying on an uninsulated pan on the hotplate is slowed significantly. The effect on boiling on insulated devices would not be as noticeable. Participants were more likely to use lids when cooking electricity only (see Table 11).

The lower occurrence of frying has to be considered in the light of the households learning how best to use their appliance. Many of the hotplates did not have the 'contained' power to fry easily with heat loss underneath and to the side of the relatively cheap hotplate. However, when the same power is applied to the base of an insulated multicooker, with minimal losses down and to the side, reaching frying temperatures becomes easier. This use of multi cookers was not evident when the households were choosing appliances, and only really came to light as the trials continued.

Table 8 Appliances used to cook foods (frequencies)

	Phase 1	Phase 2 (electric only)
Charcoal Stove	565	4
Gas stove	1224	6
Grill / oven	2	0
Electric hotplate	63	1280
Induction hotplate	3	203

Heater	0	1
Electric kettle	0	3
Electric pressure cooker	17	522
Microwave	49	84
Rice cooker	46	163
Other	28	0
Total	1997	2266

Table 9 Cooking processes used to cook foods (frequencies)

	Phase 1	Phase 2 (electric only)
Fry	340	237
Boil	1548	1627
Grill	0	0
Steam	0	4
Bake	5	6
Microwave	49	78
Pressure cook	21	262
Other	2	0
Total	1965	2214

Table 10 Utensils used to cook foods (frequencies)

	Phase 1	Phase 2 (electric only)
Bowl / plate	48	109
Frying pan	187	94
Kettle	1	1
Pot big	129	43
Pot medium	944	818
Pot small	686	597
Other	2	1
Total	1997	1663

Table 11 Use of lid when cooking foods (frequencies)

	Phase 1	Phase 2 (electric only)
No	686	472
Some	224	331

Yes	1089	1453
Total	1999	2256

5.5.2 Characteristics of different cooking devices

Given that equal numbers of participants had access to LPG and charcoal, it can be assumed that differences in the choice of devices used to cook foods reflect choice (rather than availability). The data shows that, in Phase 1, participants preferred to cook most foods using LPG, with the exception of rice. Rice is also the only food that participants commonly used electrical devices to cook in Phase 1. There appears to be a strong preference to cook some foods using gas (e.g. eggs, bananas, Other (mostly porridge)), whereas opinion is more balanced for other foods (e.g. ugali, stew, beans).

With gas (LPG) you can quickly adjust the power level using a continuous scale rather than the discrete options offered by many electric hotplates. Lag time on the control is also more of an issue for hotplates, as the plates themselves have a thermal mass. The plates more so than the exposed spirals presumably. This is also one of the reasons why professional kitchens have gas rather than electric hotplates.

It also shows that simple hotplates were most commonly used for all foods, but this may reflect appliances provided rather than preferences. Most participants chose a hotplate plus something else. A few an induction stove and something else.

Boiling is mostly done on done on gas stoves (62% of foods boiled), but a higher proportion of frying is done on gas stoves (71% of foods fried). This is probably because foods are fried for a shorter time, and LPG can be turned on/off instantly.

The equivalent data for Phase 2 is not so interesting as it probably reflects the electrical devices provided to participants, but it does show that on a small number of occasions, participants tried using pressure cookers for a variety of cooking processes, notably frying.

5.5.3 Fuel stacking

The number of cooking appliances used in preparing each meal (or case) in Phase 1 is presented in the data report. In only 16% of cases were more than one cooking device used. It suggests that participants are mixing LPG with charcoal and with electricity.

5.5.4 Energy used by different electrical appliances (Phase 2)

Per capita electrical energy figures in Table 12 indicate **that 'efficient' electrical devices such as rice cookers and microwaves use less than half as much energy as a simple hotplate**. However, both rice cookers and microwaves were mostly used to cook rice, whereas pressure cookers and hotplates were used to cook a range of foods. In order to make more meaningful comparisons, the specific energy consumption for different foods and combinations are presented. An illustrative sample of foods cooked on most appliances are compared in Figure 16 (only data points where n>=5). This figure does not show consistent trends.

Table 12 Per capita energy consumption (MJ/pers/event) of meals cooked using single electrical device (Phase 2)

Cooking device	Frequency	Mean	Median	Std.dev.	25% Quartile	75% Quartile
Hotplate	490	1.04	0.77	0.97	0.53	1.25
Induction hob	74	0.66	0.44	1.01	0.25	0.76
Pressure cooker	179	0.69	0.54	0.78	0.24	0.78
Microwave	40	0.38	0.29	0.43	0.08	0.58
Rice cooker	12	0.41	0.36	0.29	0.19	0.52

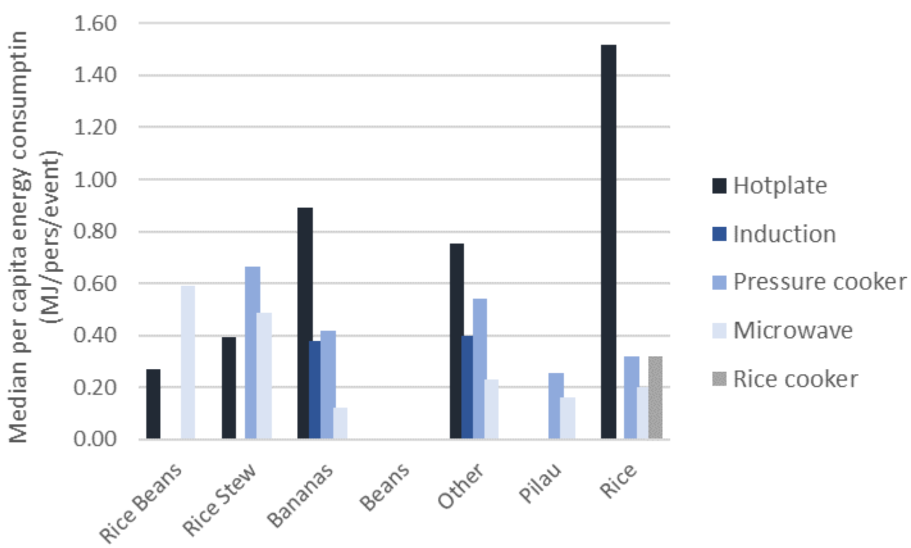


Figure 16 Specific energy consumptions of different electrical cooking appliances (n>=5)

6 Discrete Choice modelling surveys

6.1 Introduction and Method

Discrete choice experiments enable understanding of user priorities pertaining to selected products and with which the consumer need not be so familiar. It focuses on the parameters of design involved and asks respondents to make choices between two discrete types of technology with different design parameters. Essentially it asks would you like product A with these types of characteristics or would you like product B which has one parameter the same and the rest are different. The methodology has become popular in the fields of marketing and transport studies. Discrete choice modelling has considerable advantages over stated preference, particularly in this case of exploring a market for a future product. 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. DCE enables the characteristics of a future product to be presented to the consumer in a technology neutral way and for the respondent of the survey to identify the characteristics that are most important to them.

A choice modelling survey was designed to capture user preferences on specific design features of a future eCook device. Participants were asked to choose between a series of stove configurations, presented as choice cards. Each card had 2 stoves with different attributes and the participants were asked to choose which they preferred. Each set of attributes was rotated around amongst subsequent cards to build up a picture of which attribute the participant valued most and by how much. Each participant was shown 3 sets of choice pairs, consisting of 7 or 8 cards each. To test a wider range of attributes, two sets of choice cards were developed, A and B.

Each participant was also asked a set of standard questions to contextualise their responses, such as level of education, current cooking practices and access to electricity. The surveys were carried out by two enumerators as face to face interviews and responses were recorded using the Kobo Collect Android application on a tablet. Three quarters of the sample were drawn from urban areas around Dar es Salaam, and one quarter were drawn from a single rural town, Kibindu town.

6.2 Overview of data

Face to face interviews were conducted using Kobo Toolbox CAPI software. The sample of 202 interviews were conducted by two enumerators (Angel and Tafu). Three quarters of the sample were drawn from urban areas around the capital, and one quarter were drawn from a single rural town (Kibundu town). The mean time taken to walk to the nearest market was 9.0 minutes for urban respondents and 6.6 minutes for rural respondents, so it appears that all rural respondents lived within a short distance of the Kibundu market. Although they were in a rural area, they did not live in remote areas, far from markets and other facilities.

> The fact that the respondents watch TV and listen to radio bodes well for the future marketing of eCook. Cooking programs are popular worldwide and it would make sense to offer a Tanzanian cookery programme that included energy conservation while cooking delicious food.

The sample was predominantly female – 35:65 (male:female). 73% of respondents were either the head of household or the spouse of the head of household. The mean age of respondents was 35.6 years, but the sample included respondents of a wide age range. The sample was split roughly one third with primary education, one third with secondary education, and one third with some kind of tertiary education. Most respondents both listen to the radio and watch TV. They correlate strongly (r = 0.679, $p < 0.001$), showing that those who watch more TV also listen to the radio more often. 17% were isolated in not accessing either of these types of broadcast media.

Patterns of mobile phone use can serve as a proxy for technical proficiency and ability to adapt to technological innovations. 91% of respondents owned a mobile phone (or SIM card), and most of these were smartphones. Although most respondents used a phone several times a day, there remains a sizable minority who did not use a phone at all. Literacy clearly acts as a barrier to fully exploiting the potential of mobile phones, and 11% of respondents were not able to read SMS texts for themselves (n=23). Most of these (n=19) had not used a phone in the previous month. In terms of innovative services, over half of respondents used the internet and social media services (e.g. Facebook, Viber, WhatsApp) daily. Although 80% used mobile money services (e.g. M-Pesa, Halo-pesa, Airtel Money), only 25% used mobile banking applications (e.g. CRDB Simu Banking).

Again the use of facebook and social media bodes well for a viral marketing of new approaches to cooking. The use of money services bodes well for pay as you go models whether PAYG towards ownership or a utility model of paying a monthly (weekly or even daily) fee for a service.

6.2.1 Household characteristics

The mean household size was 4.8 (including children). The distribution of household sizes is presented in. 49% of households had at least one child under the age of 5 years. Details of dwelling constructions were noted and the households' main sources of drinking water are presented in Table 13.

Table 13 Main source of drinking water

		Deprived	Frequency	Percent
Valid	Piped into dwelling		76	37.6
	Piped into yard		2	1.0
	Public standpipe		51	25.2
	Protected dug well		13	6.4
	Unprotected dug well	X	14	6.9
	Protected spring		3	1.5
	Unprotected spring	X	1	.5
	Rain water		3	1.5
	Tanker truck	X	1	.5
	Bottled water		38	18.8
	Total		202	100.0

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 deprived on the education indicator if the respondent had no education or primary education only. These five dichotomous indicators (3* construction, water and education) show a good deal of internal consistency (Cronbach alpha = 0.819), so they form a reasonable basis upon which to create a composite poverty index. 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: 58% non-deprived, and 42% that are deprived in at least one indicator.

The respondents were clustered around Dar es Salam and in that sense the findings are not representative for the whole country (and they were never intended to be – they were a snapshot for market scan purposes). However, the fact that 42% were deprived shows that the findings are not confined to the middle class but have applicability to the poorer sections of the market.

Table 14 Composite Poverty index

		Frequency	Percent
Valid	0	118	58.4
	1	35	17.3
	2	11	5.4
	3	17	8.4
	4	15	7.4
	5	6	3.0
	Total	202	100.0

6.2.2 Characteristics of household electricity supply

6.2.2.1 Sources of electricity

81.2% of respondents had no electricity (n=38). However, only 12% (n=24) said they had none of the sources of electricity listed

This section confirms that electricity connections remain scarce, and that when they are there the quality of the connection is not great. However, the presence of so many solar devices among those not connected, does suggest that if a viable affordable, reliable modern energy cooking service was available, uptake might be high.

(excluding rechargeable and dry cell batteries). Of the 14 anomalies:

- 2 had solar mini-grids
- 6 had solar lanterns
- 10 had other

Most respondents had a single source of electricity, but 11% had multiple sources. Among these 23 respondents, the most common combination was national grid and solar lighting.

Respondents with connections to the national grid or to any type of mini grid were asked to give details of the type of connection; results in Table 15 show that most respondents had shared meters on a national grid supply.

Table 15 Type of connections

Source	Informal	Direct connection with shared meter	Direct connection with individual meter	Total
National grid	1	82	67	150
Solar mini grid	10	0	0	10
Biomass gasifier mini grid	0	0	1	1
Other mini grid	1	0	0	1

We can see that a considerable proportion of the respondents are already paying TSh 20000 ($10) or above. Most of this is for lights, phone charging and TV. If a cooking service of the order $12 a month was added, there is every reason to believe significant proportion of the respondents would take it up.

All households with formal connections to the national grid (Table 15) have pre-paid meters; 56% have shared pre-paid meters. Among households connected to a mini-grid, most have a type of tariff other than those listed in the survey. Most respondents topped up their prepaid electricity meter either monthly, or twice monthly. 10,000 TZS and 5,000 TZS were the most popular amounts paid when topping up. These two sets of figures have been combined to calculate the monthly cost of electricity. Monthly electrical energy consumptions have then been calculated from monthly electricity costs on the basis of the D1 monthly electricity tariffs published by Tanesco[3]:

- 0-75 kWh 100 TZS/kWh

[3] http://www.tanesco.co.tz/index.php/customer-service/tariffs

- > 75 kWh 350 TZS/kWh

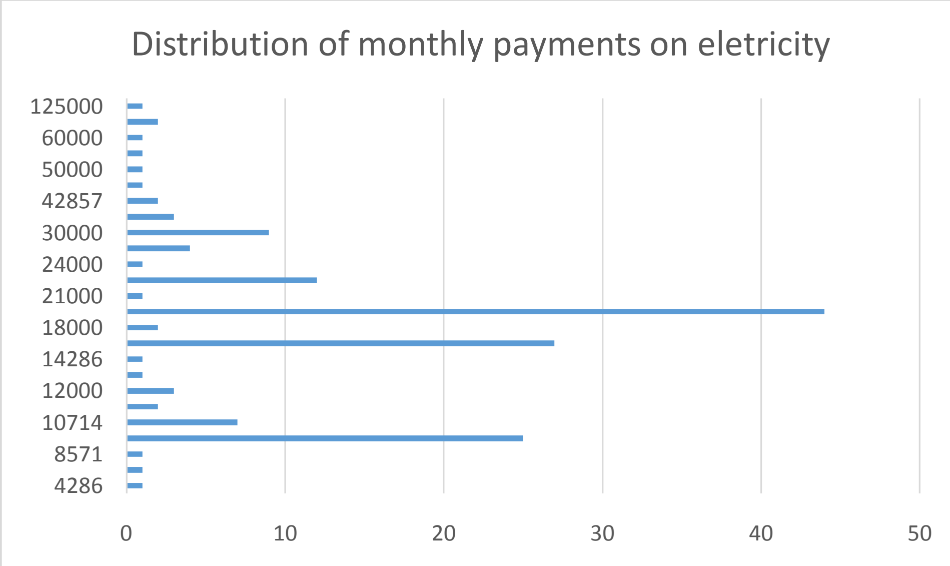


Figure 17Number of respondents making a monthly electricity payment.

Only those respondents who said they had no electricity were asked which appliances they had – see Table 16.

Table 16 Household ownership of electrical appliances

Appliance	Frequency	Valid percent
Radio (battery powered)	58	35.4
Music system (mains powered)	95	57.9
Mobile phone	161	98.2
Television	130	79.3
refrigerator	103	62.8
Electric kettle	8	4.9
Electric water heater	38	23.2
fan	142	86.6
Air conditioner	5	3.0
Electric lights	148	90.2

Respondents who accessed electricity via the national grid or any type of mini grid were asked a series of questions relating to quality of supply.

There seems to be an acceptance and appetite for electrical appliances, even with the unreliability of the existing grid. This bodes well for future reliable eCook.

Among national grid users,

- 22% felt that the voltage was inadequate for cooking on occasions,
- 71% had experienced load shedding (at some point in the past). The data shows a clear season trend, for load shedding to occur in the December to April months.
- 97% currently experienced frequent blackouts (defined as more than once a month).

Note that load shedding and blackouts were only experienced by household connected to the national grid. Patterns of blackouts during load shedding and at other times were different. Although the frequency of blackouts in both instances was similar, with most occurring once or twice a week, blackouts due to load shedding lasted much longer, typically about a day, compared with 1 or 2 hours for other blackouts.

Among respondents with experience of load shedding, 95% had received some kind of information about a schedule. Among those who did receive information (even if not accurate) (n=38), most got this information via local broadcast media (loudspeakers and radio) and from social networks (neighbours).

Whilst national grid is always available (notwithstanding blackouts, as discussed above), most mini grids are only available at certain times of the day (all are solar mini grids). Those switched on once a day are switched on at 18.00 and off around 07.00.

Load shedding and unreliable voltage, even scheduled blackouts are all reasons why cooking with electricity has been challenging in the recent past even where people are connected. The data also suggests that people will tolerate outages as long as they are informed and can plan around them. eCook takes this into account and seeks to improve the situation.

6.2.3 Characteristics of cooking practice

6.2.3.1 Meals and timing

Dinners are the meal most commonly cooked, whereas only 60% of respondents always cooked lunch or breakfast (Figure 18). The data shows that only 46% of households always cook all three meals.

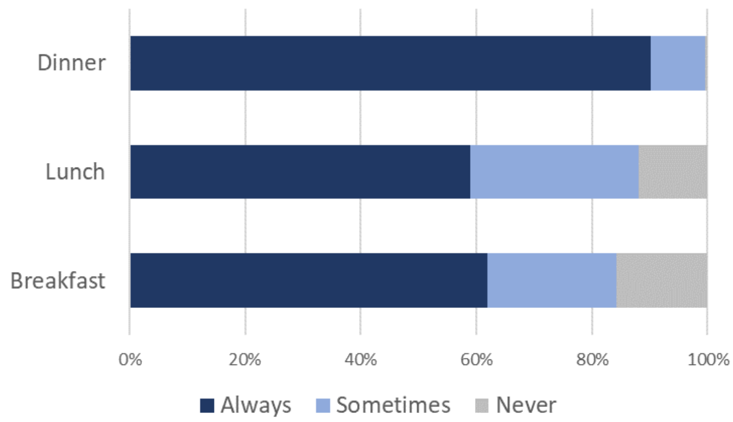


Figure 18 Meals cooked in the household

The survey also asked about heating water for various purposes. Almost all respondents heated water for hot drinks and over half heated water to purify it. All respondents who answered the questions heated water for one purpose or another.

Table 17 Heating water

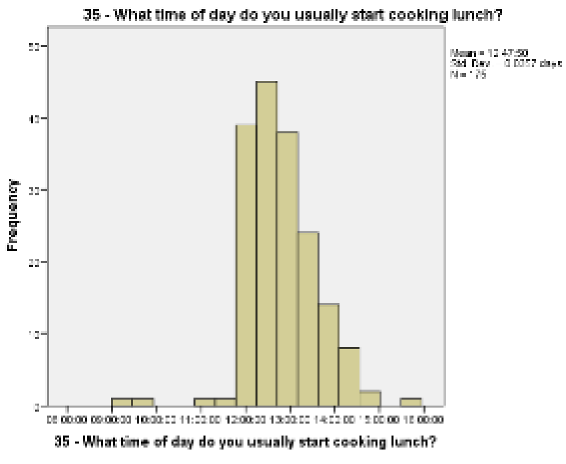
Purpose of heating water	Frequency	Percent
Heat water for bathing	41	20.3
Heat water for tea/coffee	183	90.6
Heat water for purifying water	116	57.4

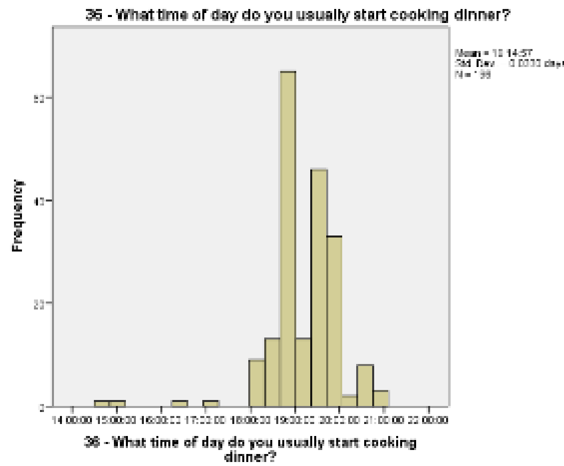
The most common times to star cooking meals (modes) were:

- Breakfast: 7.30
- Lunch: 12.00
- Dinner: 19.00

The distributions of starting times show that 90% of households start cooking:

- breakfast between 6.30 and 8.30
- lunch between 12.00 and 14.30
- dinner between 18.00 and 20.30.





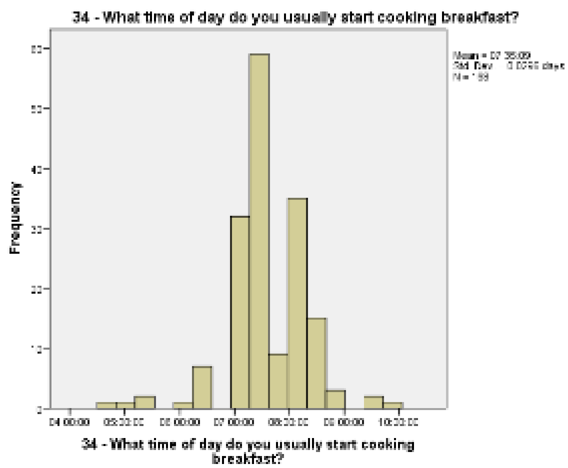
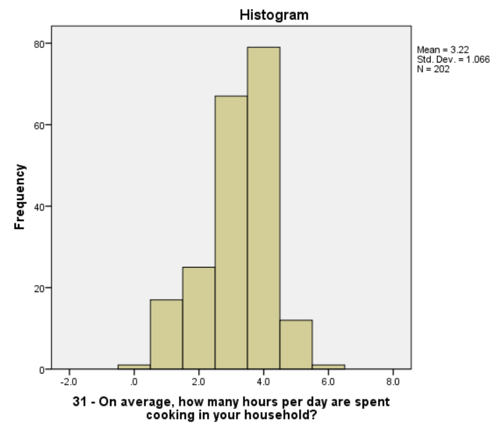


Figure 19 Distribution of time spent cooking (hours/day)



Households spend an average of 3.2 hours/day cooking (median = 3.0 hours/day). Figure 19 shows that the mode is 4 hours/day. As might be expected, there is a strong correlation between time spent cooking and the number of meals always cook ($r = 0.578$, $p < 0.001$).

In 73% of households, it was a woman who did most of the cooking, and in 21% of households men and women shared cooking; in only 7% of households did a man do the majority of the cooking. The norm was a female spouse of the head of the household to do the majority of the cooking, although in a substantial number of households cooking was shared[4]. It is interesting to note that other family members were just as likely to be male as female (N.B. no detail was gathered on who those family members were).

[4] It is assumed that cases where the spouse does the majority of the cooking yet the gender of that person is 'both' represent households where the man shares cooking with his wife.

6.3 Cooking fuels

Charcoal and LPG were the fuels most commonly used for cooking, followed by wood. Note that although substantial numbers of households used electricity and kerosene for cooking, relatively few relied on them as their main cooking fuel, implying these fuels tend to be used as a back-up supply. Most households used multiple fuels for cooking. Of the 93% of respondents who did not use electricity for cooking, only 39% had some prior experience of cooking with electricity.

Among households using only a single cooking fuel, the choice was split roughly equally between charcoal, LPG, and wood. The pairing of cooking fuels among those households using two cooking fuels along with the split of fuels regarded as the main cooking fuel, shows that:

- Electricity was only used as a supplementary (supporting/backup[5]) fuel by those using LPG
- Kerosene was used as a backup fuel with LPG and charcoal
- Charcoal was most commonly used in combination with LPG
- Preference for charcoal was split equally with LPG, and also with wood.

The cooking location within the household is split roughly equally between indoors and outdoors. Breaking location down by main cooking fuel shows how LPG is used indoors, and charcoal and wood are used outdoors (Table 18).

Table 18 Cooking location broken down by main cooking fuels

Main cooking fuel	Cooking location			Total
	Indoors	Outdoors	Both	
Electricity	1	0	0	1
Cylinder gas	55	2	16	73
biogas	0	0	1	1
Kerosene	2	1	1	4
Charcoal	3	44	41	88
Wood	9	17	7	33
Total	70	64	66	200

[5] It is a secondary fuel used for specific applications like reheating in a microwave or cooking rice in a rice cooker.

Most respondents used 14 kg LPG cylinders. Three cylinder sizes were reported by respondents: 14 kg, around 30 kg, and 80 kg. These do not correspond with standard cylinder sizes of 6gk, 15 kg, and 38 kg[6]. Nevertheless, the prices paid for the three sizes of cylinder appear to be consistent:

- 14 kg – roughly 20,000 TZS
- 30 kg – roughly 45,000 TZS
- 80 kg – 100,000 TZS

Prices paid for the 30 kg cylinders category are consistent with market prices for 15 kg cylinders:

> *"It should however be noted that, of recent especially in 2016, the prices of LPG appeared to be relatively lower than the equivalent usage quantity price of charcoal (example 1 sack of charcoal cost of TZS 40,000 -60,000 versus one 15 Kg cylinder of LPG cost of TZS 45,000 to 55,000)."*[7]

For the purposes of calculating energy consumptions, it has been assumed that these three categories are actually 6 kg, 15 kg, and 38 kg respectively.

Most respondents get a refill every two months.

Most kerosene users consume around 5 litre/month. Kerosene prices have been deduced from the monthly expenditure on kerosene, and show the price to be around 2,000 TZS/litre.

6.3.1 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.

One third of charcoal users buy charcoal on a monthly basis, but nearly 20% buy small amounts every 2-3 days. Charcoal is most commonly bought in 25 kg and 15 kg amounts (corresponding to sacks and buckets respectively. Again, 23% of charcoal users usually buy charcoal in small amounts (less than 5 kg).

There are huge differences in the prices paid for charcoal between rural and urban areas. The range of specific prices (TZS/kg) was much higher in rural areas, ranging from 67 – 1,000 TZS/kg; the range in urban areas was only 470 – 1500 TZS/kg.

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[6] http://www.esaja.com/lpg-gas/lpg-gas//p/?id1=23347
[7] http://www.ewura.go.tz/wp-content/uploads/2015/04/2017-PETROLEUM-REPORT-web.pdf

6.3.2 Wood

Only those respondents who used wood for cooking were asked for details of their consumption of wood. 90% of respondents that used wood for cooking were in rural areas.

Units of wood included:

- Bundle
- Bundle carried by hand
- Large bundle (carried by hand cart)
- Large bucket
- 10kg

No indication was given of the mass of wood associated with these units. Estimates of energy consumption have been based on 10 kg/bundle. The most commonly paid price was 1,000 TZS, for a bundle. 3,000 TZS was paid for both a bundle and a large bucket. 5,000 TZS was paid for a large bundle carried by hand cart. 33% of rural wood used paid for their wood, compared with 3 out of 5 urban users (60%).

All respondents who bought wood did so at least once a week, whereas those who gathered wood (i.e. those who paid nothing) tended to gather enough to last longer. Only 2 respondents bought wood every day.

6.4 Cooking devices

Among households in the sample, basic stoves are by far the most commonly used cooking device (Table 19). Gas devices are the next most common device. Note the relatively small number of households using improved stoves, and the absence of electric pressure cookers. Most households have two or three cooking devices. The devices used by households using only a single cooking device are consistent with their choice of cooking fuels. The survey also asked about non-cooking electrical appliances; 14 households had fridges, and 7 had freezers but freezer owners all had fridges, so these probably represent fridge-freezers i.e. 6.9% of households had a refrigerator or fridge-freezer.

Table 19 Number of households owning cooking devices

Device	Frequency	Percent
3 stone fire	64	32
Basic stove (wood, charcoal, dung etc.)	137	68
Improved biomass cookstove	5	3
single kerosene burner	30	15
double kerosene burner		
Gas burner (portable) - single	56	28

Gas burner (portable) - double	51	25
Gas cooker (rings and oven)	8	4
Gas oven	6	3
Induction stove	1	1
Electric hotplate - 1 hob	1	1
Electric hotplate - 2 hob		
Electric hotplate - more than 2 hob		
Electric Cooker (rings and oven)	4	2
Electric oven	3	2
Electric water heater	6	3
Electric frying pan		
Kettle	1	1
Microwave	8	4
Toaster -		
Rice cooker	13	6
Electric slow cooker		
Electric multicooker (pressure cooker)		
Other		

6.4.1 Energy consumptions

Figure 20 presents the total energy consumed in a month by all respondents in each settlement grouping (i.e. the urban sample is roughly three times the size of the rural sample). This shows that energy content of wood and charcoal consumed is similar in rural areas, but charcoal is the dominant energy source in urban areas.

N.B. all respondents were asked details of electricity consumption, but only respondents using other fuels for cooking were asked for consumption details of these fuels. The assumption that wood, charcoal and LPG are used only for cooking may be valid, but kerosene will be used for lighting as well as cooking. Similarly, electricity will be used for a range of other uses.

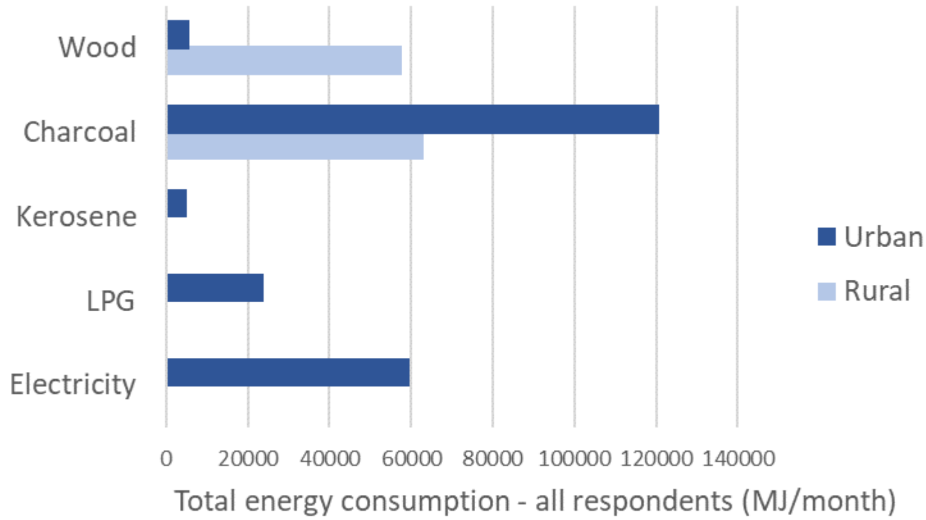

Figure 20 Energy consumptions

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 21 shows that, among respondents who use these fuels for cooking, specific consumption of electricity and LPG is similar among rural and urban respondents. However, rural users appear to use substantially more wood and charcoal.

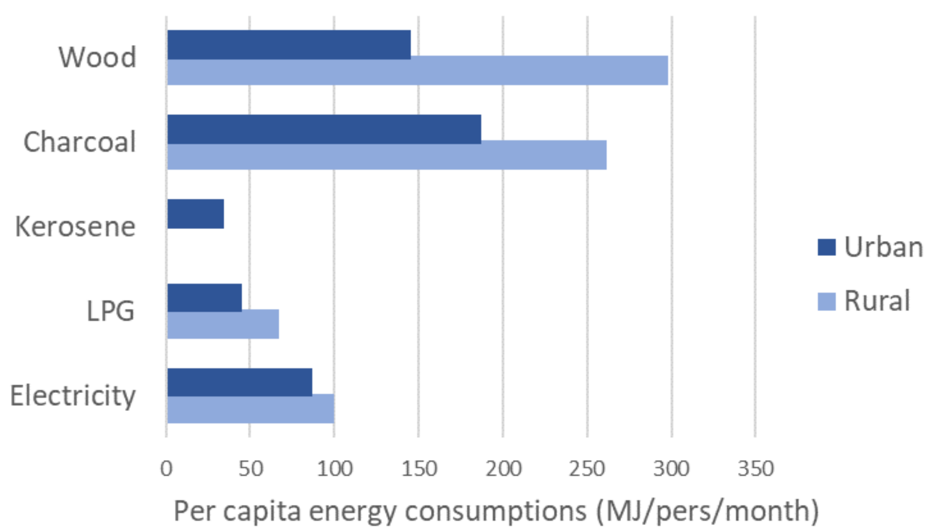

Figure 21 Per capita energy consumptions (valid users)

The analysis in Figure 21 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 (N.B. only 6% 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. Per capita consumptions of total energy have been calculated for these households by dividing by the number of household members.

6.5 Choice model results

At the time of publication of this version of the country report, we discovered that the Choice Modelling survey had not been implemented correctly. Further responses to the set B choices are required to complete a viable data set.

We are addressing this issue and the results and analysis will be included in the next version of this report

7 Focus groups

7.1 Introduction and method

Four focus groups were carried out to gain further insight into how people currently cook and how they aspire to cook. A series of questions were designed to guide the discussion however open dialogue was encouraged when new issues were brought up by the participants. An eCook prototype was demonstrated at the end of the session, inviting comments from the audience on how compatible the device was with the way the participants cook and aspire to cook.

Location	Context	Background	Comment
Ubungo	Urban	Middle-class & lower income. All female.	Several cooking diary study participants & friends
Moshi	Rural village	All female	Church group members
Kibindu	Rural town	Low income and poor. All female	
Kifuru	Rural village	Low income and poor. All female	

7.2 On gender roles

Figure 22 Focus Group in Kibindu

Unsurprisingly the Moshi focus group stated that it was mostly women do the cooking while the man is at work. Rarely do men cook even when there are home due to culture and norms. Only when the woman is sick or travelled does he cook, they all agree that with e-cookers men might be willing to cook. In Kibindi they also stated that women are the one who cooks all the time. Men do not cook because they think they will be controlled. Occasionally, female kids help their mothers to cook. However in Ubungo there were two households where the men did some cooking. While Mwanaidi did most of the cooking, her husband at least prepared the tea, and in Neema shai household they share the cooking 50/50. For Imelda she joked that the husband 'gave recommendations'.

They noted that in the old times they had a patriarchal system; so women do all the cooking and men just do 'queening'. It was actually a taboo for men to cook seen as witchcraft. Other men would have liked to maybe cook but norms didn't allow. However, in this generation- some men help their women in the households. The group felt that most men have little skill regarding the cooking and so some women prefer to cook themselves. They noted that men prefer to prepare quick foods, they have quicker and shortcut ways to cook but they are poor when it comes to energy conservations

> The comment about men liking 'quick foods' is insightful. It is likely that eCook will make cooking 'quicker' (easier), and that may be the trigger for a slight gender shift in responsibilities – by building on men's need to do things 'quickly'.

and budgeting, and they don't clean after themselves and use more utensils.

7.3 On taste and types of food

Not everybody cooks in more or less the same way? (Moshi) People, have

- ✓ Different cooking styles
- ✓ Different tastes
- ✓ Health recommendations
- ✓ Fuel prices drive to change the cooking style and even type of food

"You can cook any food anywhere however, different tastes drive the need to use different fuels". Type of food and the time it takes to prepare determines whether to use either a normal pot, good for rice, bananas, pilau or clay pot, better for kiburu, makande. The way of cooking has moved more to boiling to preserve nutrients rather than frying; before they would fry onions until burning. Unbungo use normal pot (chungu) and metal pan on charcoal and firewood stoves.

The by product of smoke – keeping insects away or as in this case, drying and ripening bananas, is potentially a real loss in traditional practice – but hopefully the benefits of eCook would outweigh such a loss, and people will find alternatives. (Perhaps solar drying under plastic needs to be promoted with eCook?)

During the rainy season people tend to change what they cook due to unavailability of firewood and charcoal; only soft foods are cooked. Beans and makande are not cooked instead ugali, vegetables, rice and other soft food are cooked repeatedly. Strategy - In rainy season, they buy more firewood and store them in the house. In extra room, above the three stone so smoke and heat from below can keep drying them. They also use this place to dry bananas when there is surplus and crush them to make banana flour and ripen bananas.

Over the years cooking has changed. In Unbungo the ways of cooking have changed, nowadays people use ingredients such as ginger, garlic, green paper, carrot, etc; previously people cook without putting any ingredients (flavouring). "These changes are good as it brought good taste."

The focus groups were asked to discuss in some detail a few of the favourite dishes and to describe the cooking process. Table 1 at the end of this section summarises the 'recipes' (or Annex).

Figure 23 Focus Group in Kifuru

7.4 Fuels and costs

Charcoal and firewood are easily available. Firewood bought at 3,000 or 2,000 for one day on dry season but reduced wood during the rainy season some of them collect firewood. (Ubungo) Firewood are bought at Tshs 500 for cooking one meal, 1000 for cooking per day. (Kibindi) Charcoal is bought at Tshs 1500 for a 20 liter bucket during dry season and 2000 during rainy season. (Kibindi) However Charcoal is expensive in the rainy season, almost double the price (Moshi). Charcoal gets expensive when its rainy. People use charcoal in mashame but it is very expensive 2000 for 2kg. only used when they don't have firewood or all firewood is wet during the rainy season. charcoal -2000 10kg, 20- 25kg 25k(80k), firewood- 2000,20k for business occasionally.

The use of LPG for 'light' foods, suggests that eCooks ability with a multicooker to cook 'heavy' foods (long term boiling of beans) could be a selling point in its comparison to its main modern energy rival LPG?

Perhaps an LPG-eCook hybrid with a multicooker is much more likely to completely displace charcoal than either alone?

About 6 in a group had LPG, which they only used to prepare light foods like tea for fear of running out of gas. The small cylinder costs 20,000 to refill and lasts 3 months. Big cylinder costs 48000- 50000 and lasts about 2-3 months -she only uses it to cook light foods too like the last stages of frying food and simmering. (Moshi) Gas is available always; price increase only comes on increased price in raw product and profit greed. (Kibindi) Big cylinder- 40k-55k,small cylinder- 19k-20k

Kerosene stove used every day for tea and porridge. 1 litre costs 2200 and lasts about one week. kerosene 1 ltr 2200-1500

7.5 Cooking with Electricity

It will be important that eCook is successful and affordable in its early roll out, otherwise it may reinforce the notion that electricity is expensive.

In one group nobody had ever cooked with electricity because they"fear to cook with it" and "inexperience"; after practice they suggested they might use it. Ubungo only use charcoal and firewood; they have never used gas or electricity. In Kibindi, some had tried it, but feared the high cost. They declared it not a reliable form of cooking. When they did use it, they used a rice cooker. There was no experience of kettles.

In Moshi, the Chairwoman has an electric stove but has it locked in the store due to "the expensive nature of electricity". She's the only one who has ever used an electric stove. Half of the group do not have electricity connection, those who have it use it for lighting, TV, radio, fridge and ironing.

7.6 On pots and pans

'pots with handles', 'buying and normal pots', 'charcoal stoves, gas stoves and firewood has a pot for some cooking-easily breaks when its hot'

7.7 Future cooking practices - what and how would you prefer to cook in the future?

In Ubungo mostpeoplewould like to use a combination of gas and electricity because of convenience and health issues. They would like to add chips and roast potatoes to their diet. In Moshi they focused on the idea they would like to 'have ease' in their cooking. Wet firewood in the rainy season is difficult.

Moshi would like to prevent smoking preferably using clean cooking appliances. Firewood is very smoky.

They would also like to save time. And they felt that such a change would not affect the type of food they cook because they have 'common food'.

Moshi would like to Advance their cooking, cook with electricity and ensure makande to be cooked every day.

In terms of the positive impacts reliable affordable cooking with electricity would yield, all three groups noted that they would save time and maintain a clean house or environment. Two of the three groups said that the cooking would be easier and that one would be able to cook anytime and anywhere. Eat hot food anytime.

Save time

Less smoke

'Have ease'

Clean house

Other activities

The group recognized that eCook had these and other potentials. This certainly bodes well for any marketing campaign – it suggests people will respond well – if eCook is affordable and reliable.

Indeed, two of the three groups went on to say that it would make their life overall easier, and release tome for other activities. All three felt they would be able to 'multitask, and focus on the 'important things', that it would Allow for income generating activities e.g. women groups. Moshi noted that Save time and money to collect the firewood which takes at least 3 hrs if you are a quick walker and know the exact place to find firewood which lasts for almost 4days. All ladies in the group do farming, animal rearing and one of them does knitting. The chairlady is a pharmacist with her own pharmacy

Moshi brought out the health and environment benefits. They noted that using electricity would likely result in Improved health; red eyes, running noses, chest pains and in Conserving environment.

They would all use electricity if it was not expensive and it was reliable. However it would have to be a device that does not depend on grid electricity which is not reliable

Kibindu felt that men will easily cooperate on cooking

Safety will be important – people have also expressed concern in other locations about their children touching hot plates – which is a little surprising given that a raging charcoal stove feels very dangerous to those used to modern energy cooking! However, the charcoal stove obviously looks and feels hot, so even children can see its dangerous. The hotplate looks the same whether its on or off.

7.8 What prevents people from using this ideal fuel/device?

If electricity were available in everybody's homes and had no cost, everybody would use electricity. However it does cost although the group noted that recently buying units has been accessed through mobile payment making it easier to buy more, which they contrasted with gas where one has to travel to the vendor. Kibindu also noted that if the cost of the system and the appliances are not expensive they will use. They stated that they would prefer the cooking system that will allow them to pay per month for a certain time and thereafter own the system

Kibindu wondered whether the appliances were affordable and the life expectancy of the appliances (are they less robust, could they be spoiled easily).

There is of course a generalised lack of electrification. **There are also some fears. Kibundu felt that** Fear of death at first prevents from using electricity but if awareness and capacity is created they will use.

Ubungo wondered whether electricity would be able to help preserve food by smoking? They noted that stoves are also used for space heating, and the smoke useful to keep insects away

7.9 On the future price

For Moshi 30k-50k per month would be the maximum price people would be willing to pay to use an eCook device (per month)?

However in the other groups everyone was willing to pay if it was monthly , it was just a question of how much

- ✓ 5 people - 5000
- ✓ 3 people - 10,000
- ✓ 2 people – 15,000

They preferred the model where a company like Tanesco would take care of maintenance and repairs

In the other group the range of monthly willingness to pay was slightly higher.

Willing to pay per month

- ✓ 1 person – 5,000
- ✓ 9 people - 10,000
- ✓ 2 people – 50,000
- ✓ 1 people – 25,000
- ✓ 2 people – 30,000

5000=$2 : that is a bit low

15000=$6 : still lower than our expectations for 2020 for a full SHS system

50000 = $20 : could sell these two people a system today!

It suggests that in Moshi, there could be some customers for a suitably reliable system.

7.10 Gender roles in the future

The group in Moshi thought that men might cook more if they used electricity. Most thought that women will do other things to improve their livelihood, most are business women, women groups and chamas. They will not need to hire househelps who still need to be paid therefore saving more money. Moshi noted that women will use the saved time to do farm activities and other family issues.

On getting women involved with the new approach, the group was asked whether women who sell charcoal also sell 'airtime vouchers' for eCook devices? The group noted that they could suggesting that all businesses go with trend. They will find other business opportunities.

Kibindu thought that the change to electricity would mean that the cooking will be rotationally between men and women because with eCook no one will know that you are cooking.

The comment about men relates to their opening gender comments – that men like 'quick foods' Kibindu thought that it would cause more sharing of the cooking within the household – by building on men's need to do things 'quickly'.

7.11 Concept Prototype feedback

After some demonstration of electrical appliances, the group had the following observations.

The observations on the electric cooker (hot plate) demo were

- ✓ Very slow
- ✓ Good food
- ✓ Only cooks when electricity is on
- ✓ Cooking in leisurely way
- ✓ No smoke
- ✓ Improved on electric shocking (as opposed to a hotplate?)
- ✓ (a need for) Safety measures- wear rubber shoes, be dry (to avoid shocks)

These comments do tend to confirm that the existing hotplates on the market are not up to the job – and are doing the idea of electric cooking a disservice.

The observations on the rice cooker demo were

- ✓ thought to just cook rice
- ✓ Can cook ugali without hitches
- ✓ Can't fasten the cooking of beans and makande

Rice cookers misnamed! Can cook other things!!

The observations on the THERMO POT **demo were**

- ✓ Just boils water
- ✓ Keeps water hot for a period of time

The observations on the PRESSURE COOKER **demo were positive – the enumerator recorded it as "A**ll positive vibes".

7.12 Questions from the groups

On being told that the system might offered on a pay monthly basis, the group were in tune with the ideas enough to ask sensible clarifying questions.

	Answer given
Can I own the system?	Yes but then you will have to take care of the system after that; maintenance and repairs
How much is the whole system?	500 usd
What's the lifetime of the batteries?	About 6yrs
How many lights bulbs can you connect to the system?	Depends Any bulbs preferably energy saving
Will the company do the installations and wiring?	Yes

The demonstration of appliances brought positive response (especially with pressure cooker) with few questions;

- Is it safe to cook with this appliances?
- What is the different between pressure cooker and rice cooker
- How can we get the pressure cooker?

Kibindu also asked

	Answer given
How much is the whole system?	Tshs 1,000,000
How much is the pressure cooker?	It ranges from Tshs 120,000 to 170,000
What is the payment mode?	Loaned and pay monthly forever, Loaned pay monthly for certain period after that owns it.
Will the company do maintenance?	If it is owned by company
When will this business start in Kibindu?	Still in research but if you want to cook with electricity you can buy appliances

7.13 So then what are the desirable features of the ideal cooking appliance?

Ubungo asked about

- ✓ Portability?
- ✓ Multitasking – can people leave food to cook and get on with something else?
- ✓ Access to pot (do you need to stir it the whole time)?

- ✓ Importance of safety- with good awareness and education on usage, safety becomes more efficient. Most just have a fear of some appliances
- ✓ Suitable mode of acquisition - self-build/cash/pay-as-you-go/utility
- ✓ Skills for operation/maintenance
- ✓ Access to fuel/device retailers

The financial questions suggest there will need to be a shift in thinking – people want to own the equipment eventually -will a utility model work?

8 Techno-economic modelling

An enhanced economic model has been developed as a part of the Innovate project. Derived from the model published in Leach and Oduro 2015, the reworking and enhancing now enables a more nuanced and accurate sizing and costing depending on specific contexts.

The aim of the model was to be able to input specific Tanzania market prices, and result in a Tanzania specific cost comparison with charcoal and LPG.

At the time of writing the Tanzania specific modelling is not available. It will be made available in the next version of this report.

9 Policy review

9.1 Current Status

9.1.1 Energy Situation

Tanzania is ranked among the growing economies with an abundance of natural resources and potential for renewable energy development. It is endowed with diverse energy sources including biomass, natural gas, hydro, coal, geothermal, solar and wind (WB, 2010), of which the potential of energy from renewable sources is large, but largely untapped. The estimated total energy consumption in Tanzania is more than 22 million tons of oil equivalents (TOE), equal to almost one billion gigajoules (GJ) or 0.7 TOE per capita. The majority of rural Tanzanians have limited access to modern energy services. **The government has realized that rural areas in Tanzania cannot be transformed into a modern economy and livelihoods cannot**

The Tatedo team undertook a policy review to inform the prospects of eCook within Tanzania.

The focus was on trying to understand the intersect between 'cooking' which has traditionally meant biomass, and policy instruments have tended to be improved stoves, and energy access, which has tended to focus on electricity and grid access.

As can be seen, the Government is aware of its challenges in these areas and works with a number of policy directives to try to improve the situation, with mixed results.

be improved significantly without a dramatic improvement in their access to modern energy services.

Modern energy, particularly electricity services, plays a key role in rural development with respect to the country's goal of achieving small and middle industrialized economy. The access to affordable, reliable and safe electricity can greatly improve food, education and health services, as well as improve opportunities for income generation as well as speeding up economic growth.

Increasing pace for electricity connection especially in rural areas is one of the fundamental principles of establishing the Rural Energy Agency (REA). **The 2016 Energy Access Situation Survey results show a significant improvement of electricity connection at household level in both rural and urban areas of the Tanzania Mainland since 2011.** The 2011/12 Household Budget Survey and the 2011 Baseline Survey Report for Energy Access and Use in Tanzania Mainland showed that 6.1 percent of rural households were connected to electricity of any form. Likewise, the 2012 Population and Housing Census recorded 7.4 percent of rural households had connected to any form of electricity including; grid, mini/micro grids solar energy and private entity/individual electricity generated from owned sources (excluding solar). Furthermore, the 2016 Energy Access Situation Survey findings show that 32.8 percent of all households in Tanzania Mainland were connected to electricity of any form with rural and urban areas recorded 16.9 and 65.3 percent respectively.

Regional differentials were still more common within and among all regions of Tanzania Mainland. Again, Dar es Salaam region has the highest proportion of households connected to electricity of any form (75.2 percent) followed by Njombe region (50.5 percent), Kilimanjaro (42.6 percent) and Katavi (40.0 percent). Regions which had proportions of households less than 20 percent connected to electricity include Rukwa (8.7 percent), Simiyu (11.5 percent), Shinyanga (12.8 percent), Geita (14.0 percent), Songwe (15.9 percent) and Kigoma (16.2 percent).

9.1.2 Future Direction

Future direction of energy for cooking is not clear although some national energy documents are supporting Sustainable Energy for all and the Energy Policy (2015) by putting action plans of efficient use of biomass resources and looking for alternative clean cooking solutions. However, efforts for provision of the rural clean energy solutions for cooking are still inadequate and priority of allocating resources for rural cooking energy development programmes is low.

> Its not surprising that the future direction is not clear. In a country where biomass still dominates cooking, there have to date been few alternatives. There is a growing awareness generally and globally that the strategy of ‘improved cookstoves’ hasn’t been that great, but until recently the alternatives have been very limited.

9.2 National Policies Related to Clean Cooking

Cooking energy is supported by several uncoordinated sectoral policies. The main ones that have large influence to the development of cooking fuels in rural and urban areas are the forest policy (1998 – still under review 2018) and energy policy (2015). The National Energy Policy (2015) focuses on market mechanisms and means to reach the objective, and achieve an efficient energy sector with a balance between national and commercial interests. The overall aim of the policy is to 1) have affordable and reliable energy supplies in the whole country, 2) reform the market for energy services to facilitate investment, 3) enhance the development and utilization of indigenous and renewable energy sources and technologies, 4) adequately take into account environmental considerations for all energy activities and 5) increase energy efficiency and conservation in all sub-sectors

The Biomass Energy Strategy (BEST, 2014) reviewed improved charcoal cook stoves (ICS) as a key area for action to reduce charcoal energy demand in one of the quickest, least expensive ways. The document stipulated that charcoal ICS are also an important way to reduce charcoal expenditures to families, which would be a key equity and distributional issue if sustainable charcoal becomes widespread. The BEST document recommended for a major, commercially-oriented, mainstreaming improved cook stove business needs to be funded and launched, prioritizing urban households, and commercial and institutional consumers, with a **target of reducing urban charcoal** demand by an indicative 50% by 2030.

> Interesting that the emphasis on urban charcoal. This a market where people are paying real money for their fuel, and this is a major opportunity for eCook. From the sound of the BEST 2014, if eCook could be stimulated, it would fit a government priority.

The overall objective of Small and Medium Enterprises Developmental Policy is to foster job creation and income generation by promoting new SMEs and improving the performance and competitiveness of the existing ones and lastly to increase their participation and contribution in the economy of Tanzania. The policy intends to promote business services, by using affordable and efficient energy services.

Some of the key regulations governing Tanzania's energy and renewable energy sectors are stipulated in the Energy and Water Utilities Authority (EWURA) Act 2001 and 2006. EWURA was established as a regulatory authority empowered to (i) promote effective competition and economic efficiency; (ii) protect consumer interests; and (iii) protect the financial viability of efficient suppliers.

The Electricity Act (2008) opened the Tanzanian energy sector for private companies and ended monopoly held by the power utility in the energy sector. The private energy operators are now allowed to get into energy business although penetration so far has been limited and is steadily increasing.

9.3 Clean Cooking - Key Government, NGO, Research and Private Sector Actors

The energy sector has several stakeholders operating from national to the local levels. Such stakeholders can be categorised into government, research, training, transport, producers, FBOs, NGOs, CBOs, etc. The main categories of stakeholders are as shown in the table hereunder:

Organization/Institution	Role
Government	
Ministry of Energy (ME)	develop energy resources and manage the sector put in place policies, strategies, regulations and programmes
Tanzania Electric Supply Company (TANESCO)	Electricity utility responsible with generation, transmission and distribution of electricity
Energy and Water Utilities Regulatory Authority (EWURA)	multi-sectoral regulatory authority responsible for the technical and economic regulation of electricity, petroleum, natural gas, and water sectors
Rural Energy Agency (REA)	promote, stimulate, facilitate, and improve modern energy access in rural areas of mainland Tanzania to support economic and social development
Research Institutions	Generation of knowledge through research and studies for the energy sector
Private Sector	Ensure energy products are available and supply them directly to retail customers
CSO Sector	promote and advocate for increased access to sustainable and renewable energy technologies and services

9.3.1 Government

The key stakeholders in the government who are related to the clean cooking are Sectoral Ministries. These are the Ministry of Energy and the Ministry of Natural Resources and Tourism. Other actors include Rural Energy Agency (REA), Energy and Water Utilities Regulatory Authority (EWURA), Tanzania Electric Supply Company (TANESCO) and Tanzania Bureau of Standards (TBS).

i. Ministry of Energy (ME)

The ME is mandated to develop energy resources and manage the sector. It is responsible for the formulation and articulation of policies to create an enabling environment for stakeholders. Promoting renewable energy is part of its mandate. The ME plays an essential policy guidance role, complementing the other major players (i.e., the REA, TANESCO, EWURA, private companies, NGOs, and financiers). The government through the Ministry of Energy is fulfilling the following roles:

As in most countries, Tanzania presents a complex mix of ministries, departments and responsibilities. Since eCook is not obviously an 'improved stove' in the biomass sense, and is in fact a mechanism whereby the grid could be more widely profitable, and where renewable energy could be rolled out, it is difficult to know exactly which stakeholders should be lobbied and in what sequence.

- Formulating and overseeing implementation of policies, laws and regulations;
- Developing and implementing plans and programmes in the energy sector;
- Attracting investment and technology in the sector; Mobilization of financial resources and participating strategically in energy investments;
- Safeguarding energy infrastructure and overseeing the implementation of Local Content initiatives and the Corporate Social Responsibility Action Plan in the Energy Sector;
- Ensure review of Standardized Power Purchase Agreement and Tariff for small power developers as well as Model Power Purchase Agreements based on the resource;
- Approving field development Plans (FDP), infrastructure development plans, tail end plans and decommissioning plans of installations;

ii. Tanzania Electric Supply Company (TANESCO)

The Tanzania Electric Supply Company Limited (TANESCO) is the sole electricity off-taker in Tanzania. Fully owned by the Government, TANESCO is the only vertically integrated electricity supplier in Tanzania. TANESCO is responsible for generation, transmission and distribution of electricity. To improve governance, performance, financial and commercial viability of the power sector as well as service delivery of electricity services. Currently, it provides nearly 60 percent of the 18 effective generating capacity of the national grid, and is responsible for transmission and distribution, serving customers on the main grid and in 20 isolated grids.

iii. Energy and Water Utilities Regulatory Authority (EWURA)

EWURA is an autonomous, multi-sectoral regulatory authority established by the Energy and Water Utilities Regulatory Authority Act. It is responsible for the technical and economic regulation of Tanzania's electricity, petroleum, natural gas, and water sectors. EWURA is vested with the responsibility of regulating energy industry. Roles of EWURA include:

- licensing, tariff review, monitoring performance and standards with regards to quality, safety, health and environment;
- promoting effective competition and economic efficiency, protecting the interests of consumers and
- promoting the availability of regulated services to all consumers including low income, rural and disadvantaged consumers in the regulated sectors.

iv. Rural Energy Agency (REA)

The mandate of the REA suggests that they are the first stakeholder when eCook is applied to rural areas. This will likely be in the shape and form of solar PV either home systems or micro grids.

The REA is an autonomous body under the ME that became operational in October 2007. Its principal responsibilities are to (i) **promote, stimulate, facilitate, and improve modern energy access in rural areas of mainland Tanzania to support economic and social development; (ii) promote rational and efficient production and use of energy and facilitate the identification and development of improved energy projects and activities in rural areas; (iii) finance eligible rural energy projects through the REF;** (iv) prepare and review application procedures, guidelines, selection criteria, standards, and terms and conditions for the allocation of grants; (v) build capacity and provide technical assistance to project developers and rural communities; and (vi) facilitate the preparation of bid documents for rural energy projects.

9.3.2 Research Institutions

Various universities and research and training institutions focus on generating knowledge through research and studies for the energy sector. These include the University of Dar es Salaam, Dar es Salaam Institute of Technology, University of Dodoma, Tanzania Commission of Science and Technologies, Mbeya Institute of Science and Technology, Arusha Technical College and the Vocational Education Training Authority (VETA), Research on Poverty Alleviation (REPOA), Institute of Research Assessment (IRA), etc.

9.3.3 Private and CSO Sectors

Various private companies are engaged in small renewable power development to sell energy services and technologies directly to retail customers. Various NGOs promote access to sustainable and renewable energy. Most of these private institutions are already working in rural areas. Some of the CSOs working in renewable energy include:

- Tanzania Traditional Energy Development Organisation (TaTEDO - Centre for Sustainable Energy Services)
- Tanzania Renewable Energy association (TAREA)
- Appropriate Rural Technology Institute (ARTI)
- World Wild Fund (WWF)
- Centre for Sustainable Development Initiatives (CSDI)
- CARE Tanzania
- Renewable Energy Zanzibar Association (REZA)
- Private Companies involved with renewable energy include:
- Kampuni ya Kusambaza Teknologia (KAKUTE)
- Rex Solar Ltd
- Mobisol Tanzania
- Zola Solar Ltd
- Mkopa Solar Ltd
- Step Solar Ltd
- BP Solar
- Alternative Energy
- ZARA Ltd
- Baraka Solar Ltd
- ENSOL Tanzania
- RESCO Tanzania
- Sustainable Energy System Company (SESCOM) Ltd
- Solar Sisters
- SEECO Ltd.

Though not specifically classified as renewable energy organisations, a number of faith-based organisations utilise renewable electricity to meet the rural energy needs of their communities.

The private sector is probably the way forward, since it should become possible by 2020 to create systems that are profitable to the supplier and yet cheaper to the consumer than charcoal and kerosene expense.

There will likely be a slight mismatch in the Solar markets – true rural dwellers only spend a fraction of their money on fuel for cooking, preferring instead to collect it (either from their own land or in the wild). The advent of a solar eCook proposition may have to compete with a very low cash cost collection of wood; much will depend on whether users see the saving sin time as important - something the focus groups emphasised. Existing solar tends to substitute for lighting which has a cash cost either in kerosene or candles or torch batteries, etc.

9.4 The National Cooking Energy Mix

Most Tanzanians depend fully or partly on firewood and charcoal for daily cooking needs. Cooking is mainly done on traditional, low-efficiency stoves, that use charcoal produced locally through **informal and uncontrolled value chains** and with basic, low-yield technology. **Alternative fuels and technologies**

that are suitable for domestic cooking are available, but have seen only very limited market development so far.

Extensive and inefficient use of biomass combined with unsustainable harvesting practices is the single largest cause of demand for biomass and depletion of forest reserves. The situation does not only represent a threat for the climate and the environment. Adverse socio-economic effects of the current practices makes the lack of access to sustainable cooking solutions a poverty trap and **create high barriers for economic development**.

Table 20 Biomass substitution effect of different forms of improved cooking

OPTION	SUBSTITUTION EFFECT	RELEVANCE
Efficient charcoal production	93% improved production would alone stabilize demand at 2016 level.	High impact
Improved cook stoves	100% usage would cut biomass consumption by almost half	High impact
LPG	Each additional 10% LPG would reduce biomass consumption by 7%	High impact
Biogas	Each biogas digester of 8 to 10 m3 can supply on average one rural household. 100 000 plants would only reduce overall demand by 1%	Low impact
Electricity	1.4 GWh or close to 800 MW capacity required to increase market share to less than 5%	Low impact
Kerosene	Substitution potential approximately half of that of LPG	Medium impact

The different alternatives ('options' in this report) represent different improvement potential as shown in Table 20. As this shows, LPG, ICS and charcoal production are important parts of the solution, with higher impact than kerosene and biogas plants.

- An improved situation will require coordinated efforts within a set of approaches:
- Develop the institutional framework that coordinates and supports efforts to ensure efficient and sustainable use of modern biomass energy resources;
- Improve sustainability of biomass energy supply;
- Improve efficiency of biomass energy utilization;
- Make available commercially competitive, non-subsidized biomass alternatives to wood energy supplies.

An important table. 1.4GWh per year? 5% of 45 million is 2.25million. This would mean 622kWh per person per year, or 1.7kWh per person per day. Which sounds a lot, even for hotplates? The 800MW assumption seems a bit more reasonable, as 800MW divided between 2.25 million people is 355W per person. But as multiple people generally cook together in a household, this would still give a 5 person household 1.8kW to play with before peak loading could even begin to be an issue. Of course, with a battery supported stove, this capacity could be much lower as it would spread out the load throughout the day.

Economic analyses of relevant alternatives to traditional cooking show that increased use of improved biomass fuel based cook stoves (Improved Cook stoves; ICS) gives the highest economic net gain for the society as a whole. The cost of implementing promotional programmes and the public efforts required for rolling out the solutions are not accounted for in the analyses; but the investments in and replacement of equipment and the running costs of the required fuels compared with the benefits in terms of saved forest resources and saved costs for the consumers in purchase and collection of wood fuel yields significant economic surplus. This is true for both charcoal and firewood.

The second highest economic viability is represented by LPG as an alternative to charcoal in urban areas. It represents significant forest saving gains and avoidance of climate gas emissions (CO2).

The alternative of LPG in urban areas could be matched by a well costed affordable eCook system.

It may not have ongoing logistic costs of LPG but it still may find it hard to compete with biomass in rural areas.

If widely introduced in rural areas, LPG would to a large extent replace firewood based cooking. Due to higher logistical costs, less savings of fuel costs and wood fuel per replaced user, LPG appears as an alternative for rural areas which would represent low economic value for the society overall.

LPG represents lower long term average costs for the households, but challenges related to realism and sustainability implies some moderation in setting targets for LPG market penetration. LPG has logistical challenges; dependence on import of LPG influences the level of energy security of this option; and for the users requires higher investments in equipment than ICS. Cooking with gas further implies changes in people's habits. **All these challenges are more difficult to overcome in rural areas than urban areas**.

In rural areas, where agricultural by-products are available, biogas digesters appear highly economically attractive. Saved cooking fuel costs combined with the value of fertilizer produced will yield financial gains for household investments in biogas digesters. A large scale rollout of biogas is however not realistic due to raw material availability limitations. The implementation, promotion and investments also represent barriers, as demonstrated by previous efforts to establish biogas plants that have produced results significantly below their targets.

Electricity is the cleanest way of cooking food and with the current domestic electricity tariffs in Tanzania the common perception is that as an energy source it is not affordable (for cooking) for the users. However, the economic value for the society as a whole is limited, and transition to electric cookers requires significant changes in people's cooking habits. The relatively costly electric cookers also make this option unaffordable, with exception for upper middle and high income population groups. Electricity is expected to remain highly marginal as cooking energy in rural and urban. Areas under the current situation

> This assumption on affordability is challenged by the cooking diaries responses.
>
> However, without energy storage, the other challenges of low voltage, wiring burn out and blackouts remain true.

In addition to the socio-economic development gains associated with increased use of the above mentioned improved cooking solutions and reduce dependence on biomass energy, additional approaches to improve the outlook for Tanzania's biomass reserves will be valuable. One of the key element in this effort is to ensure that charcoal is produced in a sustainable way.

9.5 The Most Popular Cooking Appliances

There are different cooking appliances of different types depending on type of fuels or energy used by people in particular areas. Since the use of biomass fuels is dominant and used by a large number of population, biomass energy stoves are most popular stoves in the market followed by LPG stoves.

Market Requirements	Popular Cooking Appliance (2016)
Improved Cookstoves	Generally available in urban, peri-urban and rural areas, but total distribution of less than ICS 300 000 per year. Almost 40% of people in Dar es Salaam and about 10% in the countryside are using ICSs. Production and distribution of ICS are performed by NGOs, private sector and artisans groups in the informal sector.
LPG Stoves	Tanzania National Energy Policy of 2015, emphasizes on promoting utilization of alternative fuels to wood based fuels for cooking energy such as LPG, Natural Gas and Electricity. Generally available in urban areas, and to a somewhat lesser extent in peri-urban areas. Distribution of 100-150 million tons LPG. The industry estimates that with the right fiscal environment and commitment to invest in the gas sector, the market could grow to levels of achieving the goal within few years
Kerosene Stoves	Kerosene stoves are used in some high to middle income households to cook light foodstuffs due to cost involved in purchasing of fuels. The use of kerosene in urban has gone down due to high price of kerosene and availability of other alternative cheap fuels. Most of these stoves are imported or supplied from outside the country (countries like China, India, South Africa, etc.).
Biogas stoves	Biogas utilization for cooking in households in Tanzania was initiated in by the Government through SIDO in 1975. . According to SE4ALL 2015 Action Agenda, the usage of biogas was estimated to be 0.1% in urban, 0.00% in rural. The area specific fuel used in places with feedstocks for biogas and people who could afford to incur cost for bio-digesters. These stoves are imported from outside the country
Electric Cookers	Electric cookers, ovens and microwaves are used in some medium and high income households and food businesses. Use of electric stoves is influenced by income and not affordable to the majority due to high appliance and electricity costs.It is vulnerable to blackouts. Use of these appliances requires changes in cooking habits. The electric cookers are available in different types from mostly external sources

A variety of improved cook stoves and modern technologies for cooking are found, but as noted above, their use is not wide-spread. There is lack of unambiguous classification of these technologies, standards and product certification is not introduced. **Most of these stoves are manufactured in Tanzania by NGOs, Private Sector and stove groups in the informal sectors. LPG, Biogas and Electricity Stoves are imported from outside the country and retailed to customers by local shops.**

> The published comments about the affordability of electric cooking is a common mantra, which as discussed elsewhere is not actually true.
>
> Of far more concern has been the lack of access, the unreliability of electric cooking and the lack of generating capacity. Lack of capacity may well change n the coming few years, and the lack of access argument doesn't actually hold for urban cooks. However, the unreliability does, and the perception of affordability is a way of ensuring a slow uptake in line with increases in generating capacity.

Efforts of facilitating cleaner cooking solutions started in 1990 when TaTEDO adopted some technologies introduced by WB Energy I project which was implemented by the Ministry of Energy. TaTEDO developed different prototypes of stoves and introduced solar cookers and fireless cookers in some communities. The current production of stove disposed to the market is around 15,000 units of stoves per month. The adoption in Dar es Salaam of improved Cookstoves is more than 40% while in the countryside is about 10%. The improved charcoal cookstoves are mostly manufactured in Dar es Salaam and distributed to other regions and outside the country. Recently there are a few imported charcoal stoves.

Although, improved cookstoves are predominantly informally developed and marketed stoves, solar cooker using thermal methods were introduced but adoption is still very low and solar PV electricity is used for lights and small electricity applications. The adoption of electrical appliances with battery-supported electricity like solar electric cooking will be determined by income, prices and availability. The level of income, prices and availability are among the determinants of using any source of energy and this also determine a particular type of energy technology to be used in a particular area, household, institution and enterprise.

Tanzania has natural gas reserve in Mtwara. The natural gas is transported to Dar es Salaam through gas pipeline for the national grid electricity generation. This is, at the moment, a very important source of electricity. The electricity from this source can be accessed through the national electricity grid.

9.5.1 Compatibility of Electrical Appliances with Battery-Supported Electricity

This is new technology which requires awareness creation to the public and adoption of electricity efficient appliances. The technology requires change of behaviours of people from use of woodfuels. The introduction of the ecookwill completely change the way to use the kitchen and cooking practices.

The shift to the ‘ecook practices for cooking in urban areas could be more rapid than rural areas. This is attributed to affordability, capacity building and other people still preferred cooking over her open fire rather than on new battery supported electric stove. **Others will use it for some food especially light ones depending on income and type of food.** Other families may use the stove only in a certain period especially during the summer in cool areas or for selective cooking because open fireplaces or stoves are also used for space heating. Energy saving, health reasons and cost saving will be main drivers for adopting the electric appliances and battery supported electricity. The electric pressure cookers, normal pressure cookers and other efficient electric appliances in the market will be compatible to the battery supported electricity.

This paragraph was written by our colleagues in Tanzania. It questions the affordability and the change in behaviour, although rightly notes the focus on urban markets first.

The debate about use for light foods or ‘long’ cook foods is interesting. In the latter days of the cooking diaries trial, it became obvious that use of the multicooker for ’long’ cooks was very energy efficient (compared to gas or charcoal). The insulated pressure environment could cook beans for a fraction of the energy of an open pan. The diaries data also suggest that households began to shy away from quick fry foods. However, this was likely due to the hotplate being used was of low quality and did not heat the frying pan to the desired temperatures. Again latterly it was found that frying with induction worked well.

So it’s probably not true to say eCook will be characterised by a certain type of cooking. However, our colleagues are right to speculate how it might be used, and to suggest that at the moment because it has not gone to scale we do not know.

9.6 National Fossil Fuel Reserves

Most of fossil fuels in Tanzania are imported from outside the country.The discovery of natural gas in the southern part of the country has changed this practice as this has been one of the fossil fuel reserves in the country. Natural gas is currently used for electricity generation and recently the responsible entity has announced possibility of using it in Dar es Salaam for cooking. The project - which entails using natural gas as source of energy for cooking and other domestic needs, has been undertaken on pilot stage in Dar es Salaam since 2009 and so far it has been successful. So far, three hotels, one garage, seventy houses and 36 factories in Dar es Salaam are using natural gas.

9.7 Cooking and Methods of Cooking

This is answering the question on **what do people cook and how do they cook it**. People in Tanzania cook varieties of foodstuffs. Most of foods are also found in other East African countries. The country’s food portfolio is largely based on starches and proteins like maize, rice, bananas, cassava, potatoes, millet, beans, animal meat, milk, vegetables, etc. These foods are grown in different rural areas of the country but transported to other areas through food market chains. Maize, beans, meat and vegetables based foods are cooked in the country. Others are area specific grown and consumed in one region and distributed to other areas to supply that variety of food to people with familiarity with it. There is minor changes on types of food cooked and now a days, some people in urban areas are eating from restaurant in the morning and afternoon while at home in the evening.

There is limited variation in cooking technologies and practices across different areas of the country. Most regions cook similar foods, including Ugali, Nyama/ndizi choma/kuku (Grilled meat/green banana/chicken), Pilau, Mchemsho, ndizinyama (green banana with fish or meat), mtori (plantain soup), Wali Maharage (rice & beans), wali nazi (rice cooked in coconut milk), vitumbua (rice burns), maandazi (doughnuts), mikate (breads), skonzi (scones, rolls). The methods for cooking involve boiling, simmering, frying, grilling, warming and baking, often for extended hours in order to dry or remove harmful particles.

Food in poor families is cooked on inefficient uncleaned traditional cookstoves. The main types of stoves used by urban dwellers are charcoal stoves and LPG, while rural dwellers use mainly firewood stoves. In rural areas, open three stone stoves with thermal efficiency of 7-12 percent are used. In urban areas, metal charcoal stoves with thermal efficiency of 10-15 percent on average are widely used.

Although efficiency and fuel saving are very important factors other requirements of the users should not be ignored. Some of the user’s needs, besides fuel saving include type of food, cooking comfort, portability and safety.

- Some foods e.g. dry maize and beans cooked by communities takes six hours to cook. Clay and sand stoves proves quite useful in this respect as the mass will take the heat for the first 30 minutes but later the mass retains the heat within itself as the fire is directed to the pot;
- The length of time the food takes to cook is also an important factor in the stove efficiency consideration design;
- The type of pot used in the cooking. Many pots used cannot fit very well with a situation where heat is to be forced to scrape against the sides of the pot;
- Some foods requires pounding as it cooks which influences the way the pot has to sit on the stove;
- Gender aspects are important because most household users are generally women. Most successful way to design a stove that will be widely appreciated and used is to involve women in the design;

- Cooking comfort is also an important factor. The cookstoves should be adapted to the most comfortable cooking posture (depending on the type of food, sometimes cooking could be done while standing or sometimes sitting down.
- **Saving time is another important factor that most urban households are looking for, especially the working population**. In order to save time, there are many households that use electricity to boil water especially by using an electric kettle. Saving time for rural women is also important. One of the major drawbacks of the rural three stone fire place is that one is required to be in the kitchen during the whole cooking period as she has to feed the stove with wood every few minutes, which increases the time required for tending the fire;
- Safety is also very crucial. The benefit of the improved stove is that safety is enhanced since the flame is enclosed inside the stove.

9.8 Health and Harmful Emissions

This part is answering the question **on how many people are suffering from acute respiratory illnesses due to cooking on polluting fuels.**The cooking appliance used by the majority of rural population is a traditional stove. Major drawbacks of the traditional stoves, especially the three stone firewood places are dispersion of flames and heat because of the wind, poor control over the fire, exposure to heat and smoke, and fire hazard.

Reduction of in-door smoke and harmful emissions from the households, institutions and SMEs are important considerations for improved biomass stoves. The use of these stoves contributes a lot to the improved kitchen environment especially with regard to cleanliness and health. The amount of smoke that is being produced by the traditional stoves are reduced tremendously and hence the level of coughing, headache and eye irritation also be reduced.

Various studies have associated the smoke from traditional stoves with health risks including acute respiratory infections in children, chronic obstructive lung diseases (such as asthma and chronic bronchitis), lung cancer and pregnancy-related problems. Specifically, indoor air pollution affects women and small children

Harm from indoor air pollution is perhaps one of the greatest public health crises of our time. While the world has focused on Malaria, HIV and TB, deaths by air pollution have grown such that they rival the sum of all those three diseases.

There is much that can be done with opening air spaces, ensuring draughts, increasing the efficiency of the burn, etc, but ultimately the use of biomass will continue to cause deaths for the foreseeable future. Recent studies seem to indicate that even using an improved Tier 2 or tier 3 biomass stove still doesn't change improve health.

Our colleagues point to the use of chimneys and that does improve the situation for the cook. However, studies in China suggest that a whole village using chimneys experiences 'village' level pollution as much as a household without chimneys.

eCook will take the cook into a new experience, where smoke is no longer an issue unless they burn the food by accident.

far more than any other people in the society. Women typically spend three to seven hours per day, cooking breakfast, lunch and dinner. This situation exposes them to smoke, often with young children nearby or strapped on their backs. Properly designed improved cook-stoves with chimneys have been an answer to this situation by reducing smoke exposure for the rural women and children.

It has been reported that indoor air pollution levels can reach levels 100 times above the WHO acceptable standards. According to WHO, on a global scale, nearly 28,000 deaths annually are linked to respiratory and other diseases, attributable to indoor air pollution from solid fuel use. In Tanzania, the same cause is believed to represent close to 5% of disease burden.

Changes in traditional beliefs and attitudes may be required for users of traditional stoves, particularly regarding the use of chimneys in firewood stoves. For example, some like the smell of smoke and believe that it adds to the flavour to food. Smoke naturally repels insects, animals and termites. Non-portable stoves restrict cooking to one location.

9.9 Deforestation

This part provides answer to a question of **how severe is deforestation**. The main cause of deforestation in Tanzania is agriculture, followed by use of wood for charcoal production. With regard to environmental impact of reliance on wood biomass for rural energy, deforestation and forest degradation are the main reason for concern. According to NAFORMA (2015), the estimated forest cover loss in Tanzania amounts to 372,816 hectares per year. The wood deficit from legal sources is around 19.5 million m^3 per year, which is met by overharvesting in the accessible forests and illegal harvesting in protected forests.

Charcoal production is a major contributor to deforestation. The sector is characterised by weak governance and weak market chains. According to World Bank (2010), charcoal production causes an annual loss in forest cover of 100,000-125,000 hectares. The energy efficiency of charcoal production is also poor, with conversion efficiencies of 15% or less. This is,

The role of charcoal production for domestic use is still not clear in the literature. Some argued that only commercialised production of charcoal is a significant source of deforestation, and that 'domestic' charcoal is not.

What is clear is that even in rural areas, unless firewood is planned and managed, then 'agriculture' forces the householder (generally the women) to walk further and further to collect as time goes on. Population growth (the doubling of Tanzania's population by 2050) will lead to increased pressure on the land, and each farming household relying on woodfuel needs to collect the wood from somewhere.

Even wildwood collection needs to be planned, and often the way people collect (coppicing or cutting trees) greatly affects the deforestation effect.

mainly, due to a high degree of reliance on Traditional Basic Earthmound Kilns (BEK), combined with rushed carbonisation of the wood by some charcoal producers.

9.10 Biomass Energy Strategyor Cleaner Cooking Strategy

Tanzania does not have Clean cooking Strategy but there is draft Biomass Energy Strategy which has been completed but requires some improvements.

9.10.1 Biomass Energy Strategy

The draft BEST Tanzania was designed and developed in 2014 with aim to address key issues in the biomass energy sector, particularly deforestation and degradation caused by charcoal and commercial wood fuel production. BEST baseline projections show that demand for charcoal, without supply- and demand-side interventions, will double by 2030, from approximately 2.3 million tons of charcoal in 2012[8]. Commercial biomass energy[9] is a major source of rural and urban livelihoods. **Charcoal and commercial fuel wood (firewood) generated approximately TZS 1.6 trillion ($1 billion) in revenues for hundreds of thousands of rural and urban producers, transporters and wood energy sellers in 2012**[10]. Commercial biomass energy is the largest source of cash income in rural Tanzania. Additionally, biomass energy provides the major energy source for a wide range of rural and urban activities, including commercial, institutional and industrial uses. It is estimated that this non-household demand is equivalent to approximately 15% of urban household consumption amounting to 300,000 tons of charcoal in 2012.[11]

> This s the counterpoint to the harm charcoal does. It does generate work and income for uite a large number of dispersed people.
>
> One of the concerns that has to be researched and faced is that eCook would introduce imported technology (with a long term view of creating localised employment in fabrication and assembly) and potentially change the foreign exchange balance. Imagine for the moment that this $1 billion dollars was all 'converted' to solar PV cooking systems – that is an annual foreign exchange expenditure of $1 billion added to an already stretched balance of payments.

The main conclusion from the BEST Tanzania is that forestry biomass energy demand is unsustainable. Demand for wood energy has led to increasingly negative environmental, agricultural and other local and macro-impacts. Unsustainable biomass energy demand is accelerating year-on-year because of:

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[8] Assumes 50m^3 per hectare national average (MNRT, 2013). If charcoal consumption in 2012 was 2.3 million tonnes, assuming 19% wood to charcoal conversion, then, the equivalent of nearly 350,000 ha of woodland was harvested to produce that charcoal.

[9] The term commercial biomass energy refers to biomass energy produced and sold on a commercial basis.

[10] BEST Team charcoal market surveys, TFCG, 2013; NBS, 2013b, Census data, others.

[11] Malimbwi, R.E. and Zahabu, E., 2009. Norad, 2009.

- The low priority that is accorded to biomass energy by almost all key government agencies;
- The lack of a national policy framework for biomass energy;
- Poor public awareness of biomass energy efficiency issues and options;
- Complicated, often contradictory and poorly-regulated governance of commercial biomass energy production and trade;
- A lack of replicable examples of, or models for sustainable charcoal; and,
- No mainstream commercially competitive biomass alternatives to charcoal and fuel wood.

To address these issues, the following BEST Tanzania put the following recommendations in order to intervene the demand and supply sides of the biomass energy sectors.

On the supply side, the BEST recommended to broaden the mandate for the Tanzania Forest Services (TFS), expand its budget significantly, recruit personnel and mobilize other resources.This should enable TFS to place major emphasis on working with local authorities (district and municipal councils), villages and the private sector to develop and register forest management plans that will significantly increase participatory forest management (PFM), community-based forestry management (CBFM), joint forestry management (JFM) and overall sustainable wood energy production by an indicative target of 20% by 2030 (on 2012 levels);

Local Government should support local NGOs and other activities (e.g., MEM and REA) that promote and commercialize biomass energy from agricultural wastes (e.g., rick husks, coffee husks, sisal residues, etc.) and the technology to utilize those wastes through briquettes, biogas, among others; and Charcoal producers need to be organized commercially, their activities licensed, their wood supplies sourced sustainably and their production efficiencies increased substantially with a target of achieving and indicative target of 50% efficiency improvement at a national level by 2025 (TFS and MEM).

> Supply side management is by far the best option (excuse the pun), for mitigating deforestation and for enhancing the world as it tackles climate change. While we all need to reduce our consumption that creates emissions, we also need to strengthen the trees that mitigate CO2 effects.

On the Demand Side, The best recommended for establishing a major, commercially-oriented, mainstream improved cookstoves programmes which will give priority to major consumption areas such as urban households, and commercial and institutional consumers, with a target of reducing urban charcoal demand by an indicative 50% by 2030.

The BEST also emphasized on use of biomass energy alternatives (particularly biomass briquettes and biogas). These resources are supposed to be commercially mainstreamed with an indicative target of reducing current demand (2012) for charcoal and commercial fuel wood of 5% by 2030. and,

Make non-biomass charcoal and commercial fuel wood alternatives, particularly kerosene (LPG and electricity as well), competitive on a non-subsidized basis in terms of availability and price, with a target of reducing demand for charcoal by an indicative target of 50% by 2020.

Demand side management of biomass is acknowledged as involving LPG and electricity. eCook could potentially add to this government agenda.

MEM, along with the support of EU, is finalizing the **Biomass Energy Strategy** (BEST). The strategy will identify the means of ensuring a sustainable supply of biomass energy; increasing the efficiency with which the biomass energy is produced and utilised; promoting access to alternative energy sources wherever appropriate and affordable; and ensuring an enabling institutional environment for implementation.

9.11 The National Targets

Both internationally and local numerous initiatives have been launched to improve the access to improve and modern cooking technologies and practices. Still, **national targets that are consistently referred to and that may guide the efforts have not been identified.** Similarly, no consistently applied definitions or classifications for several central concepts concerning energy for cooking have been identified.

Despite significant efforts by many domestic and international groups, there has not been any tremendous positive trend by the government regarding a ***transition to modern cooking technologies or fuels***. While a transition in urban areas may be realistic, stakeholders may have to reconsider their strategy for improving livelihoods when it comes to improved cooking conditions. **A realistic assumption is that biomass is likely to remain the dominating energy source for cooking purposes in rural areas.**

Indeed, a realistic assumption is that biomass is likely to remain the dominating energy source for cooking purposes in rural areas. However, as eCook emerges in the urban areas, and we take a 10 year view, we can see that even in rural areas, some fuel stacking will occur between wood/charcoal and eCook.

Improved cookstoves will therefore play an important role in improving livelihoods in rural areas. Policies and strategies tend to focus on a transition to modern cooking fuels and technologies, moving away from biomass. The National Energy Policy includes reference to cooking and biomass consumption under the Electricity Sub-sector and only addresses an ambition to transition to modern fuels. **Specifically, the relevant objective is: "To improve quality of life through use of modern fuels", and the associated policy statements include; i) Enhance fuel switch from wood fuel to modern energy; and (ii) Facilitate adoption of appropriate cooking appliances to promote alternatives to wood fuel.**

The Government has provided tax relief to stimulate the use of LPG in the country. Over the past ten years, LPG supply for household cooking has increased significantly. The total volume of LPG imported in financial year 2010/11 was 24,470 MT compared to 69,148 MT in financial year 2014/15. The trend shows that the LPG market is growing rapidly especially in urban centres. (NEP, 2015)

Biomass is the main thermal energy source for the large majority of households across the country. Mainly used for cooking purposes, unstainable harvesting from unmanaged forests is a major cause of deforestation and other environmental impacts.

9.12 Social and Gender Issues

The role of men is to lead and manage their households and families as providers of household services and requirements including foods, shelters, etc. Women are supporting their families and households through cooking, cleaning, collecting woodfuels, etc. Men are decision makers in households. The education in Tanzania is availed to both men and women used to be favoured in order to go to the high learning institutions. The current situation shows that there is balance in urban areas between men and women for being enrolled in the education services. The situation for rural areas is a bit different because men in rural areas have high chances of going to schools compared to women. Roles of men and women are changing according to development of new technologies and income generating activities. Most of incomes generating initiatives in the households are controlled by men and women support men in doing those activities.

> While the burden of biomass cooking has been mainly a problem for women, technology has traditionally been the domain of men. In the focus groups the women speculate that a clean 'technological' appliance like a multicooker might attract more men to cook. However, the first hurdle will be – will men 'authorise' their household to purchase 'technology' when its mainly a device for the women to use?!

There are uneven efforts of empowering women through different sectors such as energy, forestry, agriculture, and business undertakings. In the energy sector, some of them have been trained to use different clean cooking technologies such as improved cook stoves, solar cookers, fireless cookers, biogas, briquettes, etc.

Access to cooking energy and electricity is closely linked to gender equality and child-protection. Lack of reliable and safe access to energy and water forces rural women and children to spend most of their day performing basic domestic activities, including time-consuming and physically draining tasks of collecting biomass fuels. The Energy Access Survey (2017) reveals that share of male-headed households connected to electricity is 18.3%, while of female-headed only 11.7% are connected. Both factors reduce the opportunities of attending education, employment, and other income-generating and livelihood enhancing activities. For households using charcoal, the cost consumes a large part of the disposable income of rural households.

Women are disproportionally affected by indoor air pollution. It is estimated that with women in Tanzania spending 3-7 hours a day cooking, they are exposed to respiratory track diseases, eye diseases ("red eye disease").

Modern or improved cooking stoves and sustainably produced charcoal can reduce the workload of women and improve health conditions and reduce environmental and climatic impact.

11.0 Business and Finance

Business is seen as a central and pivotal pillar in the attainment of the mission of the economic sectors towards higher efficiency and productivity in the country. The SMEs policy is intending to foster job creation and income generation through promoting the creation of new SMEs and improving the performance and competitiveness of the existing ones to increase their participation and contribution to the economy in the country. Finding locally available financing at competitive rates is a significant challenge. Interest rates from a commercial bank are around 16-18% at good rate, and are more likely to be around 20-21%. The government is creating grants for off-grid energy, but these seem to be targeted at mini-grid developers. Therefore, while it is possible to get finance, this is often prohibitively expensive. Currency stability also has a significant influence on cash flow as stocks have to be purchased in dollars but sold in shillings. Fluctuations in exchange rates can quickly undermine small operators.

The key contextual factors that enables or constraint development of new businesses in the country are 1) availability of new products, 2) maintenance and repair of new

This is potentially a significant problem for eCook. The discount rates in Leach and Oduro's model are at 5% and 20%, and even at 20% eCook can work. However, it may not be the interest per se that creates challenges so much as identifying finance that is willing to take the risk, and finding the finance in the first place!

There may also be challenges finding users willing to think in terms of paying back over 4 to 5 years as opposed to the 1 year or 18 months of solar lighting systems. This could be overcome by a utility model where the user never owns the equipment but the agency provides a cooking service.

products, 3) usability of the product, 4) affordability by a large section of population and 5) product that solve problem in the society. The energy technologies which will solve energy constraints in the on-grid and off grid areas will be accepted by a large section of population. Rural electrification is the main agenda in the Government efforts of rural development. The rural electrification is supported by different facilities. These are Rural Energy Agency (REA), Tanzania Electric Company (TANESCO) and other development partners (EEP, Norwegian Government, SIDA, etc.). TaTEDO in collaboration with SEECO has been leading in the manufacturing and supply of the improved cook-stoves. Other stoves in Tanzania are imported from outside the country especially LPG, kerosene and electric stoves.

In Tanzania, traditional microfinance loans are quite localised. In rural areas, small localised credit facilities can be used to provide finance but as these microfinance institutions need to buy their own capital locally at high interest rates, adding operational costs and default risk, this sets interest rates at between 40% and 100% per annum. However, there are different financial mechanisms for supporting cleaner cookstoves and off –grid systems such as village community banks, (VICOBA), Savings and Credit Cooperatives Society (SACCOS), Micro Financial Institutions (e.g. PRIDE SEFAFU and FINCA), etc. SEFAFU is only microfinance designed for sustainable energy services. The entity is still at the infancy stages and could be boosted in order to provide credit services for electricity cooking. Tanzania is one of the world leaders in mobile money transfers (mobile phone-based money transfer), with 44% of adults having access to it and a total of 16m subscribers. There are 4 mobile money providers in Tanzania: Vodacom with M-Pesa (42% market share), Tigo with Tigo Pesa (31%), Airtel with Airtel Money (24%), and Zantel with Ezy Pesa (3%). In addition to mobile money, mobile operators in Tanzania offer other mobile financial services such as financing and micro financing services, and mobile insurance. (https://www.tanzaniainvest.com/mobile-money). To help address this, pay-as-you-go financing schemes are now becoming available for solar home systems, including mobile-enabled pay-as-you-go. However, there is no any organization that is using it to allow the customers to make payments on clean cookstoves but some companies are using it for payments on off-grid systems. The GSMA indicates that mobile money providers will continue to

> There are two domains of finance. On the one hand the supplier may need major capital set up and expand their business. If eCook is offered on a utility basis (ie the household never own the equipment but the organisation supplies a cooking service), then this major finance will be important. If on the other hand a pay as you go model is implemented with households eventually owning the equipment, micro finance and household loans will be a major factor.
>
> In either case, the ability to accept payments (and to monitor usage) through the mobile phone network will be critical, and Tanzania has an interesting balanced market for 4 dominant players. Plus the Vietnamese MNO Halo has recently started , and they have relatively imaginative and entrepreneurial value added services.

strengthen the customer experience and improve the quality of agent networks, in turn attracting more customers and encouraging greater usage of mobile money. Solar pay-as-you-go companies are lobbying mobile phone companies to improve connectivity in areas where this is impeding operations.

Tanzania has mix of international and local manufacturing industries. A survey would be required to understand strength, capability and forms of products that could be manufactured by international and local industries. However, capacity development will be required to make sure that eCook clean cooking system is manufactured by local companies like SEECO and similar companies. The supply chain for products from outside the country depending on different business models of the companies and shops which are selling them. Big stores and super markets are importing direct from outside the country. Some local shops are acquiring them from whole sellers in Dar es Salaam and continue to distribute them in different areas of the mainland. Solar PV systems are also imported from China, South Africa and Europe. Importing a consignment of solar PV system equipment from manufacturers may take one to three months. The costs of importation depend on place the system is imported and handling at the port.

Nevertheless, several steps have been taken which support the sector. VAT and tariff exemptions have been applied to imports of **small solar products**. **However, batteries are not exempted from VAT, which causes particular issues for operators selling solar home systems where component parts of the product are separate.** The previous Tanzanian President lent his voice to Off Grid: Electric's high profile plans to create 1 million solar homes, and two projects to promote and raise awareness have been implemented. Moreover, the National Electrification Program Prospectus notes that, even if all of the interventions outlined in it are realised, it will not meet targets unless "access to electricity" is re-defined. This would need to be extended to encompass those who do not have electricity within their own home (i.e. by including those who have access to central services, such as a dispensary with a fridge). This suggests that solar home systems could fill significant gaps in off-grid areas.

The separation of batteries from Solar systems and applying VAT to batteries seems to be common to a number of countries. This may be one of the more important policy changes required to make eCook affordable.

9.13 Demographics

The last official census recording the population of Tanzania occurred in 2012 and showed there were 44,928,923 people living in the country. Of this total population, 1.3 million reside on the islands of Zanzibar. This equates to a population density of 47.5 people per square kilometre (123.1 people per square mile). The population is now estimated at over 59.09 million, as Tanzania has **one of the highest birth rates in the world** and more than 44% of the population is under the age of 15. The total fertility rate is 5.01 children born per woman, which is the 17th highest of any country. Tanzania has a very uneven population distribution. In the arid regions, population density is as low as 1 person per square kilometre, about 53 people per square kilometre in the water-rich mainland highlands and up to 134 people per square kilometre. About 80% of the population lives in rural areas. The access to grid electricity has increased to more than 36% with rural electricity access of 17 % while urban 65%. Households without Power are around 37 million (USAID 2017).

9.14 Environment and Climate Change

9.14.1 Climate in Tanzania

The Tanzania climate statistics describe the average temperature and the total rainfall during a typical year. There are four main climatic zones: (1) the coastal area and immediate hinterland, where conditions are tropical, with temperatures averaging about 27° C (81° F), (2) the central plateau, which is hot and dry, with considerable daily and seasonal temperature variations; (3) the semi-temperate highland areas, where the climate is healthy and bracing; and (4) the high, moist lake regions. There are two rainy seasons in the north, from November to December and from March through May. In the south there is one rainy season, from November to March. The off-grid sector already provides 2MW of power, largely solar, to around 15% of the population.

Solar insolation values for Tanzania are at least twice that of those available in Europe because of the longer solar window available at equatorial latitudes, making solar power an attractive long term investment option for companies and individuals seeking a robust, reliable and independent power supply. The country has high levels of solar energy, ranging between 2,800-3,500 hours of sunshine per year, and a global horizontal radiation of 4–7 kWh per m2 per day. Solar resources are especially good in the central region of the country, and it is being developed both for off-grid and grid-connected solutions. In the elevated areas around Moshi and Arusha, and in Iringa and southwards, however, insolation is considerably reduced (i.e. below 4 kWh/m2/day) during the cloudy season between May and August. Solar PV electricity has been installed countrywide for various applications in schools, hospitals, health centres, police posts, small telecommunications enterprises and households, as well as for street lighting. More than half of this capacity is utilised by households in peri-urban and rural areas.

Cookstoves are used for space heating in elevated areas which are cool parts in the country. However, whenever people are using charcoal stoves are advised to use them in open air areas due to toxic gases like carbon monoxide. There is no history of damaging batteries by extreme heat or cold.

The assessed potential of small hydropower resources (up to 10 MW) is 480 MW. Installed, grid-connected, small-hydro projects contribute only about 15 MW. Most of the developed small-hydro projects are owned by private entities and are not connected to the national electricity grid. Five sites in the 300 kW–8,000 kW range are owned by TANESCO. Faith-based groups own more than 1617 with 15 kW-800 kW capacity and an aggregate capacity of 2 MW.

Several small hydro projects are also being developed as isolated mini grids and the MEM is conducting small hydro feasibility studies in eight regions: Morogoro, Iringa, Njombe, Mbeya, Ruvuma, Rukwa, Katavi and Kagera. Development partners are supporting several mini-micro grid projects throughout the country.

9.14.2 Environment Effects

Energy access and climate issues can be positively linked. For instance, non-polluting and highly efficient cook stoves and other advanced biomass systems for cooking reduce the need for woody and other biomass by more than 50 per cent compared to traditional cook stoves. This would avoid major emissions of black carbon from inefficient biomass burning, responsible for indoor pollution, additional global warming and ice-melting in particular.

Energy poverty is one of the most important obstacles to social and economic development for the poor, next to lack of access to clean water and food. Our current energy system leaves a major portion of the world's population behind. In some poor energy importing countries, the high costs of fossil fuels now eats up more than 10 per cent of the GDP and makes conventional energy increasingly unaffordable for many.

Clean, affordable and reliable energy access is one of the most important requisites for decent livelihoods, next to water and food. Unfortunately, our current energy system excludes a major portion of world's population from this fundamental right.

Climate change is affecting people around the planet, but is particularly wreaking havoc on developing nations and poorest communities. Improving the well-being of these people is the best way to help them adapt to climate change and be resilient.

Energy access and climate issues in Tanzania can be positively linked. For instance, non-polluting and highly efficient cook stoves and other advanced biomass systems for cooking reduce the need for woody and other biomass by more than 50 per cent compared to traditional cook stoves. This would avoid major emissions of black carbon from inefficient biomass burning, responsible for indoor pollution, additional global warming and ice-melting in particular.

Energy poverty is one of the most important obstacles to social and economic development for the poor, next to lack of access to clean water and food. Our current energy system leaves a major portion of the world's population behind. In some poor energy importing countries, the high costs of fossil fuels now eats up more than 10 per cent of the GDP and makes conventional energy increasingly unaffordable for many. Girls and women are particularly affected since in many developing countries they spend lots of time collecting regionally available bioenergy sources — time they cannot use for education or jobs.

Clean, highly efficient renewable energy is one key pillar to better livelihoods and health, improved education and gender balance and better learning conditions, which in turn can facilitate environmental protection. Sustainable energy access, through the adoption of renewable energy, sustainable practices and energy efficiency, will help the conservation of ecosystems, the adaptation of communities to climate change, and in the global effort to lower emissions. Not only are people who suffer most from climate change often energy-poor, but the way billions of people will access modern sources of energy will have a long lasting impact on the energy sector and climate as well. Access to renewable and sustainable energy will benefit energy-poor people and reduce effects of climate change.

To help accelerate the process of achieving a world powered by 100 per cent renewable energy by 2050, WWF Tanzania is engaging with key governments to encourage them to agree to take steps to end energy poverty by 2030. The essence of this strategy is to demonstrate that there are viable, sustainable energy access solutions for energy-poor people in the country and to encourage these solutions to be replicated and scaled up in different areas.

This section ends on a positive note, and one that eCook can harmonise with.

10 Stakeholder engagement

The National Stakeholders' Solar Electric Cooking workshop was held at TaTEDO office at Mbezi juu near KKKT Church, Dar es Salaam on 24th and 25th April 2018. The main objective of for workshop was to explore the opportunity for eCook in Tanzania. The workshop was organized by TaTEDO in collaboration with a research consortium, consisting of a development consultancy, Gamos Ltd., and two UK universities, Survey and Loughborough as part of the ongoing project activities (eCook - a transformational household solar battery-electric cooker for poverty alleviation) which are financed by DFID and Innovate UK.

A diverse group of stakeholders were invited and about 34 participants attended. They included representatives from the Ministry of Energy, Ministry of Natural Resources, private companies (from the solar lighting, clean cooking, mini-grip and utility sectors), civil society organisations (CSO), research institutions, the media and eCook research participants. The workshop was conducted for two days:

on the first day participants were acquainted with the eCook concept; while on the second day attendees carried out hands on experiments with eCook appliances, whilst discussing how this new technology can be tailored to best meet the needs of Tanzanian cooks, in particular, those from lower income households, located in urban, pre-urban or rural areas.

The moderator of the workshop Mr Jensen Shuma welcomed the participants which were followed by the self-introduction from all the participants. Then the host of the workshop, the Chief Executive Officer of TaTEDO Eng. Estomih Sawe gave the welcome remarks.

"….. But solutions exist that can empower women and help them live their lives to the fullest. However due to lack of international and national political will and associated funding, the solutions have not been promoted and the problem continue to worsen year after year. The problem is clearly revealed by the amount of daily deforestation occurring in the country, According to National Forest Resources Monitoring Assessment (NAFORMA), Tanzania is losing more than 1000 hectares of natural forest each day due to charcoal production and the loss is increasing fast." Eng. Estomih Sawe

The first session was presented by Dr. S. Batchelor from Gamos who introduced the eCook concept. Dr. Jon Leary from Gamos highlighted findings of the preliminary market analysis which was done to assess the global market size and viability, highlighting that the opportunity for solar electric cooking is biggest in East and Southern Africa. He concluded by pointing out the key messages from the preliminary market findings as follows:

- Cooking on batteries is possible as most of the Tanzanian cuisines are ecook compatible.
- Battery-supported electricity will be cost comparable with charcoal (clean cooking, access to reliable electricity).
- eCook has a vast transformative potential in Tanzania, there is a need to build long-term partnerships to make this transition happen.

Mr. Jensen Shuma presented on eCook potential of Tanzania. He started by pointing out key messages which include

- Tanzania is endowed with diverse forms of energy resources which have not been explored including natural gas, hydro, coal, biomass, geothermal, solar, wind and uranium.
- Biomass-to-energy, mostly for cooking is responsible for more than 84% of the total primary energy consumption in Tanzania
- Tanzania has high potential for solar battery electric cooking (solar isolation ranging from 4.69 to 6.24 kWh/m2.day)
- Current trends in pricing indicate that by 2020 solar PV will supply electricity for cooking with 2-3 years payback,
- With proper delivery model both low, middle, and high income households can benefit from solar electric cooking
- With concerted efforts, a portion of the segment of population using biomass for cooking may switch to solar battery cooking in the future

The cooking diaries part was presented by Mrs. Albina Minja from TaTEDO. She informed on key parameters and methods used during cooking diaries research. Ms. Minja also shared her personal experience before and after cooking diary study. She informed that before the study, Gas and charcoal were her main source of fuel for cooking. She uses a cylinder of gas for one and half month which cost Tshs 45,000 and 15kg of charcoal per month ≈ Tshs 30,000 with long cooking time

During and after the cooking diary study she use an average of 2 units per day = Tshs 704, 60 units per month amounting to Tshs 21,127 with little cooking time and the food taste the same for most dishes.

On her recommendations, she stated that:

- Cooking on charcoal and LPG is very expensive!
- Preliminary results suggest most HHs can cook with 2kWh/day
- Cooking practices can have as much influence on energy use as appliances and fuels, so could reduce this to below 1kWh/day
- Voltage affects cooking as much as blackouts
- Cooking with electricity is possible in Tanzania

Mr. Shima Sago from TaTEDO presented findings from the Focus group discussion which was done in Ubungo district. Ms. Karen from Gamos presented on gender and energy. Dr. Jon Leary (GAMOS) led a on choice modelling. He stated that Choice modeling survey involved 200 participants in the Charcoal markets.

The findings showed that the electricity is not reliable because of

- Blackouts occurred several hours twice a week (Figure 12.
- Extended to the entire day during load shedding.
- Voltage is high enough for cooking, but likely to be much slower.

Mr. FransisMwila from CEEEZ Zambia (Figure 16) shared the experiences he had on the eCook project from Zambian context. The first day workshop was closed by Mr. EvaristNg'wandu who expressed thanks to all the participants

Design and Assembly For Day 2 Participants of the workshop were asked to take part in a design challenge whereby they were divided into 3 groups each with 4 to 5 people from various energy sectors. Each group had one cook and one person from the solar lighting/utility & clean cooking sector and where asked to initial brainstorm a design solutions, which involved eCook hardware and Business models & marketing strategies.

eCook Practices In this part each group was given tasks as follows

- To prepare TZ meals using chosen appliances in small groups' i.e Banana with meat, ugali with meat and vegetables, rice with beans and rice with meat.
- To record energy consumption using plug in meters.
- Provide feedback from cooks on usability of chosen appliances
- Calculate the energy used by using design challenge modeling spreadsheet,

Economics The group participants were asked to

- Calculate actual energy used during eCook practice session.
- Modelling of battery/PV hardware required to support cooking.
- Refine eCook packages.

Group presentation: The session involved presentation of designed challenge of each group in front of the judges and participants. Each group were judged based on five criteria; i) Target market and impact ii) Business model, iii) Responding to cooks' feedback, iv) Technical viability and v) Innovation (Annex 2 illustrate). The winner group was "Nishati yagharamanafuu" group (Figure 20).

The features of their model were as follows:-

"The Cost and ownership

- *Low cost between Tshs 30,000-35,000*
- *Pay as you go system implemented by a private company/agency and categorized according to the income level of the customer.*
- *Initial payment of 20% which is about Tshs. 6,000-7,000 per month.*

Marketing strategy

- *social media campaigns*
- *Local campaign.*

Cooks feedback

- *Energy serving*
- *Time management*
- *Tidy*
- *No smoke and ashes*

Technical viability

- *Backup charging of batteries through grid.*
- *Maintenance and replacement of parts to be taken care by private company/agency.*

Innovation

- *A system should have ports for charging other appliances like torch light, TV, radio and phones and cooking heating water capacity be around 1.5kW."*

Ideas from the "Nishati yagharamanafuu" group

Figure 24: The winners of the eCook Design challenge; "Nishatiyagharamanafuu" group with their prizes.

After all the discussions, and deliberation of the workshop, Mr. Jacob Mayala on behalf of Dr. Hamisi Hassan Mwinyimvua, Permanent Secretary,the Ministry of Energy presented a closing speech.

For about a decade, we have observed rapid spread of solar PV panels across many countries, particularly here in Africa. This has already transformed millions of lives, however, it has yet to have an impact on the cooking energy needs of poor households.

The recently completed global market analysis highlights Tanzania as having enormous potential for solar battery electric cooking primarily due to more than 84% of people who rely on unsustainably sourced charcoal and firewood for their cooking needs and staple foods that are highly compatible with battery-supported electricity. Frequent blackouts, voltage fluctuations, and emerging electric cooking market create a significant opportunity for Grid-eCook, whilst the vast off-grid population and an established Solar Home Systems (SHS) offer highly favourable conditions for solar PV- electric cooking."
Dr. Hamisi Hassan Mwinyimvua

Moreover, he said that the research findings and demonstrations of solar battery electric cooking observed in TaTEDO during the workshop will have Paradigm Shiftto the electric cooking using new and efficient technologies, especially solar electric cooking to thousands of Tanzanians. He requested that the research, workshop reports and recommendations to be shared to the ministry which will enable the Government and other stakeholders to effectively support the proposition into reality.

He concluded by conveying gratitude to the UK Government through their development agency (DfID/UKAID and Innovate UK) for the financial contribution of the research project and workshop.

11 Gender insights

There follows a presentation based on the gender analysis undertaken by the team.

Steps to gender mainstreaming in energy sector

- (Shankar, 2010)
  - Step 1: assessment of linkages between gender equality and energy
  - Step 2: identify entry points /opportunities for introducing gender perspectives
  - Step 3: identify approaches or methodology for incorporating gender perspective in these works.

Visual representation of gender mainstreaming in energy sector

(Quasmi, 2014)
Prioritizing gender equality
Incorporating gender into politics
Including women in decision making processes
Shifts in institutional culture

Gender issues in energy

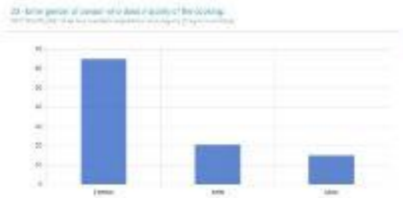
- Energy policies are not gender neutral
- Energy sector is dominated by men especially at the decision making levels
- Health problems associated with indoor pollution from biomass fuels W.H.O estimated about 18,990 deaths in Tanzania from indoor pollution in 2007
- Electrification is not a solution for cooking in rural areas especially because its expensive and highly unreliable therefore

Levels of gender mainstreaming

At legislation, policies, and strategies level
At the organization and department level
At the household and family level

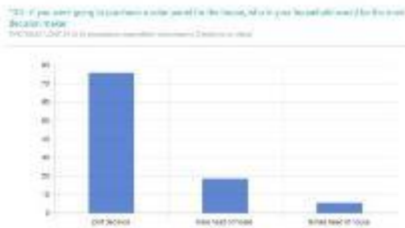
Gender roles in Tanzania

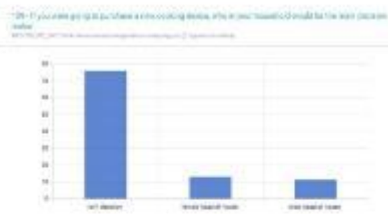
- Ceesay (2013): "Tanzania just like the other sub- Sahara countries is a male dominated society women are still considered inferior to males. Women are the ones slaving over dangerous flames preparing meals for their husbands and family."
- Jones (2013): aspects of gender inequality exists in Tanzania because of the cultural ideas that came with its early settlers of Arab descent. Tanzania being patriarchal, girls and women are under the control of men and are always accorded lower social status
- The low standards of women's education makes it hard for them to participate in lawmaking or the act of changing cultural standards



Choice modelling data

- Unsurprisingly – women do the cooking
- A little surprisingly, Solar Panels would be a joint decision, with a slight bias towards the men
- A little surprisingly, new cooking appliances would be a joint decision.





- Empower women with knowledge and information on personal level concerning these new technologies. at a
  - This will boost their confidence in using these now appliances and fuels.
- Most cooking diary participants in Tanzania had a negative perspective of pressure cookers because they thought they are dangerous & use a lot of electricity. After extensive training and demonstrations, they all reported their new love for the appliance & now prefer the pressure cooker.

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Recommendations for e-cook

Charcoal Value Chain

	Status quo	Likely impact of e-cook	Potential new livelihood opportunities
Producers	Cutting trees and burning to produce charcoal	More unemployment in the rural areas	?
Transporters	Transporting charcoal from the production area to the market area	Less charcoal to transport therefore trucks will be jobless	Transporting the SHS and the e-cook appliances
Wholesalers	Sell the charcoal in wholesale	Reduced income due to reduced market	Could sell the e-cook appliances in wholesale or in retail
Retailers	Selling charcoal in small quantities	Reduced income for charcoal retailers	Opportunity to retail electricity through airtime vouchers
Stove manufacturers	Manufacturing improved cook stoves	Reduced demand for ICS resulting to unemployment	Production of spare parts to the e-cook appliances
Stove retailers	Selling improved cook stoves	Reduced demand for ICS resulting to unemployment	Selling ecook systems
Consumers	Charcoal buyers	Reduced charcoal buying	More time for income generating activities

Presentation made by KAREN CHEPKURUI,
at the E-COOK TANZANIA, Stakeholder meeting
APRIL, 2018

but first
n sell them
way they
can improve their financial status.

- Solar sister in Tanzania is also helping women be entrepreneurs by providing plans and materials to sell solar-powered lanterns.
- Lucey the co-founder of solar sister says "the best way to introduce a new technology into a household is by a woman hearing from a sister or cousin"

- Involve both men & women from the beginning to collect information on designing & marketing a product that will be beneficial & attractive to both men & women, as both are key HH decision makers in Tanzania.
  - E.g. through single & mixed gender focus groups and surveying both genders in the choice modeling.

- Improved health due to reduced indoor air pollution and reduced drudgery. W.H.O estimated 18,990 deaths from indoor air pollution in Tanzania in 2017 primarily from pulmonary diseases
- Improved economic status of women; more time can be spent on income generating activities such as selling clothes, agriculture and so forth

Improved energy solutions like e-

search@gamos.org | PV-ecook.org

12 Concept Prototyping

As discussed in the main foundational reports (Batchelor 2013, Batchelor 2015, Leach and Oduro 2015, Brown and Leary 2015), the price point for an eCook system is not yet with us, but will likely arrive around 2020. The creation therefore of a concept prototype for demonstration was at a cost too high for the average consumer, but was undertaken to demonstrate the equipment that would be required, and to get feedback on the performance. The Tanzania concept prototype was constructed of components that were off the shelf in Tanzania (further indicating the imminence of the shift in technology and its general availability).

12.1 Design specification

The eCook Tanzania concept prototype was designed to:

- demonstrate that it is possible to cook on battery-supported electricity; and
- to obtain feedback from end-users and other key stakeholders that could guide the design of the next generation of prototypes.

It was designed according to the following criteria:

- Cost:
  - in the long-term, the components for similar systems should cost less than $500, but due to the restrictions on the availability of specialist components, this initial prototype could cost up to $2,000.
- Portability:
  - it should be possible to transport the entire system to events where it can be showcased.
  - during the Innovate funded research, these included the focus groups and stakeholder workshop, and beyond the initial research project, showcasing opportunities and other research opportunities.
- Safety:
  - it must not be dangerous for users with basic training and familiarity with off-grid systems to operate the system.
- Usability:
  - cooks should be able to plug in off-the-shelf electric cooking appliances and use them in a similar way to if they were plugged into the main grid.

    - it should also be able to power low power DC appliances such as mobile phones or LED lights to demonstrate the additional energy services it can provide.
    - it should be possible to see how much energy is remaining in the batteries and how much has been used by each appliance.
    - it should be possible for TaTEDO staff with basic training to operate the system and for others to cook with it under their supervision.
- Energy storage:
    - it should be able to store enough energy to comfortably cook a meal for 5 people during a demonstration.
    - it should be able to charge from solar PV and the grid.
- Communication:
    - it should be clearly laid out so that it is easy to explain what each of the components is and how they work together.

12.2 The eCook TZ Mark 1 Concept Prototype

The eCook Tanzania Mark 1 Concept Prototype consists of 1.2kWh LiFePO4 battery storage, an 800W inverter/charger, a 30A solar controller and set of energy-efficient electric cooking appliances. It could be charged from solar panels and/or the grid, making it a hybrid PV/Grid-eCook system. It was sized to allow a small family (2-3 people) cooking efficiently using energy-efficient cooking practices to be able to do the majority of their cooking. For peaks in demand (many relatives coming to visit) or dips in supply (very cloudy days and/or blackouts lasting longer than a day), it would need to be supported by an alternative stove.

12.3 Key performance metrics

Metric	Performance
Maximum power	800W
Energy storage	0.8-1kWh
Cooking appliances	Thermo-pot Electric pressure cooker Rice cooker
Additional appliances	LED light USB mobile phone charger
Charging time	3-4 hours at 300W/25A
Power sources	Solar PV (300W panel recommended) Grid

Typical applications	Cooking most meals for a small family (2-3 people) on an everyday basis Cooking a single meal for 5-10 people during a demonstration
Key strengths	Cooking anywhere, anytime for up to 6 years (when battery is expected to fail)
Key weaknesses	Heavy and bulky, can only use 1 appliance at a time, requires some training and behaviour change to use effectively

12.3.1 How it works

Electricity generated by the solar panels or drawn from the grid is stored in the LiFePO4 batteries, giving approximately 1kWh of useful energy for cooking. The solar charge controller monitors the state of charge of the batteries, slowing and then stopping charging when they become full as overcharging can be dangerous. The inverter/charger does the same with the power coming from the grid.Inverters are expensive and bulky. They add another potential point of failure and make the whole system less efficient. They can also limit the maximum power that can be drawn (and therefore which appliances can be used). The development of DC cooking appliances is an important next step.

DC loads can be connected via the solar charge controller and AC loads via the 3-way extension cable connected to the inverter/charger. DC loads are limited by the current rating of the solar charge controller (30A, i.e. 360W at 12V), although they could be connected directly to the batteries. Whilst AC loads are limited by the power rating of the inverter/charger (800W).

Figure 25: Wiring diagram of eCook TZ Mark 1 Prototype.

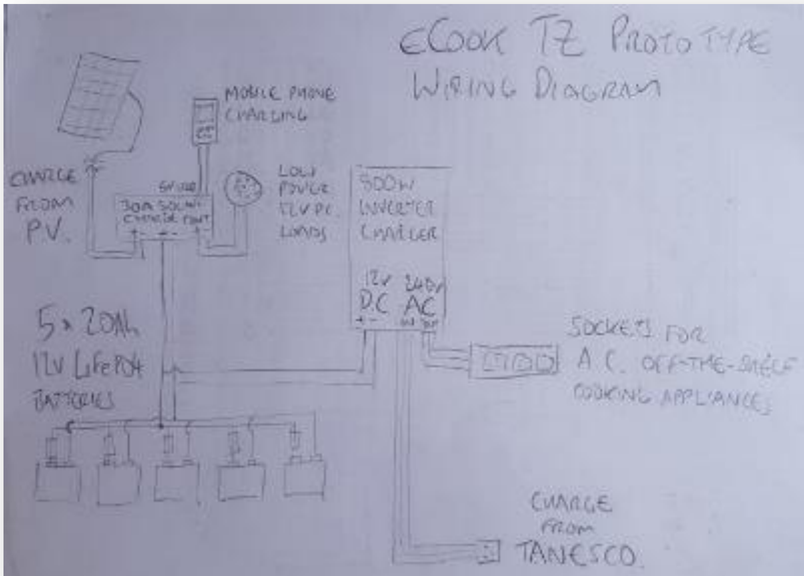

Figure 26: Photos of eCook TZ Mark 1 Prototype key components (before the wiring was tidied up!).

12.3.2 Cost

The total cost for all the components came in at 1,480 USD, however there is significant scope for optimisation. The LiFePO4 batteries were obtained as a spare part at a cost of 500USD/kWh, whilst factory gate prices in China are expected to fall to 200USD/kWh or less by 2020. To some degree the retail price in Tanzania reflects the transport costs, customs and profit margin, however we expect the landed price in Tanzania to drop over the next few years. An inverter will not be necessary in DC only systems, leaving just the solar or the AC charger depending upon the application. The number of appliances, size of the box and length of cabling/connections can also be reduced significantly by creating a single multifunctional battery-integrated DC cooking appliance. As a result, a total cost of 700USD for a commercially-produced unit in 2020 seems feasible, and less than $500 for a mass produced version.

The main justification for component choice was availability. Over 20 solar suppliers were contacted in Dar es Salaam, however, none were able to supply lithium ion batteries of above 10Ah. The 12V 20 Ah LiFePO4 batteries used in the eCook TZ Mark 1 prototype were obtained on the good will of Orb Energy in Nairobi as a spare part for their Solectric 600 solar home system. These are the biggest lithium ion batteries they currently supply and are not usually sold separately. A similarly exhaustive search was carried out in Nairobi, however there were no other options.

> Establishing a supply chain for larger scale (>10Ah) lithium ion batteries in East Africa will be key to achieving affordability. Currently the only options are spare parts for SHS or importing directly from the factory in China.

As stated it is expected that the availability of lithium ion batteries will improve in the future. Smaller batteries are already in use in a number of solar home systems and global prices are also dropping. The 120 USD per 20Ah unit, this equates to 500USD/kWh, which we expect to come down as global work on electric vehicles and energy storage decrease the cost of lithium by learning rates[12]. However, in fact, on return to Nairobi, the price had increased to 200USD per unit, or 833USD/kWh. With no other option and a short deadline to build a new prototype for Kenyan stakeholders, there was no other choice but to purchase. Orb Energy cited reductions in the order quantity (just 50 units with a MoQ of 1,000 for the previous price) and lack of import tax exemptions for batteries shipped as spare parts instead of complete solar home systems. This is an important short term fluctuation that will need to be considered when planning starting up roll out of the system.

Even after obtaining the LiFePO4 batteries, it was still very difficult to find LiFePO4 compatible charging equipment. LiFePO4 has a different charging regime to lead acid and the research team had received conflicting advice on the implications of charging LiFePO4 batteries with a lead acid charger. A VictronMultiComp inverter/charger with a LiFePO4 charging setting was obtained in Nairobi and a solar controller with a LiFePO4 setting was obtained in the UK.

> More insight is needed into the implications of charging LiFePO4 batteries with lead acid chargers. With the proliferation of lead acid batteries and chargers around the world today, there would be considerable benefit if it there were some compatibility. We need to know what are the risks of doing this in terms of both safety and battery lifetime.

Importing equipment directly from China was considered, however due to the long shipping distance and factory lead time for producing samples, it was not a viable option for this project. Lithium ion batteries bigger than laptop size cannot currently be carried on an aeroplane, so must be shipped or transported overland. This not only makes prototyping much more difficult, but will also slow down the supply chain for commercial eCook products.

Table 21: Parts list for eCook TZ Mark 1 Prototypecomponents.

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[12]Technological learning, i.e., cost reductions as technology manufacturers accumulate experience

Component	Specification	Brand	Supplier	No.	Unit cost	Total cost
Box	Tough Tote		Game	1	25 USD (60,000 TZS)	25 USD
Batteries	12V 20Ah LiFePO4	Optimum Nano-Energy	Orb Energy, Nairobi	5	120 USD (12,000 KES)	600 USD
Solar charge controller	30A LiFePO4 compatible		Amazon.co.uk	1	40 USD (30 GBP)	40 USD
Inverter/charger	800W LiFePO4 compatible	Victron	Centre for Alternative Technologies, Nairobi	1	600 USD (60,000 KES)	600 USD
Electric pressure cooker	850W, 4 litres	Singsung	Small electrical appliance store, Kariakoo	1	50 USD (120,000 TZS)	50 USD
Thermo-pot	750W, 3 litres		Small electrical appliance store, Downtown Dar es Salaam	1	55 USD (130,000 TZS)	55 USD
Rice cooker	700W, 5 litres	Von Hotpoint	Small electrical appliance store, Kariakoo	1	20 USD (50,000 TZS)	20 USD
Plug-in energy meters	3kW max power	Energenie	Amazon.co.uk	2	20 USD (15 GBP)	40 USD
Misc. components	13A 3-way extension cable, DC cables, screws, PowerPole connectors, 30A blade fuses & holders, cable ties, LED light, USB cable, rope, plywood mounting board	Various	Amazon.co.uk, Orb Energy, small hardware stores in Kariakoo and Downtown Dar es Salaam	Total for all	50 USD	50 USD
					TOTAL:	***1,480 USD***

12.3.3 Portability:

All items are contained within a tough plastic storage box and fastened down to prevent damage during transit on rough roads. The battery storage and power electronics were mounted onto a plywood board with either screws or cable-ties. The plywood board sits in the top of the box, leaving space for the appliances, food and utensils for demonstrations and basic tools for troubleshooting underneath.The box could be carried by one strong person, but its size and weight leave considerable room for improvement.

12.3.4 Safety:

The main safety risks were:

- Fire or explosion from short circuiting, over charging or over discharging of the battery or overloading of cables or components.
- Electric shock from live cables or components.

Mitigation measures included:

- Each of the 5 LiFePO4 battery was individually fused with 30A automotive blade fuses. The highest surge current measured was 90A, but the inverter limits continuous power to 800W and therefore a maximum of 76A (at 10.5V).
- All internal cabling was fastened down with cable ties to minimise the risk of cables catching and disconnecting when taking the main circuit board out of the box.
- All connections on the DC side were made with Anderson connectors which offer plastic insulation around terminals to prevent short circuits if they are accidentally disconnected.
- The prototype was tested by fully charging and discharging several times when first assembled. It was then used to cook lunch at the TaTEDO office for several weeks.
- Each LiFePO4 battery came with 1.5mm^2 cables coming out of the BMS. In a sealed environment (such as the storage box), they should carry a maximum current of 17.5A. With the above maximum current of 76A, this is 15A per battery, which is within this limit, assuming all of the 5 batteries are connected. Each battery is protected by a BMS, disconnects the load when the battery state of charge falls below a pre-set level (approximately 80% discharged, which equates to somewhere between 9 and 10V). During early testing, the low voltage

> The BMS cables supplied with the LiFePO4 batteries were a key weak point in the eCook TZ Mark 1 prototype. For safety reasons, LiFePO4 battery packs have a BMS (Battery Management System) built in to prevent over charging or over discharging. As a result, even if a LiFePO4 battery is supplied with conventional battery terminals, there may well be components inside the BMS that will fail at higher C-rates unless the battery has specifically been designed for this.

> A single LiFePO4 battery pack with a single BMS is more robust than multiple units in parallel or series, as each battery is slightly different and each BMS will cut off supply at a slightly different point.

> Measuring the state of charge of a lithium ion battery is more complicated than lead acid, as the voltage/stage-of-charge curve is much flatter. Future prototypes should aim to incorporate similar state of charge indicators to mobile phones or laptops (likely coulombic counting and learning algorithms to detect capacity from full cycles), which also use lithium ion batteries. These may need to reflect the influences of higher C-rates.

disconnect of the inverter was set to 9.5V and the BMS in individual batteries would begin to trip, as each battery discharged at a slightly different rate. This then increased the current drawn from each other battery, causing the 1.5mm^2 wires to heat up. Fortunately the fuses started blowing on the remaining batteries, cutting off the current supply. This problem was resolved by increasing the inverter's low voltage disconnect to 10.5V, well above the threshold for the BMSs. As the voltage vs. state of charge curve for LiFePO4 is relatively flat until beyond 80% discharged, there useful energy sacrificed by doing this is relatively little. In practical terms, it sacrificed about 5 minutes of cooking time at full power, but still runs for more than an hour at 800W.

12.3.5 Usability

To cook with the prototype, the user simply switches on the inverter and plugs an appliance into one of the three sockets in the extension cable. The appliance will operate as if it were plugged into the grid, until the batteries run out. The inverter was programmed to cut off power well before there could be any risk of damaging the batteries through excessive discharge. To charge the batteries, the user must either connect a solar panel to the solar charge controller or plug the inverter/charger into the grid. Charging time from the grid is 3-4 hours, at a rate of 25A or 300W. Therefore, a 300W solar panel in full sun could also charge the batteries in a similar timeframe.

> Insulated appliances can offer significant energy savings, however they are bulky and are usually only supplied with a single pot. Space is likely to be limited in the kitchens of poorer households, if there even is a dedicated kitchen space at all. Future prototypes should focus on expanding the functionality of off-the-shelf insulated appliances (e.g. allowing the user to manually control the heat level in a rice/pressure cooker) to increase the proportion of cooking that can be done on a single appliance.

The eCook TZ Mark 1 Prototype was paired with 3 energy-efficient cooking appliances obtained from retail stores in Dar es Salaam. All devices save energy by insulating the cooking pot and automatically controlling the cooking process:

- A 750W 3litre thermo-pot – heats water at full power until it reaches 100C. Turns on at full power to top up heat when control system senses temperature has dropped significantly.
- An 850W 4l pressure cooker – cooks at full power until it reaches 120C, then turns off until the control system senses that the temperature is too low (somewhere between 100 and 120C) and turns on at full power again. Turns off when timer switch reaches the end. Decreases cooking time of long boiling dishes by approximately half by increasing the temperature inside the pot through pressurisation.

- A 750W 5l rice cooker – cooks at full power until the temperature in the pot rises above 100C, then automatically switches on to warm mode (approx. 40W).

Due to the maximum power limitation of the inverter/charger, it was only possible to power one appliance at a time. However, multiple appliances could cook at the same time as the pressure cooker is insulated, so retains heat well and only uses power occasionally to top up the internal temperature.

The inverter had a maximum power limit of 800W, but it was possible to use the 850W rated pressure cooker, as the output voltage could be manually lowered, effectively downrating the power consumed by each appliance. An 800W inverter/charger was selected purely because of the constraints of availability of LiFePO4 compatible components in East Africa. A 1.2kW inverter would have allowed the majority of off-the-shelf single plate electric cooking appliances to be used without having to downrate the voltage. However, the 1.5mm2 cables in the batteries would likey have become overloaded with 50% extra power, meaning that more batteries or batteries with proper terminals would have been needed.

Low power DC appliances could be connected via the solar controller. Either to the 12V port or the 5V USB. A 2W LED light and multi-plug USB phone charger from the Orb Energy solar home system was left plugged into the solar controller

The solar controller could display PV voltage, battery voltage and PV input current. The battery voltage display enables the user to know how much energy is left in the batteries. However, this is challenging with LiFePO4 batteries, as the voltage/state of charge curve is much flatter than lead acid, meaning that unless the batteries are almost completely charged or discharged, the voltage remains almost the same.

> Voltage has a massive impact on power and therefore heat delivered by a cooking appliance. It is likely that consumers who have tried cooking with electrical appliances on weak grids with fluctuating voltage will find the experience of cooking battery-supported electricity via an inverter much more predictable, as an inverter produces a constant voltage (until the battery runs out!). However, DC appliances are likely to cook faster when the battery is full (13.6V for LiFePO4) than when empty (9-10V for LiFePO4). The power produced by a resistive heater is proportional to the square of the voltage, so a 25% drop in voltage equates to a 44% drop in power. Fortunately, the relatively flat voltage/state-of-charge curve for LiFePO4 means the heat supplied by the stove is only likely to vary significantly when almost full or almost empty. Insulated appliances are also likely to mitigate this effect, as heat is retained inside the pot from earlier in the cooking process when the voltage was higher.

2 AC plug-in energy meters from the cooking diaries were supplied with the prototype. These could be used to measure the energy consumed by each appliance during demonstrations and by subtraction,

what is left in the battery bank. They can also be used to measure how much energy has been drawn from the grid to charge the batteries via the inverter/charger.

12.3.6 Userfeedback

After some demonstration of electrical appliances, the group had the following observations.

The observations on the electric cooker (hot plate) demo were

- ✓ Very slow
- ✓ Good food
- ✓ Only cooks when electricity is on
- ✓ Cooking in leisurely way
- ✓ No smoke
- ✓ Improved on electric shocking (as opposed to a hotplate?)
- ✓ (a need for) Safety measures- wear rubber shoes, be dry (to avoid shocks)

These comments do tend to confirm that the existing hotplates on the market are not up to the job – and are doing the idea of electric cooking a disservice.

The observations on the rice cooker demo were

- ✓ thought to just cook rice
- ✓ Can cook ugali without hitches
- ✓ Can't fasten the cooking of beans and makande

Rice cookers misnamed! They can cook other things!!

The observations on the THERMO POT **demo were**

- ✓ Just boils water
- ✓ Keeps water hot for a period of time

The observations on the PRESSURE COOKER **demo were positive – the enumerator recorded it as "A**ll positive vibes".

12.3.7 Energy storage:

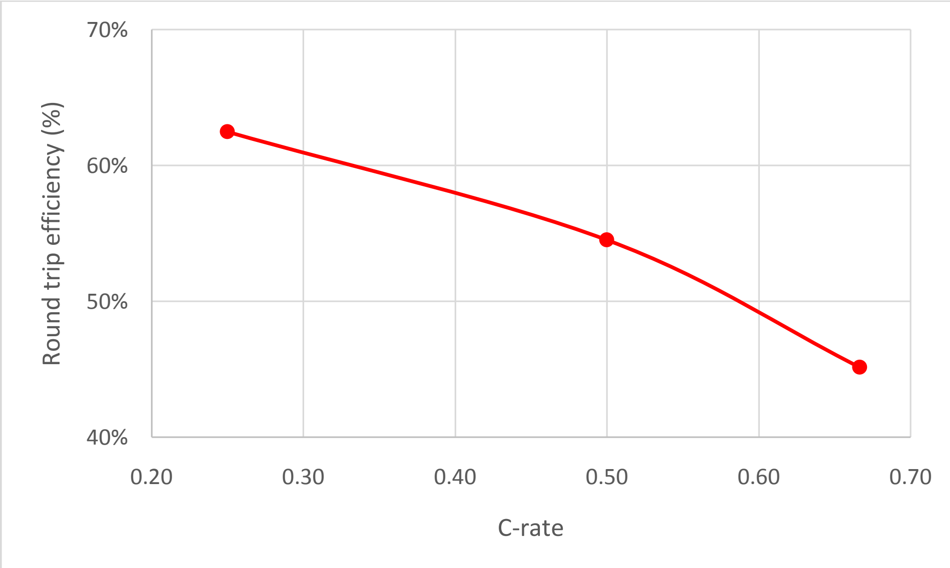
The prototype was capable of cooking a meal for 5 people during a demonstration, as long as the cook cooked efficiently. For example, cooking 1/2kg of dry Rosecoco beans without putting the lid on the pressure cooker is likely to take several hours and use in excess of 2kWh. However, the same beans could comfortably be cooked with less than 0.3kWh if using the pressure cooker as intended. In fact, almost any food can be cooked in the pressure cooker with 0.3kWh, meaning that even if only 0.8kWh were available, a two-dish meal could comfortably be cooked without recharging.

The relationship between C-rate and useful energy available from the batteries should be investigated further. Until DC cooking appliances become available, optimising the low voltage disconnect point for inverters could greatly increase usable storage.

Even at a low C-rate (C/4), round trip efficiencies were lower than expected (63%). Further work is required to determine where the inefficiencies are and to optimise the system.

A 30A LiFePO4 compatible solar controller enabled the prototype to charge from solar arrays of up to 360W, which should charge the batteries in 3 hours of full sun. It was observed that to charge the batteries from a fully discharged state (low voltage disconnect tripping at 10.5V) consistently required 1.6-1.7kWh. When discharging, the capacity of the batteries was proportional to C-rate. This could have been due to the fact that the voltage/state of charge curve varies with C-rate. Heavier loads pull down the voltage further, yet the low voltage disconnect on the inverter was set at a constant value (10.5V), independent of loading. This is likely to cause batteries under heavy loads to trip out the inverter (and therefore end the test) earlier.

Figure 27: Relationship between C-rate and useful energy available from the batteries.



12.3.8 Communication

The prototype was successfully used to demonstrate the concept of cooking with batteries at several stakeholder events and focus groups. It could be demonstrated in two modes: 'on-the-table' and 'under-the-table'. 'On-the-table' mode involved taking the plywood board with the main components mounted on it out of the box and displaying them on top of the table to explain what each component does. 'Under-the-table' mode was simply closing the lid of the box, with only the 3-way extension cable reaching above the table. In this mode, the focus is on the appliances and demonstrating how each one works. To date, the protoype has been demonstrated at:

> Future prototypes should also have 2 modes: one that allows more technical people to see inside and another that shuts away the all components and allows the user to get on with cooking

- Focus group discussions in Kifuru, Kibindu, Moshi and Ubungo.
- eCook TZ stakeholder workshop at TaTEDO, Dar es Salaam.
- Awareness raising and demonstrations on efficient energy technologies (improved charcoal stoves, solar, briquettes and eCook) in Utete, Rufiji District.
- World Environment Week Exhibitions, Dar es Salaam.

Figure 28: 'On-the-table' mode, allowing demonstrators to explain how the system works.

Figure 29: 'Under-the-table' mode (with lid off for the photo), allowing the cook to use the prototype as if the appliances were connected to the grid.

12.3.9 Key learning points

- Appliances of up to 1,000W can be used on an 800W inverter by lowering the output voltage
- Set low voltage disconnect to 10.5V instead of 9.5V to avoid the BMS in individual batteries cutting out
- Maximum discharge current of LiFePO4 batteries is limited by the components in the BMS as much as the chemistry of the battery itself.
- Chargers designed for lead acid can charge LiFePO4 batteries, but will not reach 100% state of charge, as they lower the voltage in the float stage of the charging cycle. LiFePO4 does not require float charging.
- You can cook with more than one appliance at a time if they are insulated by alternating power between them
- Coulombic counting would give a much better indication of the State of Charge than voltage, but it would have to correct for C-rate.
- Component selection restricted by availability of LiFePO4 batteries and compatible hardware in East Africa. This is expected to improve in the coming years.
- Round trip efficiency is much lower than expected. This could potentially be fixed by using a low voltage disconnect that adjusts with C-rate.

13 Conclusion

The breadth of data and analysis in this report makes a single narrative conclusion difficult. There are clear indications particularly from the diaries and focus group exercises, that households would adopt electricity for cooking – if the price and other conditions were'right'. There were a number of comments particularly about the multicooker about how clean it was (and they meant cleanliness in terms of sweat and clothing rather than the development communities use meaning clean as emitting now emissions). These features whereby one can set up a meal and do other things, plus that one does not 'sweat' over hot coals, and one's dress remains clean, are possibly very powerful arguments when marketing eCook in the future.

However, there are some reservations. Cost is a major factor, but (the lack of) reliability and availability were obviously at the forefront of people's experience. If PV-eCook is fully implemented then such factors are all mitigated – eCook offering a reliable offering that can be made available even where there is no grid electricity at the moment. Even where the grid is available, Grid-eCook offers greater reliability and availability.

However the cost is not yet there. The cost of building the demonstration prototype shows the current situation – a shortage of components of the right size on the market (batteries, inverters, cookers), and a high cost for the available components (batteries at $520/kWh). This comes as no surprise to us. Our premise since 2013 has been that components will become cheaper and more available as learning rates kick in to Lithium Batteries, and by 2020 system will be affordable.

With this Tanzania experience we stand by such prediction or hypothesis. The component prices are coming down and all commentators agree that learning rates on PV and Batteries have not yet levelled out.

Behaviour change is as important as we had originally thought, but our understanding of how people cook and the compatibility with different electrical appliances has improved. We can now see that the motivations to change behaviour to adopt an aspirational product that offers more than what a charcoal stove can (or even LPG) are an alternative and seemingly more viable pathway than creating something that mimics as closely as possible the slow and inefficient nature of charcoal stoves**. This work in Tanzania has shown that perhaps a move directly to multicookers could be possible.**

We had originally thought that hotplates would be the most popular and easily understood transition – hot plate = hot charcoal – it makes sense to the onlooker. However, this work in Tanzania suggests that multicookers (where the 'hotplate' is encased in insulation) can be understood and accepted by householders relatively easily. It has also shown that with multicookers, significant savingsin energy can be made (compared to hotplates). For some foods such as beans this is a factor of 5 or more. Such responses from these real Tanzanian's cooks suggests that the size of the system can perhaps be reduced such that it still covers the majority of day to day cooking. With such a reduction, the cost of the system reduces, making the 2020 target for a viable commercial product inclusive of a profit margin that makes it sustainable supply might be more in reach than we originally thought.

The policy review and the stakeholders meetings confirm that there is a hunger within the Government and other decision makers for a solution to the enduring problem of biomass cooking. Policies tend to support eCook, and certainly targets seem to enshrine a solution like eCook. It will be important to raise awareness of the solution and co-construct with the Tanzanian Government the emerging solutions. This will not be a quick process, and a vision of 5 to 10 years should be held rather than expecting short returns with a cheap but inadequate eCook solution.

Perhaps the value of this work in Tanzania can be summed up as:-

Either

Or

Figure 30: Pictorial re-definition of 'eCook' after Tanzania (and Zambia, Myanmar and Kenya) in depth findings. (Note, battery purposely smaller than in Figure 1, due to energy savings)

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15 Appendices

15.1 Appendix 1 - Problem statement and Background to Innovate ecook project

15.1.1 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[i] 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 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'. World Bank Atur & Jammi 2014 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. (World Bank Atur & Jammi 2014)

"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 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.

15.1.2 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 31 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[ii](Batchelor 2015b; Brown & Sumanik-Leary 2015; Leach & 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 (eg cooking energy needs, technology performance, component costs). There is uncertainty in many of the 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.

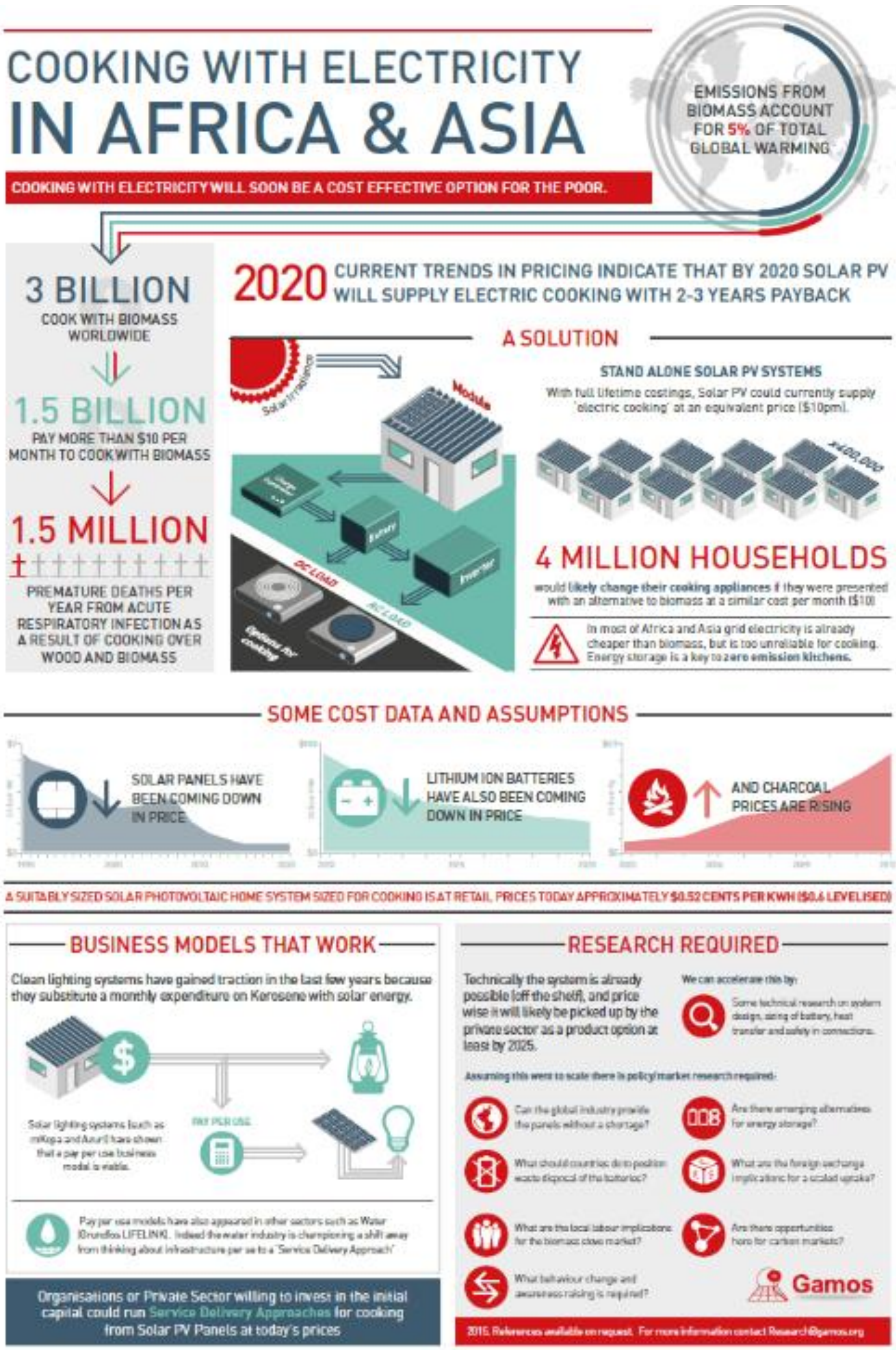

Figure 31Infographic summarising the concept in order to lobby research and policy actors.

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 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.

15.2 AppendixCooking practices and foods cooked from focus groups

An exercise for someone – how many of these could be done in a multi pressure cooker?

Key Blue, Kibundu, White Moshi, Green Ubungo

What do you cook	How do you cook
Ndizi, maharage	Light fire wood, boil beans, prepare bananas while beans get ready Prepare tomatoes, onions carrots. put together with banana till ready add a little coconut milk and serve. Mostly cooked during the day.
makande	Sort your beans and wash then mix with washed maize then Soak, prepare dry firewood and light fire. This needs a lot of firewood and heat. Put into the fire and keep lighting the fire. Prepare carrots, onions, green pepper, garlic. When beans are almost ready; taste to determine. Add the ingredients with salt and oil and cover reduce the heat by removing some of the wood. Then wait to simmer. Taste to determine if they are ready.
pilau	Prepare wood, prepare meat with onions tomatoes carrots and boil meat to make it soft if not already soft then fry all the meat with ingredients and add water. Sort the rice and wash it the mix with the meat in the fire then reduce heat and wait to simmer as it

	cooks
ugali	Prepare green vegetables and cut into tiny pieces and fry with onions. Bring water to boil and make porridge then after boiling add more flour and keep turning till ready then move it to a plate ready for serving. Clay pot cooks differently as it retains heat and keeps cooking food even after fire is gone.
Kiburu(mtore wa maharage)	Prepare fire and clay pot put beans and water into the pot until ready for adding bananas (mshale,ngombe) then add and wait for it to cook well and add a little magadi and remove the foam . Put banana leaves to steam it and let it simmer as you do other activities. Wait till you smell the tasty flavour, add a little water to your liking then mash it traditionally. Cooked anytime
Ugali (sembe)	Light fire (fire wood or Charcoal), prepare metal pan and put water and put into the fire, leave the water to get warm, prepare porridge, after it boil put lid on for some time and then prepare ugali.
Ugali (Cassava)	Light fire, put metal pan of water into the fire, leave the water until it boil, put cassava flour and prepare your ugali.
Rice (vegetable oil)	Light charcoal stove, prepare rice, put a metal pan of water into the fire, leave the water to boil, put the boiled water aside, take another metal pan, put cooking oil, put ingredients (onions, carrot, green paper) and rice, fry for some time, put some amount of hot water, put a lid, after 10 minutes steer it and then put the lid on, put charcoal on top.
Rice (coconut)	1st Woman Scrape the coconut, prepare the 1st coconut juice and put aside, prepare 2nd and 3rd coconut juice put together. light up charcoal, put the 2 and 3rd coconut juice into the metal pan and put into fire, steer it until it boiled, put rice and put lid on, after 5 to 10 minutes steer and put the 1st coconut juice (tuibubu), put lid on and put charcoal on top 2nd Woman Scrape the coconut, prepare the coconut juice and put aside, light up charcoal, put the all coconut juice into the metal pan and put into fire, steer it until it boiled, put rice and put lid on, after 5 minutes steer, put the lid on and put charcoal on top
Pilau	1st woman

	Prepare all ingredients (garlic, ginger, onions), put metal pan into the fire with cooking oil, put ingredients when it becomes light brown, put rice and fry for sometime, put enough water and steer, put lid on, put charcoal on top. 2^{nd} woman Boil water and put aside, fry the onions until it become light brown (kahawia), put garlic, ginger and pilau ingredient and steer, put water (estimate enough water) and then put rice, put lid on.
Pilau Nyama	Prepare garlic, onions and lemon, mix with meat and boil, ensure it has enough soup. Put the metal pan on fire, put cooking oil and ingredients (onions, garlic, ginger) and fry, put rice and fry for some time, put soup on the rice and steer, add some water if soup is not enough, steer and the lid on.
Maharage	Prepare beans, wash and put on the metal pan, put ginger, garlic and green paper, put on fire. Scrape the coconut, prepare 1^{st} and 2^{nd} coconut juice and put aside. After the beans is ready, put the second coconut juice and leave for until it boil without lid on, put the 1^{st} coconut juice and leave until it boil.
Mchunga	1^{st} Woman Sort out the mchunga and wash, put the metal pan on the fire, put salt then mchunga and boil, steer until it is ready. Prepare coconut then fry your mchunga as other vegetable. 2^{nd} Woman Sort out mchunga rub with salt and wash, boil mchunga and then fry
Kisamvu	Sort out, put into the kinu, add onions and paper, pound until it becomes somehow soft, put into the metal pan, wash the kinu and use that water to boil the kisamvu until it is ready, fry as other vegetables
Mlenda (Bwando)	Sort out and wash, put on the metal pan, add nyanya chungu, put magadi, put into fire and boil until it is ready

Ndizi Nyama (Malindi)	Boil water and put enough soup. Prepare banana, tomato, garlic and ginger, coconut. Wash banana and put on the metal pan, add all ingredients, put soup and boil. When it is about to be ready, put the meat and coconut.
Matoke, meat, beans	Boil meat and beans, fry ingredients then add bananas meat and beans to make stew. sometimes covered with banana leaves to steam
Ugali and fish- sato(from the l.victoria)	Scale and wash then boil with onions tomatoes and some oil for a short time like 10mins, others add coconut milk-first grind is put aside, use the second grind in the stew first then add the first grind later to have a thick stew and if you use cocnut milk you will have to let it boil it for like 15mins in it put it away. Boil water for ugali (sembe), just as it gets hot add some flour to avoid cuddles then stir and cover repeat until its ready. (Dona) the unground and cleared maizeflour process is the same but it takes longer to cook
Rice meat	Cut into pieces and wash to cook first she uses gas. Grind Tangawiziabd add to meat to simmer and cover, have tomatoes carrots, tangawizi, onions, hoho, garlic, black pepper then add to the simmered meat, add oil and water ,and sprinkle some lemon juice and cover to boil for 15 -20mins. Comes out thick and tastey stew and put side. Rice- wash and rinse thoroughly and drain the water, have boiled water, add salt, a little oil and the rice and sprinkle (iliki)in a charcoal stove. Reduce charcoal heat when it the water drains out you stir it then put charcoal on the cover for about 10mins with very small heat under. Green veges- cut, wash and put onions, hoho and carrots and oil to simmer for 5mins.
Ugali (cassava) and dried shark (papa)	Shark- wash with hot water or boil it and prepare the ingredients, squeeze coconut milk, have oil in the pot add onions, tomatoes and other, add salt. Put the shark in and let it boil and add the first squeeze and boil for like 5 mins then add the other coconut milk then boil for 5 mins , its ready Dry your cassava, grind by hand or machine. Put water and add flour before it starts boiling on firewood heat for like 5-6 minutes. This is because firewood heat is very strong.
makande	Maize is not dried. Light the fire, have water boil, add your maize in for like 15mins when the water is out add beans either dried or fresh and add more water to boil till ready. You add oil and salt for taste and its ready. Dried maize- 0.5 kgs, beans 0.5 kg mix wash and put in the pressure cooker and add water and set it to 90minutes,depressurize.

	Prepare onions,hoho carrots and add in, grind coconut milk and add the second grind , salt and any other spices, boil then add first grind then wait for the coconut to get ready then serve.
Pork 1kg	Charcoal stove-Wash and put in the pot,addtangawizi,salt lemons and simmer. Prepare potatoes (4), onions,chilli and garlic.add potatoes and let it boil,when the water is coming to end starts to brown add all the ingredients and let simmer till ready.

[i] 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)

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