Opportunities & Challenges for eCook Tanzania

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Acknowledgement

The findings presented in this report would not have been possible without the dedication of our research participants and the attendees of our stakeholder workshop, which was fuelled by the kind and generous support of the staff at TaTEDO, both those named as authors and the supporting staff. Together, they helped reveal what really goes on in Tanzanian kitchens and to uncover the needs and aspirations of everyday Tanzanian cooks. Their willingness to experiment and share their experiences created an unexpectedly rich learning opportunity, for which we are very grateful. Finally, we thank the donors, UK Aid (DfID) via Innovate UK for partial funding and the directors and shareholders of Gamos who matched the funding for the benefit and public good of Tanzania. Additional analysis was carried out under the Modern Energy Cooking Services (MECS) programme, also funded by UK Aid.

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Executive Summary

This report summarises the findings from a series of studies **carried out in Tanzania**, with the aim of informing the development of a **battery-supported electric cooking concept, eCook**. It is part of a broader programme of work, designed to identify and investigate the opportunities and challenges that await in high impact markets such as Tanzania.

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). 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 (battery-supported solar electric cooking) 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 (battery-supported grid-connected electric cooking) 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.

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

- Cooking diaries
- Choice modelling surveys
- Focus groups
- Techno-economic modelling
- Gendered analysis
- Prototyping
- Stakeholder workshop

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

1.1 Key findings

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'. 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 Electric Pressure Cookers (EPCs) could be possible. Many households in urban areas already have access to grid electricity, which is reliable enough to cook with, given that the EPC mitigates this unreliability to a certain extend.

However, there are some reservations. Cost is a major factor, but (the lack of) reliability and availability were obviously at the forefront of many people's experience. Where the grid is available, Grid-eCook offers greater reliability and availability. Where it is not, reliable electricity can be made available anywhere with PV-eCook.

The price point may not yet been reached for battery-supported eCooking, however the evidence from the cooking diaries shows that it is already cost effective to cook with off-the-shelf energy-efficient electric cooking appliances. The cost and challenges involved in building the demonstration prototype highlight the current situation – challenges in sourcing key components locally (higher capacity lithium ion batteries and DC cooking appliances) and a high cost for what is available (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 for lithium ion batteries in particular. If adequate supply chains are established, by 2020 eCook systems will be affordable in Tanzania.

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.

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1.1.1 Cooking diaries

The key findings from the cooking diaries are that cooking with electricity is compatible with Tanzanian cuisine and that modern energy-efficient appliances are highly desirable to everyday Tanzanian cooks. In particular, the Electric Pressure Cooker (EPC) is a prime candidate for future eCook products, as it can significantly reduce the energy demand for the biggest energy consumers: “long boiling” dishes.

In fact, in some areas of Dar es Salaam, the grid is already strong enough for direct AC cooking, meaning there is an opportunity already on the table to promote off-the-shelf appliances, in particular, EPCs. However, battery-supported appliances are likely to make electric cooking much more attractive, as blackouts and brownouts frequently caused users to revert back to their baseline fuels. LPG is already popular in Dar es Salaam and while electric hotplates do not offer anything new for LPG users, the ability to cook faster and multi-task, whilst also saving money make a fuel stacking scenario with EPCs extremely attractive.

1.1.2 Choice modelling

The choice modelling study has highlighted several opportunities and challenges for future eCook product/service designers. Blackouts and brownouts (voltage dips) seem to be infrequent enough that direct AC electric cooking could be possible for many people. However, electricity is barely used for cooking in Tanzania today, with charcoal and LPG dominating the cooking landscape in urban areas. In rural areas, wood and charcoal dominate.

Electricity is perceived as expensive for cooking – given the low prices of cooking fuels, this is not surprising. However, the evidence from the cooking diaries shows that cooking with energy-efficient electric cooking appliances is significantly cheaper, indicating that changing this perception will be key to unlocking eCook’s potential in Tanzania. In particular, Electric Pressure Cookers (EPCs) seem well matched with Tanzanian consumer preferences, as they can boil & fry, with the boiling part roughly twice as fast as conventional pots.

1.1.3 Techno-economic modelling

This case study showed that even in contexts, where the cost of electricity is high, yet biomass fuels are available at a very low cost, there are opportunities for eCooking. TaTEDO’s solar/biomass hybrid mini-grid in Kibindu was modelled using Leach and Oduro's (2015) techno-economic model. By combining the most efficient appliance, the EPC, with the most energy-efficient practices to create an ultra-efficient eCooking solution targeted at the foods that are most energy-intensive foods: ‘heavy foods’. This is likely to be the first step for eCooking in the most adversarial contexts.

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1.1.4 Gender

A gendered analysis of eCook in Tanzania highlighted the opportunity for a shift in gender roles in the kitchen. eCook can make cooking quicker and easier - pressing a button is much quicker than lighting & tending fires and efficient appliances such as the electric pressure cooker can cut cooking times in half. If cooking is easier, men may be willing to take on more responsibility in the kitchen. Future marketing campaigns should target both genders, as the decision to purchase is likely to be made together in most Tanzanian households.

It also highlighted cooking as productive activity that is often overlooked in energy access programs and that changing perceptions will have a pivotal role. Changing the perception of pressure cookers from dangerous to safe and the perception of electricity as too expensive for cooking are likely to be key enablers for eCook.

Peer-to-peer female led business models (e.g. Avon cosmetics or Solar Sister) are particularly promising, as watching someone you are familiar with cook the dishes you know, asking them questions and trying it out yourself is likely to help many to overcome the reservations they may have about this new technology.

1.1.5 Prototyping

Assembly of a prototype eCook device in Tanzania showed that on 2018, many of the basic components required to build a cost-effective and technically optimised eCook system were still not available. Establishing a supply chain for larger scale (>10Ah) lithium ion batteries in East Africa will be key to achieving affordability. The development of DC cooking appliances is another important next step

Clearly indicating how much energy remains in the batteries, expanding the functionality of energy-efficient cooking appliances and controlling their supply voltage were found to be key enablers for future eCook devices. Future prototypes should aim to incorporate similar state of charge indicators to mobile phones or laptops. *There is a need to expand* the functionality of off-the-shelf insulated appliances to increase the proportion of cooking that can be done on a single insulated appliance. Voltage has a massive impact on power and therefore heat delivered by a cooking appliance, however batteries can stabilise the voltage to give consistent performance or vary the voltage to offer the user control.

1.1.6 National policy and markets review

The review of national policy showed that high level support is already in place for key drivers behind eCook: environmental protection (deforestation and climate change), health (indoor air pollution), gender equity and energy access (electricity).

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The review of national markets showed that Tanzania has a world leading mini-grid and rapidly growing off-grid solar sector, meanwhile, charcoal use in Tanzania is creating several global deforestation hotspots. Mini-grids with spare capacity at peak times could begin to market off-the-shelf electric cooking appliances today. Hydropower is still the most cost-effective option, however solar mini-grids are opening up new opportunities. The market for solar home systems is developing rapidly - in rural Tanzania, off-grid solar systems now outnumber grid connections.

eCook offers TANESCO & mini-grid developers the opportunity to increase their revenue per connection and greatly enhance their development impact. In fact, smaller households with efficient appliances can already cook very cheaply using TANESCO's 75kWh/month lifeline tariff. Tanzania is one of the world leaders in mobile money transfers, which is expected to make small repayments on future eCook products/services much easier.

1.1.7 Stakeholder workshop

Key stakeholders from the electrification and clean cooking sectors confirmed that eCook has the potential to address several of Tanzania's interlinked development challenges, however coordinated action is required to overcome the key barriers highlighted during this study. Live cooking demonstrations with participants from the cooking diaries showed that energy-efficient electric cooking appliances were capable of cooking popular Tanzanian dishes. The food was judged to be just as delicious as at home yet was prepared for a fraction of the cost.

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2 Introduction

This report presents one part of the detailed in country research carried out 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, practitioners and researchers with new knowledge and evidence.

This report presents findings from the design, assembly and testing of a concept prototype to inform the future development of eCook within Tanzania. It is one component of a broader study designed to assess the opportunities and challenges that lay ahead for eCook in high impact potential markets, such as Tanzania, funded through Innovate UK's Energy Catalyst Round 4 by DfID UK Aid and Gamos Ltd. (https://elstove.com/innovate-reports/). A much deeper analysis of the data collected during this project was supported by the Modern Energy Cooking Services (MECS) programme, which included the writing of this report.

The overall aims of the Innovate project, plus the series of interrelated projects that precede and follow on from it are summarised in in *Appendix A: Problem statement and background to Innovate eCook project*.

2.1 Background

2.1.1 Context of the potential landscape change by eCook

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

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2.1.2 Introducing 'eCook'

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

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

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

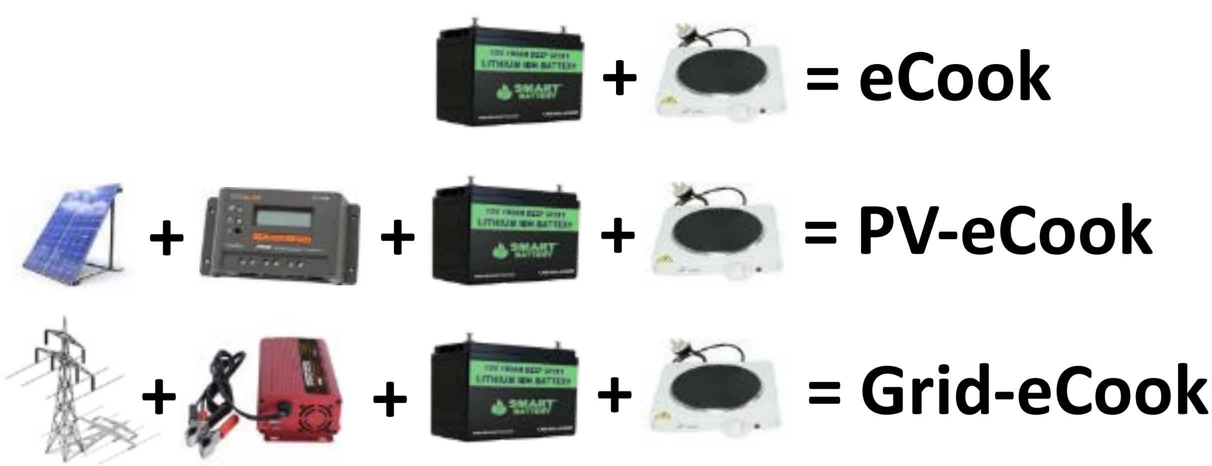

Figure 1: Pictorial definitions of 'eCook' terminology used in this report.

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3 Why Tanzania?

3.1 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.

3.2 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

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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 mechanisms (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.

3.3 Africa

Kenya, **Tanzania** and Uganda all represent large markets that are likely to transition quickly (dark green colour on Figure 2 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).

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

3.4 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 3), such as **Tanzania**, Zambia and Uganda.

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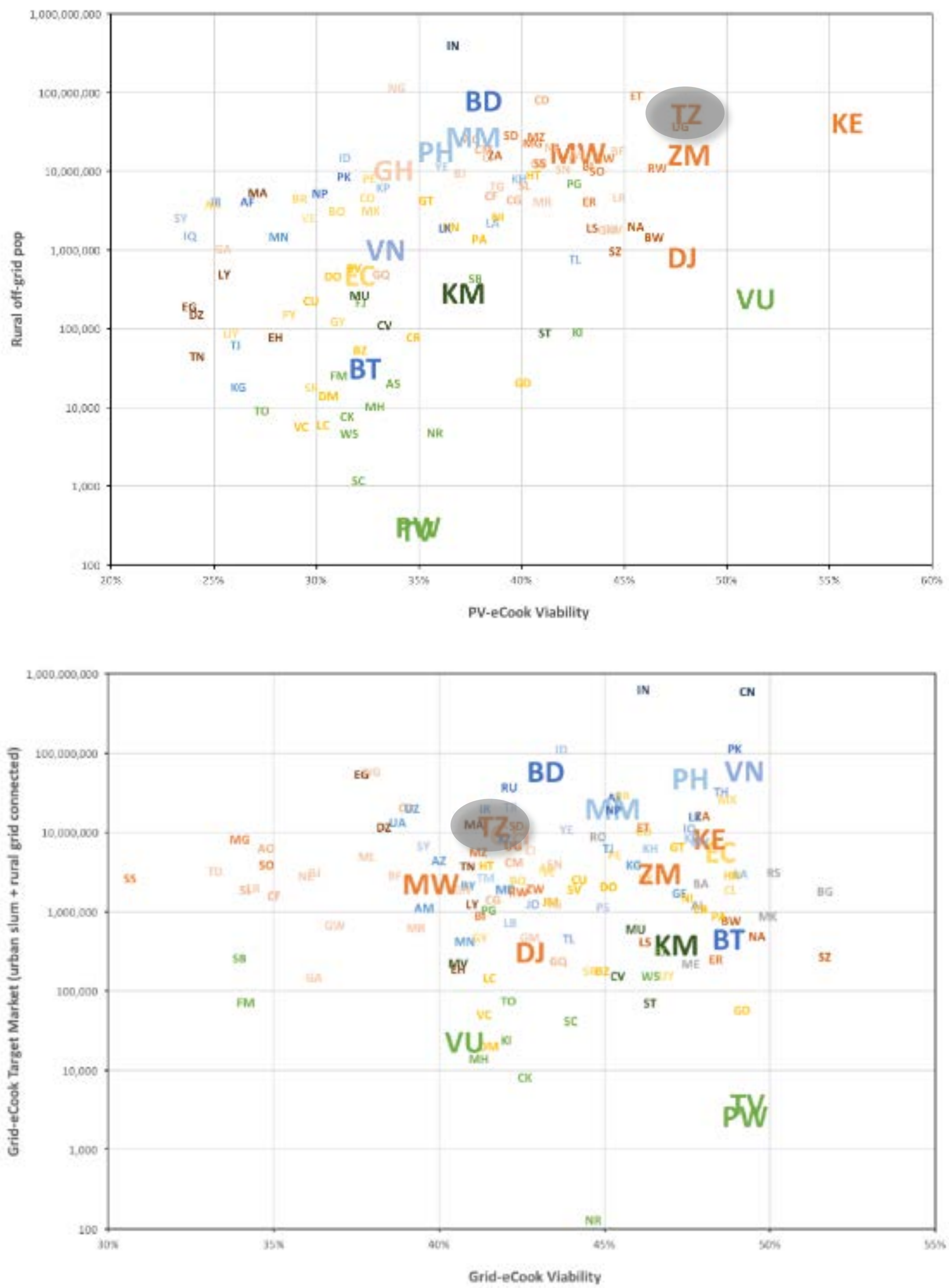

Figure 3: Comparison of size of PV-eCook (top) and Grid-eCook (bottom) target market segments by electrification and demographic status with ease of reaching these market segments.

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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 found.****.*

3.5 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 4 offers 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.

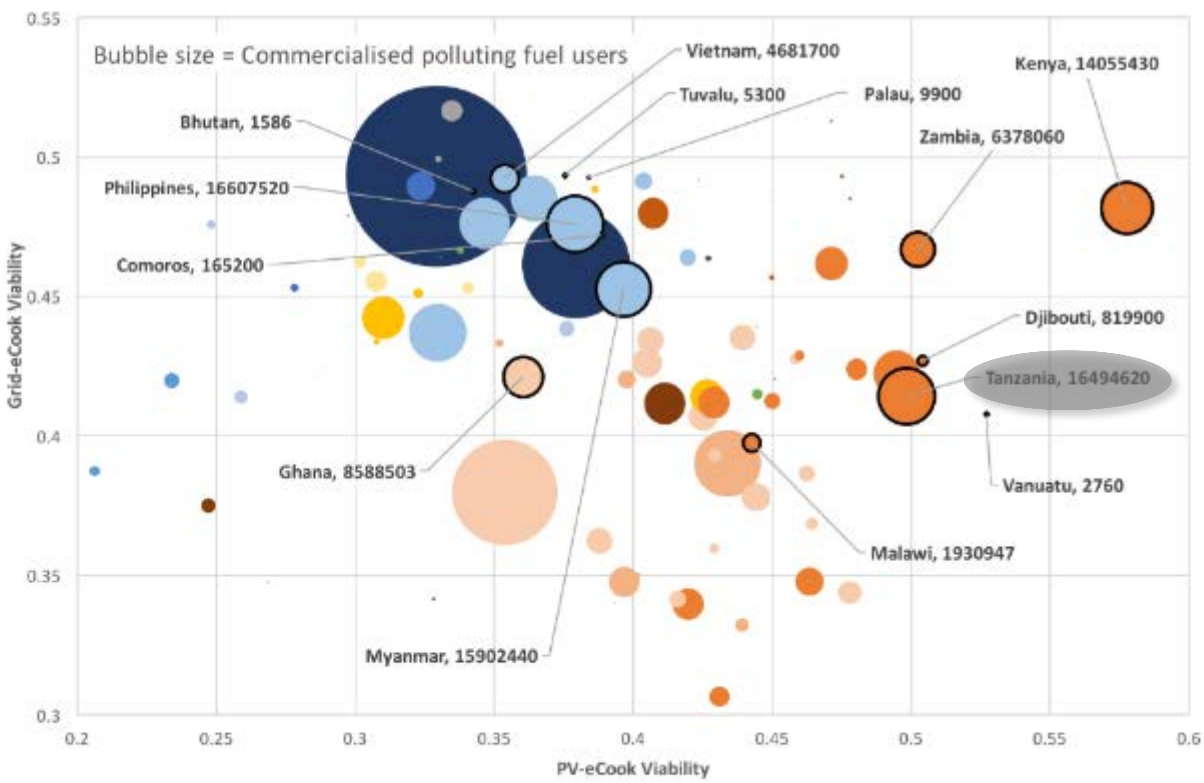

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Figure 4 Size of commercialized polluting fuel (kerosene, charcoal, coal) users market segments and ease of reaching them with Grid-eCook or PV-eCook solutions.

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.

3.6 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 5). However, Prof. Jumanne Maghembe, 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).

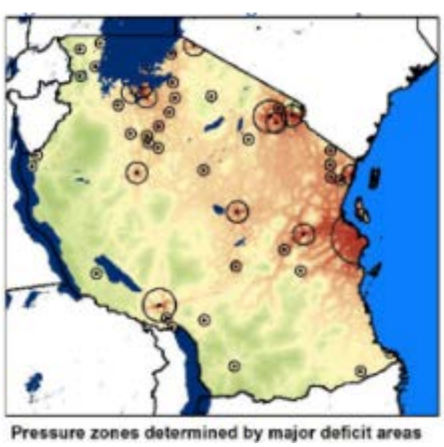

Figure 5 Pressure on Tanzanian woodsheds from the harvesting of wood fuels for HH energy in urban centres.

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,

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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.

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4 Aims, objectives & methodology

Given the technical and socio-economic feasibility of the systems in the near future, Gamos, Loughborough University and the University of Surrey have sought to identify where to focus initial marketing for eCook. Each country has unique market dynamics that must be understood in order to determine which market segments to target are and how best to reach them. Leary et al. (2018) carried out a global market assessment, which revealed Tanzania as the second most viable context for PV-eCook, due to its strong SHS industry and the fact that it is one of the world's biggest charcoal markets, creating several global deforestation hotspots.

The detailed findings from each of the activities carried under the eCook Tanzania Market Assessment are available from https://elstove.com/innovate-reports/ and www.MECS.org.uk.

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 rapidly take 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. Cooking as normal for the first 2 weeks, then transitioning to electric cooking for the next 4.
- 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 aspire to cook and the compatibility of these cooking practices with the strengths and weaknesses of eCooking.
- 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.
- National policy & markets – a review of national energy, environmental, health and gender policy and the state of the electrification and clean cooking sectors.

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- 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.

5 Key findings

The following section presents the key findings from the activities carried out in Tanzania. It draws together a broad range of activities from prototyping to stakeholder engagement designed to reveal the opportunities and challenges that await for the concept of battery-supported cooking.

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5.1 Cooking diaries

This section presents the key learning points from the cooking diaries study:

- ***Cooking with electricity is compatible with Tanzanian cuisine and that modern energy-efficient appliances are highly desirable to everyday Tanzanian cooks.***
- ***In particular, the Electric Pressure Cooker (EPC) is a prime candidate for future eCook products, as it can significantly reduce the energy demand for the biggest energy consumers: "long boiling" dishes.***
- ***In fact, in some areas of Dar es Salaam, the grid is already strong enough for direct AC cooking, meaning there is an opportunity already on the table to promote off-the-shelf appliances, in particular, EPCs.***
- ***However, battery-supported appliances are likely to make electric cooking much more attractive, as blackouts and brownouts frequently caused users to revert back to their baseline fuels.***
- ***LPG is already popular in Dar es Salaam and while electric hotplates do not offer anything new for LPG users, the ability to cook faster and multi-task, whilst also saving money make a fuel stacking scenario with EPCs extremely attractive.***

Detailed findings are available from https://elstove.com/innovate-reports/ & www.MECS.org.uk.

Figure 6: A cooking diaries participant in Dar es Salaam measuring electricity use by an EPC with a plug-in meter and gas use by weighing the LPG cylinder.

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

5.1.1 Overview of methodology

The aim of the cooking diaries study is to gain a deeper understanding of how Tanzanian households cook and how compatible this is with electricity. This mixed methods approach gathers data from various sources: cooking diary forms, energy measurements, a registration survey an exit survey.

Despite decades of work on improving the efficiencies of biomass stoves, there seems to be little available data on 'how' people cook. Modern fuels such as gas & electricity are more controllable & can be turned on/off in an instant. There are also a huge range of electric cooking appliances, each designed for specific processes (e.g. microwave for reheating). Therefore, it is important to know how often people are frying, boiling, reheating or doing something else entirely.

22 households (HHs) were asked to keep detailed cooking diaries, recording exactly what they cooked, when and how for six weeks. For the first two weeks they were asked to cook as they would normally, using their usual fuels and stoves. For the remaining four weeks, they were asked to transition to cooking with electricity, using a range of electric cooking appliances, including hotplates, rice cookers, Electric Pressure Cookers (EPCs), induction stoves, kettles and thermo-pots, plus any electrical appliances they already owned. Fuel quantities were measured by weighing charcoal, kerosene or LPG cylinders before and after each "*cooking event*"; plug-in electricity meters were used for the electric cooking appliances.

IN PARTICULAR, THE ELECTRIC PRESSURE COOKER (EPC) IS A PRIME CANDIDATE FOR FUTURE ECOOK PRODUCTS, AS IT CAN SIGNIFICANTLYREDUCE THE ENERGY DEMAND FOR THE BIGGEST ENERGY CONSUMERS: "LONG BOILING" DISHES.

The study samples were drawn from urban households in Dar es Salaam and therefore represent an evolved mix of traditional and modern cuisine. A database of foods cooked; cooking time and duration; and energy used was assembled. The probability distributions for the energy required to cook each meal type were produced, and disaggregated as far as possible to explore the influence of a variety of parameters, including fuel, appliance and meal type.

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

5.1.2 Key learning points

5.1.2.1 Appliance choice

Excluding blackouts, almost all meals were cooked on electricity during phase 2, which suggests that the electric appliances selected for the study were broadly compatible with Tanzanian cooking practices. Frying was less common in phase 2, presumably because gas in particular, offers much closer control of heat levels. It could also have been due to voltage dips, which would have reduced stove power output & slowed down frying considerably.

THE COOKING DIARIES SHOWED THAT COOKING WITH ELECTRICITY IS COMPATIBLE WITH TANZANIAN CUISINE & THAT MODERN ENERGY-EFFICIENT APPLIANCES ARE HIGHLY DESIRABLE TO EVERYDAY TANZANIAN COOKS.

There is a clearly an opportunity to promote the use of off-the-shelf AC efficient electric cooking appliances in Dar es Salaam & potentially other parts of Tanzania. In middle- and upper-income areas, blackouts are infrequent enough that batteries are not really necessary, especially for households who already cook with LPG and can quickly swap the food over if a blackout does strike at mealtime.

EPCs were preferred for dishes that require boiling, as pressure cooking can reduce the time of the boiling stage by half. However, as the data shows, they can also fry & are therefore often referred to as multicookers. This is in contrast to stove-top pressure cookers, which are almost exclusively used for boiling. Frying is done at a higher temperature than boiling and foods frequently dry out and burn if not stirred frequently. A shallow frying pan makes frequent stirring easier; however, the EPC can only operate with the deep sided pot it is supplied with.

LPG IS ALREADY POPULAR IN DAR ES SALAAM AND WHILE ELECTRIC HOTPLATES DO NOT OFFER ANYTHING NEW FOR LPG USERS, THE ABILITY TO COOK FASTER AND MULTI-TASK, WHILST ALSO SAVING MONEY MAKE A FUEL STACKING SCENARIO WITH EPCS EXTREMELY ATTRACTIVE.

5.1.2.2 Energy demand

As expected, water heating is a significant energy demand & should not be underestimated in the design of an eCooking system – or users are likely to be disappointed when the batteries end up flat halfway through a meal. Unlike cooking, which usually occurs at set mealtimes, water heating occurs throughout the day for a variety of purposes including bathing & purification, but mainly for tea/coffee.

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

One of the major challenges for eCook (especially PV-eCook) system designers will inevitably be coping with the variability in energy demand. LPG can easily cope with days of exceptionally high demand (e.g. cooking for visitors). In contrast, eCook systems will be limited to the size of the battery, which is the most expensive component, so will need to be sized very carefully.

IN SOME AREAS OF DAR ES SALAAM, THE GRID IS ALREADY STRONG ENOUGH FOR DIRECT AC COOKING, MEANING THERE IS AN OPPORTUNITY ALREADY ON THE TABLE TO PROMOTE OFF-THE-SHELF APPLIANCES, IN PARTICULAR, EPCS. HOWEVER, BATTERY-SUPPORTED APPLIANCES ARE LIKELY TO MAKE ELECTRIC COOKING MUCH MORE ATTRACTIVE, AS BLACKOUTS AND BROWNOUTS FREQUENTLY CAUSED USERS TO REVERT BACK TO THEIR BASELINE FUELS.

5.1.2.3 Load profiles

Dinners were found to be the most energy-intensive meal on the Tanzanian menu – bad news for utilities, as this coincides with peak demand for electricity. The average load profile in Figure 7 shows that cooking can occur from 3am until midnight, but is concentrated into morning, midday & evening peaks, with the latter the most significant. Unfortunately, this is also peak time for most utilities & mini-grids. Importantly for solar electric cooking, it is after the sun has set, however this may be earlier in a rural context, where daylight hours have more influence on daily routines.

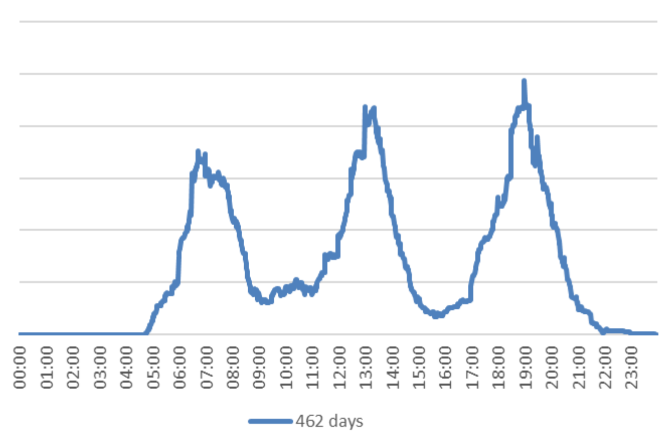

Figure 7: Average load profile for all complete days of data recorded during this study.

5.1.2.4 Fuel stacking

The motivations for transitioning to electricity are strong, however it seems likely that most participants will continue fuel stacking to some degree. Battery-supported appliances would directly address the strongest motivation to continue fuel stacking: blackouts. They are likely to be a key enabler for electric cooking, especially in poorer neighbourhoods, where blackouts are more frequent.

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

5.2 Choice modelling surveys

This section presents the key learning points from the Discrete Choice Modelling (DCM) study, which highlighted several opportunities and challenges for future eCook product/service designers:

- ***Blackouts and brownouts (voltage dips) seem to be infrequent enough that direct AC electric cooking could be possible for many people.***
- ***However, electricity is barely used for cooking in Tanzania today, with charcoal and LPG dominating the cooking landscape in urban areas. In rural areas, wood and charcoal dominate.***
- ***Electricity is perceived as expensive for cooking – given the low prices of cooking fuels, this is not surprising.***
- ***However, the evidence from the cooking diaries shows that cooking with energy-efficient electric cooking appliances is significantly cheaper, indicating that changing this perception will be key to unlocking eCook's potential in Tanzania.***
- ***In particular, Electric Pressure Cookers (EPCs) seem well matched with Tanzanian consumer preferences, as they can boil & fry, with the boiling part roughly twice as fast as conventional pots.***

Detailed findings are available from https://elstove.com/innovate-reports/ & www.MECS.org.uk.

Figure 8: Enumerators training for the choice modelling survey in Dar es Salaam.

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

5.2.1 Overview of methodology

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

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 overstated 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.

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

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

5.2.2 Key learning points

5.2.2.1 Overview of sample

The sample was heavily weighted towards urban participants from Dar es Salaam, but around ¼ were from a single rural town, Kibindu. The sample was female biased, but this is not surprising, as there was no cash incentive offered & the focus on cooking likely attracted more female respondents. The mean household size was found to be 4.9 (including children). 43% of the sample were deprived in at least one of the indicators relating to education, home construction materials & source of drinking water.

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5.2.2.2 Quality of grid electricity

Roughly ¾ of respondents were connected to the national grid, whilst 1/8 were without access to electricity. 1/16 were connected to TaTEDO's solar/biomass hybrid mini-grid in Kibindu.

BLACKOUTS AND BROWNOUTS (VOLTAGE DIPS) SEEM TO BE INFREQUENT ENOUGH THAT DIRECT AC ELECTRIC COOKING COULD BE POSSIBLE FOR MANY PEOPLE.

Blackout patterns were different during load shedding and at other times. 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

Nearly 80% of grid-connected respondents reported that the voltage is always high enough for cooking with electricity, however as only 5% of respondents actually cook with electricity, it is unclear whether this assessment is from practical experience or speculative.

Participants report that load shedding is most frequent from December to May, however, it is unclear why this is.

5.2.2.3 Metering

All households with formal connections to the national grid have pre-paid meters. This creates a much more direct link between expenditures & cooking practices, meaning that people are much more likely to be aware of the difference in cost between efficient & inefficient appliances.

However, half the sample (54%) share a meter. This is problematic because these are likely to be the poorest consumers, but by aggregating their bills, they only receive a single lifeline tariff allowance. What is more, it is much more difficult for them to see the cost difference for cooking with energy-efficient appliances. The evidence from the focus groups shows that some landlords/ladies simply prohibit their tenants from cooking with electricity on the presumption that it is too expensive.

It is possible to top up your electricity meter with just enough units to cook a single meal, i.e. in the same way that many people pay for charcoal. However, nobody reported actually doing this. Most respondents (92%) reported topping up their electricity meter every 2-4 weeks. This means there is likely to be a disconnect between what people spend on electricity & their cooking practices, as changing the way you cook won't have an effect on how much you are spending for several weeks.

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5.2.2.4 Cultural cooking patterns

3 meals per day is the most common cooking pattern, with 55% of respondents always cooking 3 & 90% sometimes doing so. 77% always cook at least 2. Breakfast is typically prepared from 7:30, lunch at 12:30 & dinner at 19:15. Respondents spend an average of 3.3 hours/day cooking.

Coastal Tanzania's hot climate means that only 23% of participants heat water for bathing, however 54% heat it to purify it & 99% heat it for tea/coffee.

5.2.2.5 Gender

Unsurprisingly, participants reported that women are usually responsible for cooking (72%), however, in 3% of households, men do the majority of cooking & in 25% it is a shared responsibility, indicating that marketing ecook products & services to men is also important. In fact, the evidence from the focus groups suggests that appliances such as electric pressure cookers (EPCs) can make cooking much easier, which may encourage more men to cook.

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

5.2.2.6 Fuel stacking

Most households used multiple fuels for cooking (58%). Charcoal was the most common cooking fuel (70%), followed by LPG (50%) & wood (25%). Electricity (6%)& kerosene (16%) were used by some households as backup fuels.

ELECTRICITY IS BARELY USED FOR COOKING IN TANZANIA TODAY, WITH CHARCOAL AND LPG DOMINATING THE COOKING LANDSCAPE IN URBAN AREAS.IN RURAL AREAS, WOOD AND CHARCOAL DOMINATE.

Of the 94% of respondents who did not use electricity for cooking, only 36% had some prior experience of cooking with electricity.

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

Basic biomass stoves & LPG stoves are the most popular cooking devices amongst participants. Very few people own improved biomass stoves. Electric cooking appliances are also not common, however 5% of

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respondents own a rice cooker. Rice is a major staple in coastal Tanzania & cooking rice in a rice cooker is much easier. Importantly though, it is also very energy-efficient, creating a key opportunity for battery-supported cooking.

Two thirds of the sample (65%) reported using multiple cooking devices, with some households reporting owning up to 7 different cooking devices!

Charcoal is the dominant energy source in urban areas, whilst in rural areas it is split between charcoal & wood. However, this masks the fact that far more biomass fuel is needed to deliver the cooking service, as much of it is wasted during the cooking process.

ELECTRICITY IS PERCEIVED AS EXPENSIVE FOR COOKING – GIVEN THE LOW PRICES OF COOKING FUELS, THIS IS NOT SURPRISING. HOWEVER, THE EVIDENCE FROM THE COOKING DIARIES SHOWS THAT COOKING WITH ENERGY-EFFICIENT ELECTRIC COOKING APPLIANCES IS SIGNIFICANTLY CHEAPER, INDICATING THAT CHANGING THIS PERCEPTION WILL BE KEY TO UNLOCKING ECOOK'S POTENTIAL IN TANZANIA.

LPG was widely considered to be the safest fuel.

Charcoal is regarded as convenient whereas firewood was not. 80% of respondents thought that wood it is a burden to collect.

5.2.2.7 Existing expenditures

Monthly mean expenditures on fuels among respondents who used them for cooking were:

- Electricity (cooking & other applications): 22,000 TZS (10 USD)
- LPG: 15,000 TZS (6.5 USD)
- Kerosene: 9,400 TZS (4 USD)
- Charcoal: 24,000 TZS (10.5 USD)
- Wood: 12,000 TZS (5 USD)

These expenditures seem low compared to expected ecook discounted costs. However, they should be treated with caution, as LPG & charcoal are more commonly used as primary cooking fuels, whilst kerosene & electricity are most commonly used as backup. Fuels, in particular electricity, are also used for other applications in addition to cooking.

Unit costs for each fuel were:

- LPG: 3,250 TZS/kg (1.42 USD/kg)
- Kerosene: 2,000 TZS/litre (0.87 USD/litre)
- Charcoal:
  - Urban: 686 TZS/kg (0.3 USD/kg)
  - Rural: 282 TZS/kg (0.12 USD/kg)
- Wood (when purchased): 100 TZS/kg (0.04 USD/kg)

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There is a generally trend for some electricity & gas users plus some charcoal & wood users to purchase enough for 2-4 weeks however, 20% of charcoal users, likely the poorest, buy just enough for a few days.

5.2.2.8 Health

Respondents agreed that smoke is harmful to health with wood smoke being more harmful than charcoal. Charcoal users believe that the smoke from a charcoal fire is safe compared to LPG and wood users. The same is true for wood users about wood smoke. Wood users also felt the strongest about smoke being good for chasing insects away.

5.2.2.9 Business models

The majority of participants (82%) felt positively about renting equipment & using a cooker provided by the utility (80%), which will likely result in the lowest monthly cost, as this model has the longest repayment horizon.

Mobile money is likely to be a key enabler for eCook, as it can make collecting small, but regular repayments much easier. The mobile money industry is accelerating rapidly in Tanzania, with over 80% respondents using it, however most of whom do so infrequently (1-2 times a month). Almost all respondents owned mobile phones, indicating high levels of technical proficiency & possibly a greater willingness to adopt new innovations. Half of respondents regularly use the internet & social media platforms, indicating that social media marketing strategies could be employed for ecook products/services, but would likely need to be complimented by other means.

IN PARTICULAR, ELECTRIC PRESSURE COOKERS (EPCS) SEEM WELL MATCHED WITH TANZANIAN CONSUMER PREFERENCES, AS THEY CAN BOIL & FRY, WITH THE BOILING PART ROUGHLY TWICE AS FAST AS CONVENTIONAL POTS.

Almost all indicated a preference for paying for high value items in instalments. The majority (62%) indicated that quarterly repayments were preferable to monthly, or weekly. However, this may be a stretch for the 20% of charcoal users who buy fuel every few days.

5.2.2.10 Discrete choice modelling results

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

- Taste – there was a clear preference for a device that does not make food taste smoky.
- Power – people preferred a device that would boil fast (compared to slow), but there was no preference for a medium powered device that would boil a bit more rapidly than a slow device.
- Cooking – prefer to be able to both boil and fry

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- Cost – preference for low cost device.

Electric Pressure Cookers (EPCs) seem well matched with Tanzanian consumer preferences, as they can boil & fry, with the boiling part roughly twice as fast as conventional pots.

The most important stove features are:

- Smoke – people would prefer a device that avoids generating any kind of smoke especially wood smoke.
- Capacity – people want to be able to cook for larger numbers of people (8 people).
- Low cost.

People's strongest preference is for a device that avoids the kind of smoke generated by a wood fire. Wood smoke is much thicker than charcoal smoke throughout the entire duration of cooking. However, charcoal smoke contains much higher levels of the silent killer: carbon monoxide.

The only functionality features with significant preference were:

- Ability to cook on both sunny & rainy days.
- Low cost.

Women were found to value a lid for the pot, the ability to fry as well as boil, having 2 hobs instead of 1 & avoiding the smoke from wood fires more than men. This could well be because as principal cooks in most households, they are more in touch with the practicalities of cooking, rather than simply being a consumer of the finished product, tasty food.

Traditional cooking practices such as cooking without a lid, using a single cooking device & preferring a smoky flavour are reflected in choices made by rural respondents.

Respondents classified as more technically proficient were less likely to choose options with smoky flavour and more likely to choose devices that could both boil & fry.

Respondents classified as deprived, older people & rural people all expressed greater preference for smoky flavour.

Rural households, firewood users & respondents classified as deprived all prioritised lower cost options significantly more than others. They were also more willing to tolerate the smoke from wood fires, clearly showing that they are willing to sacrifice their health to stay within their means.

People who used LPG were more willing to accept a device that could do only part of their cooking, which is consistent with their current fuel stacking practices.

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5.3 Techno-economic modelling

This section presents the key learning points from the techno-economic modelling:

- ***Even in contexts, where the cost of electricity is high, yet biomass fuels are available at a very low cost, there are opportunities for eCooking.***
- ***By combining the most efficient appliance, the EPC, with the most energy-efficient practices to create an ultra-efficient eCooking solution targeted at the foods that are most energy-intensive foods: 'heavy foods'.***
- ***This is likely to be the first step for eCooking in the most adversarial contexts.***

Detailed findings are available from https://elstove.com/innovate-reports/ & www.MECS.org.uk.

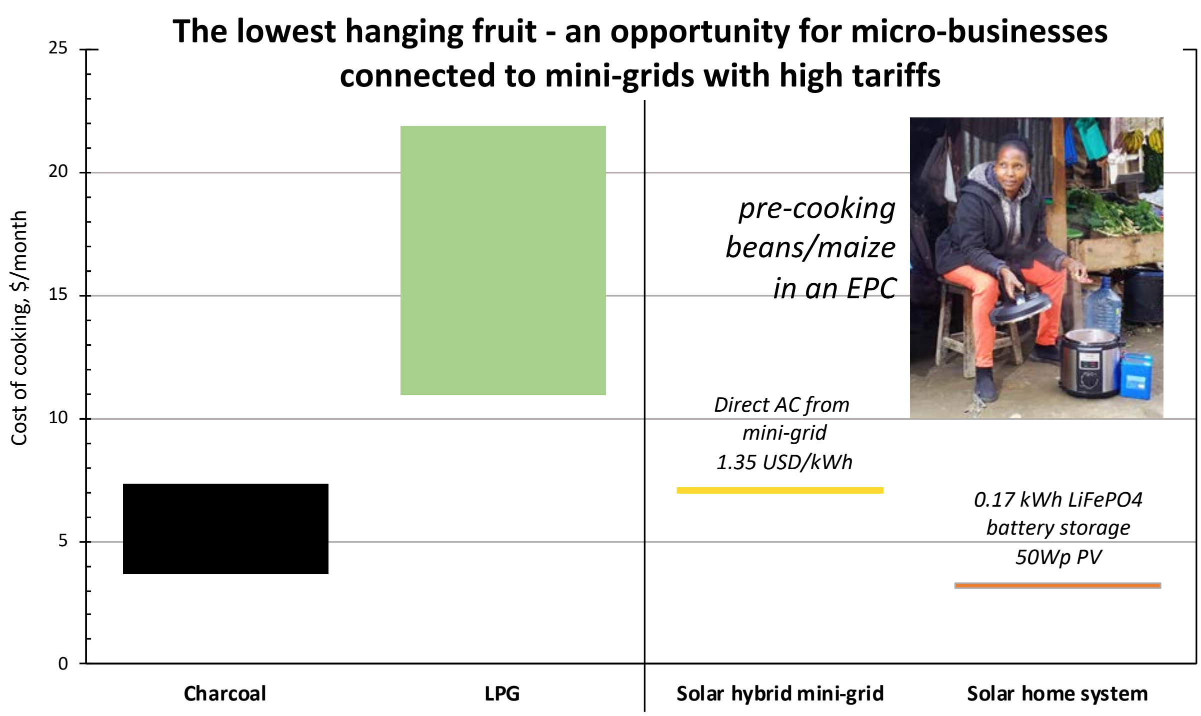

Figure 9: Selected modelling results for solar-biomass hybrid mini-grid Kibindu, Tanzania, with 5-year financing horizon for direct AC and 20 year for solar battery-supported DC systems.

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

5.3.1 Overview of methodology

The daily energy demand figures from the cooking diaries were used as inputs to a techno-economic model to explore the potential viability of a range of eCooking solutions in a range of different contexts. Three fuel/appliance stacking scenarios were modelled in each context:

1. 100% electric cooking, stacking inefficient and efficient electric cooking appliances;
2. 50% electric cooking with efficient appliances, stacking with baseline fuels for the remaining 50%; and
3. EPCs for boiling heavy foods only.

The modelling explores off-the-shelf Alternating Current (AC) eCooking appliances for strong grids and battery-supported Direct Current (DC) or hybrid appliances that can run on both direct AC and battery-supported DC for weak grids and off-grid solutions. In remote off-grid regions, it focusses on solar powered battery-supported eCooking. The analysis looks at the costs for eCooking expected in the near term, 2020, and with projections to 2025. The 2025 analysis accounts for important trends: (a) reducing costs for eCooking through technical and organisational learning; and (b) the assumption of increasing charcoal, LPG, firewood and kerosene prices. Both utility and lease-to-own business models are modelled with 20- and 5-year repayment horizons respectively, and costs are compared to those for a household cooking with traditional fuels.

5.3.2 Key learning points

TaTEDO's solar/biomass hybrid mini-grid in Kibindu was modelled using Leach and Oduro's (2015) techno-economic model. This case study illustrated the lowest hanging fruit, that is likely to be the first step for eCooking in the most adversarial contexts, where the cost of electricity is high, yet biomass fuels are available at a very low cost (Figure 9). It focusses in on the most efficient appliance, the EPC, and combines it with the most energy-efficient practices to create an ultra-efficient eCooking solution targeted at the foods that are most energy-intensive foods: 'heavy foods'. The case study results show that for a micro-business pre-cooking 500g beans per day, an EPC is already cost comparable with charcoal, despite the extremely high tariff of 1.35 USD/kWh. LPG is by far the most expensive option. However, the mini-grid tariff is so high that the most cost-effective solution would in fact be to create a standalone solar eCooking system sized for a single load in the EPC each day. This is already cost effective in 2020 under a private sector lease to own business model with a 5-year repayment horizon.

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

5.4 Focus group discussions

This section summarises the findings from four Focus Group Discussions (FGDs) held in Tanzania:

- ***LPG is currently the aspirational fuel for most households in Tanzania, but cooking with electricity is an attractive proposition, especially since automated energy-efficient appliances such as the EPC can make cooking much easier.***
- ***The use of LPG for 'light' or soft foods, suggests that eCook's ability to cook 'heavy' foods (e.g. long boiling of beans) with a multicooker could be a strong selling point***
- ***Access, affordability (or perception of affordability) and reliability are the main barriers holding back wider adoption of electric cooking, however safety is also a concern.***
- ***Unsurprisingly, it is mostly women do the cooking, however things are changing and eCook could catalyse this process.***
- ***Households previously relying solely on firewood now using significant amounts of commercialised fuels, notably charcoal and LPG.***

Detailed findings are available from https://elstove.com/innovate-reports/ & www.MECS.org.uk.

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

5.4.1 Overview of methodology

Everyday cooks from rural, urban and peri-urban contexts were asked about their current cooking practices and how they aspire to cook in the future. The participatory sessions involved a live cooking demonstration of popular local foods with a prototype eCook device.

Figure 10: A cooking diaries participant explaining to other focus group participants in Ubungo how easy it is to cook one of Tanzania's major staples, ugali, in a rice cooker.

5.4.2 Key learning points

The evidence from these FGDs suggests that **LPG is currently the aspirational fuel** for most households in Tanzania, but cooking with electricity is an attractive proposition, especially since automated energy-efficient appliances such as the EPC can make cooking much easier. It confirms that **access, affordability (or perception of affordability) and reliability** are the **main barriers** holding back wider adoption of electric cooking, however safety is also a concern.

LPG IS CURRENTLY THE ASPIRATIONAL FUEL IN TANZANIA, BUT COOKING WITH ELECTRICITY IS AN ATTRACTIVE PROPOSITION, ESPECIALLY SINCE AUTOMATED ENERGY-EFFICIENT APPLIANCES SUCH AS THE EPC CAN MAKE COOKING MUCH EASIER.

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

Unsurprisingly the focus groups confirmed that **it is mostly women do the cooking, however things are changing and eCook could catalyse this process**. Rarely do men cook even when there are home due to culture and norms. One group reported that in older times, it was actually a taboo for men to cook, it was seen as witchcraft. Some men might have liked to cook but social norms didn't allow. However, in this generation, some men do help their women in the households. 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'.

UNSURPRISINGLY, IT IS MOSTLY WOMEN DO THE COOKING, HOWEVER THINGS ARE CHANGING AND ECOOK COULD CATALYSE THIS PROCESS.

There is evidence of cooking practices changing, with **households previously relying solely on firewood now using significant amounts of charcoal and LPG**, especially in urban areas. Participants in peri-urban Moshi are reportedly spending 1 USD/day on firewood, i.e. 30 USD/month if they buy every day! In urban Ubungo, those that use firewood spend less, approximately 0.45 USD/day, however this still works out at 13.5 USD/month! In contrast, where it is available, participants are spending roughly 9 USD/month on LPG.

HOUSEHOLDS PREVIOUSLY RELYING SOLELY ON FIREWOOD NOW USING SIGNIFICANT AMOUNTS OF COMMERCIALISED FUELS, NOTABLY CHARCOAL AND LPG.

The use of LPG for 'light' or soft foods, suggests that eCook's ability to cook 'heavy' foods (e.g. long boiling of beans) with a multicooker could be a strong selling point in its comparison with its main modern energy rival LPG. 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. The Moshi participants saw eCook, in particular the EPC, as particularly attractive, as it would allow them to cook makande to be cooked every day.

THE USE OF LPG FOR 'LIGHT' OR SOFT FOODS, SUGGESTS THAT ECOOK'S ABILITY TO COOK 'HEAVY' FOODS (E.G. LONG BOILING OF BEANS) WITH A MULTICOOKER COULD BE A STRONG SELLING POINT

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

Figure 11: Demonstrating how easy it is to cook 'heavy foods' such as beans in the EPC at Kifuru village.

There is a general perception that electricity is too expensive and too unreliable for cooking, with the few participants that had tried cooking with electricity dismissing it as a viable option for their household. It will be important that eCook is affordable and reliable in its early roll out, otherwise it may reinforce these notions. Willingness to pay to use a system like the one demonstrated during the session ranged from $2 USD/month (far too low) to $20 USD/month (which our modelling indicates is easily achievable as a discounted monthly payment on a battery-supported system).

ACCESS, AFFORDABILITY (OR PERCEPTION OF AFFORDABILITY) AND RELIABILITY ARE THE MAIN BARRIERS HOLDING BACK WIDER ADOPTION OF ELECTRIC COOKING, HOWEVER SAFETY IS ALSO A CONCERNG.

Whilst the hotplate received quite negative feedback in the cooking demonstrations, the EPC, rice cooker and thermo-pot were much more attractive to participants. 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 energy-efficient appliances were particularly attractive because they would make cooking easier and release time for other activities. The ability to automatically control heat on modern electric cooking appliances is likely to make cooking easier, which may well lead to more sharing of the cooking within the household. All groups felt they would be able to 'multitask' and focus on 'more important things'.

All of the dishes described by participants can be cooked in an EPC or rice cooker, as the main cooking process is boiling, sometimes with a bit of shallow frying. Pressure cooking would save more on some

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dishes than others. Recipes with long boiling sections, where all ingredients are added at beginning have the highest energy saving potential. Frying & depressurising to add ingredients one by one throughout cooking process is easy enough to do on an EPC but will increase energy demand significantly. The clay pot was considered useful, as it retained heat, so kept cooking after the fire went out. Some participants put charcoal on top of the lid when cooking pilau, as it heats the food from above and below. The insulation on a rice cooker and EPC perform similar functions, ensuring even cooking & energy-efficiency.

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5.5 Gender

This section summarises the findings from a gendered analysis of eCook in Tanzania:

- ***eCook can make cooking quicker and easier - pressing a button is much quicker than lighting & tending fires and efficient appliances such as the electric pressure cooker can cut cooking times in half.***
- ***If cooking is easier, men may be willing to take on more responsibility in the kitchen.***
- ***cooking is a productive activity that is often overlooked in energy access program.***
- ***future marketing campaigns should target both genders, as the decision to purchase is likely to be made together in most Tanzanian household.***
- ***Changing the perception of pressure cookers from dangerous to safe and the perception of electricity as too expensive for cooking are likely to be key enablers for eCook.***
- ***Peer-to-peer female led business models (e.g. Avon cosmetics or Solar Sister) are particularly promising, as watching someone you are familiar with cook the dishes you know, asking them questions and trying it out yourself is likely to help many to overcome the reservations they may have about this new technology.***

Detailed findings are available from https://elstove.com/innovate-reports/ & www.MECS.org.uk.

Figure 12: Taking notes during the Ubungo Focus Group Discussion, where the role of men in the kitchen was brought to the forefront.

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5.5.1 Overview of methodology

This section presents a **gendered analysis of how the eCook concept might fit into the Tanzanian context**, drawing upon data obtained from the other activities, in particular the focus groups and cooking diaries. Clancy et al. (2012) categorised the potential gendered effects of modern and efficient energy solutions into time saving and drudgery reduction; income generation; resistance to change and transformation of gender roles. In this study, Clancy et al.'s (2012) categories are used as a framework to consider the potential gendered impacts, barriers and drivers of the eCook concept.

ECOOK CAN MAKE COOKING QUICKER AND EASIER - PRESSING A BUTTON IS MUCH QUICKER THAN LIGHTING & TENDING FIRES AND EFFICIENT APPLIANCES SUCH AS THE ELECTRIC PRESSURE COOKER CAN CUT COOKING TIMES IN HALF.

5.5.2 Key learning points

Time saving & drudgery reduction - eCook can make cooking **quicker and easier**. The people who could save most time and effort are those who collect fuelwood. Whilst they could benefit from adopting eCook products/services, they are not eCook's initial target market because they have no existing expenditure to repay the capital costs of the equipment. However, transporting bulky fuels such as a sack of charcoal and even an LPG cylinder from the point of sale to the kitchen is still an arduous task that reoccurs monthly and could be substituted with carrying a new set of batteries once every six years. What is more, **pressing a button is much quicker than lighting & tending fires** and efficient appliances such as **the electric pressure cooker can cut cooking times in half**.

IF COOKING IS EASIER, MEN MAY BE WILLING TO TAKE ON MORE RESPONSIBILITY IN THE KITCHEN

Income generation - cooking is a productive activity that is often overlooked in energy access programs. There is a clear opportunity to apply the time saved to create new livelihoods for women who adopt eCook systems by cooking more food for sale. Of course, there is also the potential to enhance the existing livelihoods of street vendors, restaurants and shops selling cooked food.

Resistance to change - the evidence from the choice modelling surveys suggests that **future marketing campaigns should target both genders**, as **the decision to purchase is likely to be made together in most Tanzanian households**. eCook is likely to be an aspirational product/service for both men and women, as not only can it transform the kitchen, but on most days,

COOKING IS A PRODUCTIVE ACTIVITY THAT IS OFTEN OVERLOOKED IN ENERGY ACCESS PROGRAM

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the energy left in the battery can also enable access to TV, lights, radio, mobile phone charging and other low power energy services. **Changing the perception of pressure cookers from dangerous to safe** and the p**erception of electricity as too expensive for cooking** are likely to be key enablers for eCook.

FUTURE MARKETING CAMPAIGNS SHOULD TARGET BOTH GENDERS, AS THE DECISION TO PURCHASE IS LIKELY TO BE MADE TOGETHER IN MOST TANZANIAN HOUSEHOLD

Transformation of gender roles - eCook will make cooking quicker and easier, which may be the trigger for a slight gender shift in responsibilities, as **men may be willing to take on more responsibility in the kitchen**.

A case study of female-led social enterprise in the energy access sector was undertaken to understand how gendered business models could accelerate the uptake of future eCook products/services:

5.5.2.1 Solar Sister case study: key findings

Solar Sister uses an Avon-style product distribution model as an innovative method of spreading solar technology. The Avon business model works by recruiting sales representative who bring their own social networks. Solar Sister recruits, trains and mentors the sales reps, who are expected to invest their own capital to buy the products and then resell them, firstly to family members and friends, then as their circle expands, to friends of friends and finally their community at large. Whilst this could work for efficient electric cooking appliances without batteries, such as electric pressure cookers, the business model will clearly need to be adapted to focus on finding new subscribers for eCook services, as eCook products themselves are likely to cost several hundreds of dollars.

CHANGING THE PERCEPTION OF PRESSURE COOKERS FROM DANGEROUS TO SAFE AND THE PERCEPTION OF ELECTRICITY AS TOO EXPENSIVE FOR COOKING ARE LIKELY TO BE KEY ENABLERS FOR ECOOK

The Avon-style business model relies on word of mouth and capitalises on the fact that trust and familiarity between the sales rep and the consumers (family, friends and acquaintances) is more persuasive than conventional sales methods that rely on selling to strangers. In fact, this business model is already employed to market improved biomass & biofuel cookstoves. The aspirational nature of eCook is likely to provide a strong driver to attract new users. By watching someone you are familiar with cook the dishes you know, asking them questions and trying it out yourself is likely to help many to overcome the reservations they may have about this new technology. Another advantage of the Avon-style business model is that the sales agents can also offer after-sales services, supplying specialist parts such as sealing

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rings for pressure cookers and offering friendly advice on how to make the tastiest meals with this new equipment.

Successfully leveraging existing social media communities could greatly expand the scalability of the Avon business model as a marketing strategy for eCook. Cooking-themed Facebook groups in East Africa with over 1 million users and local food bloggers regularly receive hundreds of thousands of hits on their video recipes on YouTube.

PEER-TO-PEER FEMALE LED BUSINESS MODELS (E.G. AVON COSMETICS OR SOLAR SISTER) ARE PARTICULARLY PROMISING, AS WATCHING SOMEONE YOU ARE FAMILIAR WITH COOK THE DISHES YOU KNOW, ASKING THEM QUESTIONS AND TRYING IT OUT YOURSELF IS LIKELY TO HELP MANY TO OVERCOME THE RESERVATIONS THEY MAY HAVE ABOUT THIS NEW TECHNOLOGY

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

5.6 Prototyping

This section summarises the findings from the eCook prototyping in Tanzania:

- ***In 2018, many of the basic components required to build a cost-effective and technically optimised eCook system were still not available.***
- ***Establishing a supply chain for larger scale (>10Ah) lithium ion batteries in East Africa will be key to achieving affordability***
- ***The development of DC cooking appliances is another important next step***
- ***Future prototypes should aim to incorporate similar state of charge indicators to mobile phones or laptop.***
- ***There is a need to expand the functionality of off-the-shelf insulated appliances to increase the proportion of cooking that can be done on a single insulated appliance***
- ***Voltage has a massive impact on power and therefore heat delivered by a cooking appliance, however batteries can stabilise the voltage to give consistent performance or vary the voltage to offer the user control.***

Detailed findings are available from https://elstove.com/innovate-reports/ & www.MECS.org.uk.

Figure 13: The eCook TZ Mark 1 Prototype at a workshop for a select parliamentary committee on energy in Dodoma.

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5.6.1 Overview

The eCook Tanzania Mark 1 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.

The eCook Tanzania prototype has been (and continues to be) very successful in **demonstrating the concept of battery-supported cooking to a broad range of stakeholders**, from future potential users to policy makers. Future demonstration prototypes should also have 2 modes: one that allows more technical people to see inside and another that shuts away the gubbins and allows the user to get on with cooking.

IN 2018, MANY OF THE BASIC COMPONENTS REQUIRED TO BUILD A COST-EFFECTIVE AND TECHNICALLY OPTIMISED ECOOK SYSTEM WERE STILL NOT AVAILABLE.

- ESTABLISHING A SUPPLY CHAIN FOR LARGER SCALE (>10AH) LITHIUM ION BATTERIES IN EAST AFRICA WILL BE KEY TO ACHIEVING AFFORDABILITY
- THE DEVELOPMENT OF DC COOKING APPLIANCES IS ANOTHER IMPORTANT NEXT STEP

5.6.2 Key learning points

The prototyping carried out in Tanzania showed that in 2018, **many of the basic components required to build a cost-effective and technically optimised eCook system were still not available**. In particular, higher capacity lithium ion batteries and DC cooking appliances were very specialised pieces of equipment that required direct importation. The total cost for all the components came in at 1,480 USD, however there is significant scope for optimisation. As a result, a **total cost of 500USD for a mass-produced unit in 2020 seems feasible**.

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. 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, however the risks in terms of both safety and battery lifetime are not currently clear.

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Future prototypes should use a single LiFePO4 battery pack with a BMS (Battery Management System) designed for C-rates of up to 2C. For safety reasons, LiFePO4 battery packs have a BMS built in to prevent over charging or over discharging. 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. The thin BMS cables supplied with the LiFePO4 batteries were a key weak point in the eCook TZ Mark 1 prototype, as they are designed for much lower currents. 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.

FUTURE PROTOTYPES SHOULD AIM TO INCORPORATE SIMILAR STATE OF CHARGE INDICATORS TO MOBILE PHONES OR LAPTOPS.

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. Clearly communicating to users how much energy is left in the battery is vital to reduce the frustration of the battery running out halfway through cooking. 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.

THERE IS A NEED TO EXPAND THE FUNCTIONALITY OF OFF-THE-SHELF INSULATED APPLIANCES TO INCREASE THE PROPORTION OF COOKING THAT CAN BE DONE ON A SINGLE INSULATED APPLIANCE.

The **development of DC cooking appliances** is another important next step. Inverters are expensive and bulky, adding another point of failure and making the whole system less efficient. They also limit the maximum power that can be drawn, therefore defining which appliances can be used and whether they can be used simultaneously or not. 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 other inefficiencies are and to optimise the system accordingly. Nonetheless, **a broad range of AC electric cooking appliances were available on the market** and insulated appliances were selected as they offer substantial energy savings, which can greatly reduce the size of the battery.

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Future prototypes should focus on expanding the functionality of off-the-shelf insulated appliances to **increase the proportion of cooking that can be done on a single insulated appliance**. For example, by allowing the user to manually control the heat level in a rice/pressure cooker. **Insulated appliances can offer significant energy saving** and keep food warm once it is ready **s**, however they are bulky and are usually only supplied with a single pot. **The rice cooker, Electric Pressure Cooker (EPC) & thermo-pot were selected** for the eCook Tanzania Mark 1 Prototype. **Pressurisation is also important** for reducing cooking times on long boiling dishes such as beans. However, space is likely to be limited in the kitchens of poorer households, if there even is a dedicated kitchen space at all.

VOLTAGE HAS A MASSIVE IMPACT ON POWER AND THEREFORE HEAT DELIVERED BY A COOKING APPLIANCE, HOWEVER BATTERIES CAN STABILISE THE VOLTAGE TO GIVE CONSISTENT PERFORMANCE OR VARY THE VOLTAGE TO OFFER THE USER CONTROL.

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 electric appliances on weak grids with fluctuating voltage will find the experience of cooking with 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.

This also creates an opportunity for an **alternative control mechanism**, as allowing the user to vary the voltage supplied to the appliance using, for example DC/DC converters, can enable another form of manual control

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5.7 Review of National Policy & Markets

This section summarises the findings from a review of national policy and markets in Tanzania:

- ***Policy support is already in place for key drivers behind eCook: environmental protection (deforestation and climate change), health (indoor air pollution), gender equity and energy access (electricity).***
- ***Tanzania has a world leading mini-grid sector.***
    - ***Mini-grids with spare capacity at peak times could begin to market off-the-shelf electric cooking appliances today.***
    - ***Hydropower is still the most cost-effective option, however solar mini-grids are opening up new opportunities.***
- ***The market for solar home systems is developing rapidly - in rural Tanzania, off-grid solar systems now outnumber grid connections.***
- ***Charcoal use in Tanzania is creating several global deforestation hotspots.***
- ***eCook offers TANESCO & mini-grid developers the opportunity to increase their revenue per connection and greatly enhance their development impact.***
- ***Smaller households with efficient appliances can already cook very cheaply using TANESCO's 75kWh/month lifeline tariff.***
- ***Tanzania is one of the world leaders in mobile money transfers.***

Detailed findings are available from https://elstove.com/innovate-reports/ & www.MECS.org.uk.

Figure 14: TaTEDO presenting the opportunity for eCook to a parliamentary select committee on energy in Dodoma.

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5.7.1 Overview of methodology

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. It is part of a broader programme of work, designed to identify and investigate the opportunities and challenges that await in high impact markets such as Tanzania. The study had two dimensions:

1. to review the **current regulatory framework** in Tanzania and assess which polices are likely to **accelerate the uptake** of the eCook concept and which may present **significant barriers**.
2. to assess the st**ate of the existing clean cooking and grid/mini-grid/off-grid electrification markets,** which may provide the foundation for future eCook products/services

5.7.2 Aligning the electrification and clean cooking sectors

This review has confirmed that there is a **strong market for eCook products and services in Tanzania**. Electrification and clean cooking are currently seen as two separate domains, however **eCook has the potential to unite the two**. To date, progress in electrification has been relatively rapid, whilst clean cooking has lagged behind. Tanzania has a **world leading mini-grid sector** and the **market for solar home systems is developing rapidly**. It is also one of the world's **biggest charcoal markets**, creating several global deforestation hotspots. eCook presents a transformative opportunity to leverage this encouraging progress to drive forward the equally important goal of ensuring universal access to clean cooking by 2030, in line with SDG 7.

ECOOK OFFERS TANESCO & MINI-GRID DEVELOPERS THE OPPORTUNITY TO INCREASE THEIR REVENUE PER CONNECTION & GREATLY ENHANCE THEIR DEVELOPMENT IMPACT

The potential impact of eCook cuts across various national development priorities – from gender equity to sustainable forestry. As in most countries, Tanzania presents a complex mix of institutions & responsibilities. Since eCook is not obviously an 'improved stove' in the biomass sense (it is also mechanism to increase access to reliable electricity) it is difficult to know which stakeholders to lobby & in which sequence. Whilst **TANESCO** is clearly the major stakeholder for Grid-eCook, and **REA's** mandate suggest they will be an important player in the off-grid space, however the SPPs (**Small Power Producers**) open up new opportunities in rural areas via Mini-Grid-eCook. The private sector is likely to drive ecook forward, as by 2020 it should be possible to create systems that are profitable to the developer, yet cheaper to the consumer than expenditures on charcoal or kerosene. In rural Tanzania, **off-grid solar systems now outnumber grid connections**, creating a huge opportunity for PV-eCook.

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5.7.3 Cooking with grid electricity

SMALLER HOUSEHOLDS WITH EFFICIENT APPLIANCES CAN ALREADY COOK VERY CHEAPLY USING TANESCO'S 75KWH/MONTH LIFELINE TARIFF

Frequent blackouts and voltage fluctuations on TANESCO grid suggest supporting electric cooking appliances with a battery would enable much more widespread adoption of electricity as a primary cooking fuel. Voltage instability can affect cooker performance as much as blackouts. Cooking with appliances designed for 220V is noticeably slower below 200v and impossible below 150v. TANESCO has a high dependence on hydropower, which is likely to lead to further load shedding in future dry seasons

In fact, the cooking diaries show that **smaller households with efficient appliances can cook using TANESCO's 75kwh/month lifeline tariff**. However, lobbying EWURA to increase lifeline tariff allowances or create a time of use tariff could be key enablers for larger households or those with shared meters. However, further tariff increases should be expected as despite rising 40% in 2012, TANESCO is still unable to cover its costs. Importantly though, **eCook offers TANESCO the opportunity to increase its revenue per connection** & reduce dependence on emergency generators through distributed storage. What is more, if all new connections included distributed household storage via Grid-eCook, the load profile would be much flatter and supporting infra-structure could be much smaller and cheaper.

TANZANIA HAS A WORLD LEADING MINI-GRID SECTOR

- MINI-GRIDS WITH SPARE CAPACITY AT PEAK TIMES COULD BEGIN TO MARKET OFF-THE-SHELF ELECTRIC COOKING APPLIANCES TODAY.
- HYDROPOWER IS STILL THE MOST COST-EFFECTIVE OPTION, HOWEVER SOLAR MINI-GRIDS ARE OPENING UP NEW OPPORTUNITIES

In fact, the 120USD that many Tanzanian households have already paid for a grid connection is likely to be more than enough for a deposit on a PV-eCook system. What is more, the techno-economic modelling shows that at 700USD, the investment cost of a PV-eCook system in 2020 is likely to be less than grid extension or mini-grids, which have to recover the majority of their costs through consumption charges.

5.7.4 The opportunity for cooking on mini-grids and solar home systems

Tanzania is a **global leader in mini-grid development,** presenting a diverse range of opportunities. Mini-grid-eCook should target **spare capacity at off-peak hours** on hydropower mini-grids or load limited solar mini-grids with battery-supported cooking appliances. In fact, mini-grids with spare capacity at peak times could begin to market **off-the-shelf electric cooking**

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appliances today. Time of use tariffs could incentivise off-peak cooking. Tariffs on private mini-grids are currently significantly higher than TANESCO's, but efficient appliances such as the electric pressure cooker are still likely to be cost effective. The **resources available in each part of the country vary significantly**, creating different opportunities for Mini-Grid-eCook. In wet and hilly topography, such as Kilimanjaro, Mbeya or Njombe, **hydropower is still the most cost-effective option**. Meanwhile, **solar mini-grids are opening up new opportunities** for renewable generation in regions without hydro or biomass resources.

THE MARKET FOR SOLAR HOME SYSTEMS IS DEVELOPING RAPIDLY - IN RURAL TANZANIA, OFF-GRID SOLAR SYSTEMS NOW OUTNUMBER GRID CONNECTIONS.

In communities where many households are already paying for cooking fuel, eCook could greatly **enhance the development impact of mini-grids**. Mini-grids in peri-urban areas are likely to be more attractive for Mini-Grid-eCook, as people are more likely to be paying for cooking fuel than in rural areas.

So**lar lighting in Tanzania is booming - in 2014 the industry was reportedly worth 9 million USD**. M-kopa, Zola & Mobisol seem to be the market leaders in Tanzania's solar home system market. Working with them to develop a cooking upgrade for their existing customers will be an obvious route to scale for PV-eCook.

Strong solar irradiation & a hot, but not extreme climate make the Tanzanian climate virtually ideal, as PV panels will produce more, batteries are unlikely to be damaged by extreme temperatures & stoves are not expected to perform the dual function of space heating, greatly reducing energy demand & therefore battery size/cost. PV-eCook systems at the foot of Kilimanjaro would need almost twice as much PV as in Dodoma. Fortunately, most of Tanzania is much less cloudy. However, **PV is no longer the major cost in off-grid solar systems**, it is battery storage, which would be equal in both cases. The solar resource is high & steady throughout the year in almost all of Tanzania, so PV-eCook systems can be cost-effectively designed for year-round use. Targeted **exchange programs for, in particular, female solar entrepreneurs in the clean cooking industry** could help prepare them for PV-eCook.

5.7.5 Clean cooking

The review revealed that **policy support is already in place for key drivers behind eCook**: **environmental protection** (deforestation and climate change), **health** (indoor air pollution), **gender equity** and **energy access** (electricity). The SEforAll GTF (Global Tracking Framework) currently measures **access to clean cooking solutions in Tanzania at just 2%.** A quantum leap will be required to meet the >75% target for

2030! However, no coordinated clean cooking strategy yet exists, leaving the future direction unclear. Biomass still dominates cooking and to date there have been few alternatives.

POLICY SUPPORT IS ALREADY IN PLACE FOR KEY DRIVERS BEHIND ECOOK: ENVIRONMENTAL PROTECTION (DEFORESTATION AND CLIMATE CHANGE), HEALTH (INDOOR AIR POLLUTION), GENDER EQUITY AND ENERGY ACCESS (ELECTRICITY).

Charcoal use in Dar es Salaam is causing a **global deforestation hotspot**. Current mitigation strategies focus on improving the efficiency of charcoal supply and reducing demand through more efficient biomass stoves and LPG. A Biomass Energy Strategy (BEST) has been developed, however, there is a growing awareness globally that the strategy of 'improved cookstoves' needs something new to break out of this 'business as usual' cycle. Charcoal is the fuel of choice for the rich and as Tanzania's economic hub, Dar es Salaam is the epicentre, with 88% of the population cooking with charcoal. **Dar residents spend an average of 50,000TZS (22USD) every month**, creating an attractive potential revenue stream for future Grid-eCook products.

Tanzania's population will double by 2050. Not only will this push up urban demand for charcoal, but unless firewood collection is well managed, rural people will have to walk further & further. Tanzania's rapid population growth is likely to accentuate the problem of deforestation even further, **pushing up the price of wood fuels** to even higher levels. This will only amplify the economic argument for ecook, as the existing expenditures on biomass fuels will be even greater & broader.

Although harmful, **charcoal does create livelihoods for many rural people**. There is a long-term view of local fabrication/assembly, however at least initially, eCook would substitute a local industry for imported technology & potentially change the foreign exchange balance by up to $1 billion dollars! Stove manufacture is an important industry in Tanzania. Whilst microwaves & induction stoves may require hi-tech production lines, **local manufacture of simple resistive insulated cooking devices** such as rice cookers, hotplates & electric pressure cookers should be possible in the medium-/long-term.

CHARCOAL USE IN TANZANIA IS CREATING SEVERAL GLOBAL DEFORESTATION HOTSPOTS.

LPG is displacing kerosene as the fossil fuel of choice in Tanzanian kitchens. Tanzania has recently started to produce gas in Mtwara & piped gas connections are being trialled in Dar es Salaam. However, it remains to be seen whether the costs of establishing the piped infrastructure plus maintenance & fuel costs can be competitive with bottled LPG.

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Electricity for cooking is declining in popularity in Tanzania, whilst charcoal is gaining – perception of affordability & lack of generating capacity have been major barriers. Lack of capacity may well change, however historically little has been done to challenge the perception of affordability, as it has ensured slow uptake in line with increases in generating capacity. This common assumption on the affordability of electric cooking is challenged by the findings from the cooking diaries. The behavioural change challenges should absolutely not be underestimated; however, neither should the drivers for sustained use – primarily convenience & cost savings. **Dispelling the myth that electric cooking is expensive** is likely to be much easier with prepaid meters, as customers will see how much they are spending much quicker.

5.7.6 Finance

TANZANIA IS ONE OF THE WORLD LEADERS IN MOBILE MONEY TRANSFERS

There are two domains of finance: suppliers need major capital to set up & expand their business., whilst households will also need finance to **repay the high upfront cost of the individual systems**. Both must be in place for ecook to succeed. High interest rates could be a significant problem for ecook. The discount rates in Leach and Oduro's (2015) 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 & finding the finance in the first place. Users may shy away from 4-5yr payback periods, as solar lighting typically works on 1yr. However, utility models address this - users never own equipment, instead **purchasing cooking services**.

Engaging with TBS & TAREA to ensure **quality eCook products & components can be imported without taxes & poor-quality items are kept** out will be key. 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. This may be one of the more important policy changes required to make Grid-eCook affordable.

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. The prevalence of mobile money systems in rural areas will be a key enabler for the innovative business models that PV-eCook will require. Creating awareness of PV-eCook amongst vikobas, SACCOs, trust funds & MFIs will be key to unlocking the financing that rural people will need. The lack of collateral is also likely to be an issue for peri-urban potential PV-eCook customers living in rented homes & with no agricultural assets.

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5.8 Stakeholder workshop

This section summarises the findings from a stakeholder workshop in Tanzania:

- **Key stakeholders from the electrification and clean cooking sectors confirmed that eCook has the potential to address several of Tanzania's interlinked development challenges, however coordinated action is required to overcome the key barriers highlighted during this study.**
- **Live cooking demonstrations with participants from the cooking diaries showed that energy-efficient electric cooking appliances were capable of cooking popular Tanzanian dishes. The food was judged to be just as delicious as at home, yet much easier to prepare and for a fraction of the cost.**

Detailed findings are available from https://elstove.com/innovate-reports/ & www.MECS.org.uk.

Figure 15: Attendees of the stakeholder workshop hosted by TaTEDO in Dar es Salaam.

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5.8.1 Overview of workshop

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. eCook is a potentially transformative household battery electric cooker that will soon be cost effective for households cooking on charcoal, LPG and kerosene. In addition, it offers a clean cooking solution; provide reliable and affordable electricity access.

The workshop gathered participants from various organisations, companies and agencies for energy both inside and outside the country including the Ministry of Energy, Ministry of Natural Resources and Tourism and TANESCO, Mobisol, Ensol, TaTEDO, Gamos, CEEEZ, DIT, UDSM and some of the eCook project respondents.

The workshop was conducted for two days; on the first day participants were acquainted with the eCook concept, while on the second day attendees get the hands-on experiments with eCook appliances. Attendees carried out hands on experiments with eCook appliances, whilst discussed 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.

eCook CONCEPT (Day One) involved various sessions which among others include;

- Introduction of the eCook and its potential contribution to Tanzania development objectives.
- eCook Tanzania research findings to date.
- eCook Zambia and Myanmar.
- Opportunity and challenges for the eCook Tanzania.

eCook IN PRACTICE (Day Two) included the following sessions:

- Design challenge Part I – Design & Assembly.
- Design challenge Part II – eCooking.
- Modelling eCook.

KEY STAKEHOLDERS FROM THE ELECTRIFICATION AND CLEAN COOKING SECTORS CONFIRMED THAT ECOOK HAS THE POTENTIAL TO ADDRESS SEVERAL TANZANIA'S INTERLINKED DEVELOPMENT CHALLENGES.

LIVE COOKING DEMONSTRATIONS WITH PARTICIPANTS FROM THE COOKING DIARIES SHOWED THAT ENERGY-EFFICIENT ELECTRIC COOKING APPLIANCES WERE CAPABLE OF COOKING POPULAR TANZANIAN DISHES. THE FOOD WAS JUDGED TO BE JUST AS DELICIOUS AS AT HOME, YET MUCH EASIER TO PREPARE & FOR A FRACTION OF THE COST.

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

- Design challenge Part III – Economics.
- Design challenge Part IV – Presentation & Prize-giving ceremony.

The workshop was concluded by the closing speech from representative of Ministry of Energy, Mr. Jacob Mayalla who expressed gratitude to workshop organizers (TaTEDO, Gamos, Loughborough University, The University of Surrey, DfID / UKAID and Innovate UK) for providing the opportunity to the Ministry of Energy to close the workshop.

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

6 Conclusion

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'. 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 Electric Pressure Cookers (EPCs) could be possible. Many households in urban areas already have access to grid electricity, which is reliable enough to cook with, given that the EPC mitigates this unreliability to a certain extend.

However, there are some reservations. Cost is a major factor, but (the lack of) reliability and availability were obviously at the forefront of many people's experience. Where the grid is available, Grid-eCook offers greater reliability and availability. Where it is not, reliable electricity can be made available anywhere with PV-eCook.

The price point may not yet have been reached for battery-supported eCooking, however the evidence from the cooking diaries shows that it is already cost effective to cook with off-the-shelf energy-efficient electric cooking appliances. The cost and challenges involved in building the demonstration prototype highlight the current situation – challenges in sourcing key components locally (higher capacity lithium ion batteries and DC cooking appliances) and a high cost for what is available (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 for lithium ion batteries in particular. If adequate supply chains are established, by 2020 eCook systems will be affordable in Tanzania.

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.

The detailed findings from each of the activities carried under the eCook Tanzania Market Assessment are available from https://elstove.com/innovate-reports/ and www.MECS.org.uk.

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

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8 Appendix

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

8.1.1 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

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households globally will gain access to, at least, minimally improved[1] 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'. IEG World Bank Group (2015) note that 22 countries in the Africa Region have less than 25 percent access, and of those, 7 have less than 10 percent access. Their tone is pessimistic in line with much of the recent literature on access to modern energy, albeit in contrast to the stated SDG7. They discuss how population growth is likely to outstrip new supplies and they argue that "unless there is a big break from recent trends the population without electricity access in Sub-Saharan Africa is projected to increase by 58 percent, from 591 million in 2010 to 935 million in 2030." They lament that about 40% of Sub-Saharan Africa's population is under 14 years old and conclude that if the current level of investment in access continues, yet another generation of children will be denied the benefits of modern service delivery facilitated by the provision of electricity (IEG World Bank Group, 2015).

[1] 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)

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> *"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.

8.1.2 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 16 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[2] (Batchelor, 2015b; Brown and Sumanik-Leary, 2015;

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

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Leach and Oduro, 2015; Slade, 2015). The commission arose from discussions between consortium members, DFID, and a number of other entities with an interest in technological options for cleaner cooking e.g. Shell Foundation and the Global Alliance for Clean Cookstoves.

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

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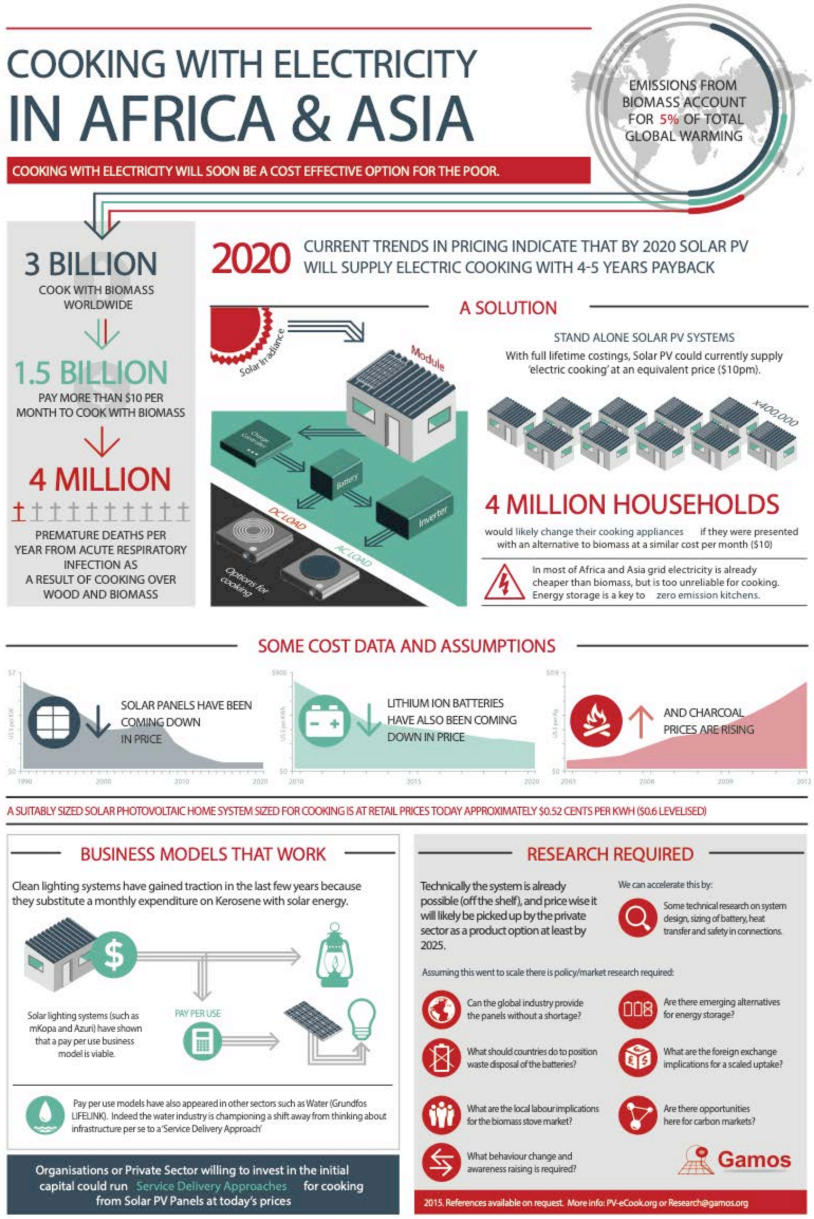

Figure 16 Infographic summarising the concept in order to lobby research and policy actors.

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

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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.

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8.1.3 Summary of related projects

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

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

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

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

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

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

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

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

Worldwide, nearly three billion people rely on traditional solid fuels (such as wood or coal) and technologies for cooking and heating[3]. This has severe implications for health, gender relations, economic livelihoods, environmental quality and global and local climates. According to the World Health Organization (WHO), household air pollution from cooking with traditional solid fuels causes to 3.8 million premature deaths every year – more than HIV, malaria and tuberculosis combined[4]. Women and children are disproportionally affected by health impacts and bear much of the burden of collecting firewood or other traditional fuels.

Greenhouse gas emissions from non-renewable wood fuels alone total a gigaton of CO_2e per year (1.9-2.3% of global emissions)[5]. The short-lived climate pollutant black carbon, which results from incomplete combustion, is estimated to contribute the equivalent of 25 to 50 percent of carbon dioxide warming

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

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

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

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globally – residential solid fuel burning accounts for up to 25 percent of global black carbon emissions[6]. Up to 34% of woodfuel harvested is unsustainable, contributing to climate change and local forest degradation. In addition, approximately 275 million people live in woodfuel depletion 'hotspots' – concentrated in South Asia and East Africa – where most demand is unsustainable[7].

Africa's cities are growing – another Nigeria will be added to the continent's total urban population by 2025[8] which is set to double in size over the next 25 years, reaching 1 billion people by 2040. Within urban and peri-urban locations, much of Sub Saharan Africa continues to use purchased traditional biomass and kerosene for their cooking. Liquid Petroleum Gas (LPG) has achieved some penetration within urban conurbations, however, the supply chain is often weak resulting in strategies of fuel stacking with traditional fuels. Even where electricity is used for lighting and other amenities, it is rarely used for cooking (with the exception of South Africa). The same is true for parts of Asia and Latin America. Global commitments to rapidly increasing access to reliable and quality modern energy need to much more explicitly include cooking services or else household and localized pollution will continue to significantly erode the well-being of communities.

Where traditional biomass fuels are used, either collected in rural areas or purchased in peri urban and urban conurbations, they are a significant economic burden on households either in the form of time or expenditure. The McKinsey Global Institute outlines that much of women's unpaid work hours are spent on fuel collection and cooking[9]. The report shows that if the global gender gap embodied in such activities were to be closed, as much as $28 trillion, or 26 percent, could be added to the global annual GDP in 2025. Access to modern energy services for cooking could redress some of this imbalance by releasing women's time into the labour market.

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

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

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

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

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To address this global issue and increase access to clean cooking services on a large scale, investment needs are estimated to be at least US$4.4 billion annually[10]. Despite some improvements in recent years, this cross-cutting sector continues to struggle to reach scale and remains the least likely SE4All target to be achieved by 2030[11], hindering the achievement of the UN's Sustainable Development Goal (SDG) 7 on access to affordable, reliable, sustainable and modern energy for all.

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

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

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

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

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

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

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Figure 17 shows how the key components of the programme fit together. We will seek to have the MECS principles adopted in the SDG 7.1 global tracking framework and hope that participating countries will incorporate modern energy cooking services in energy policies and planning.

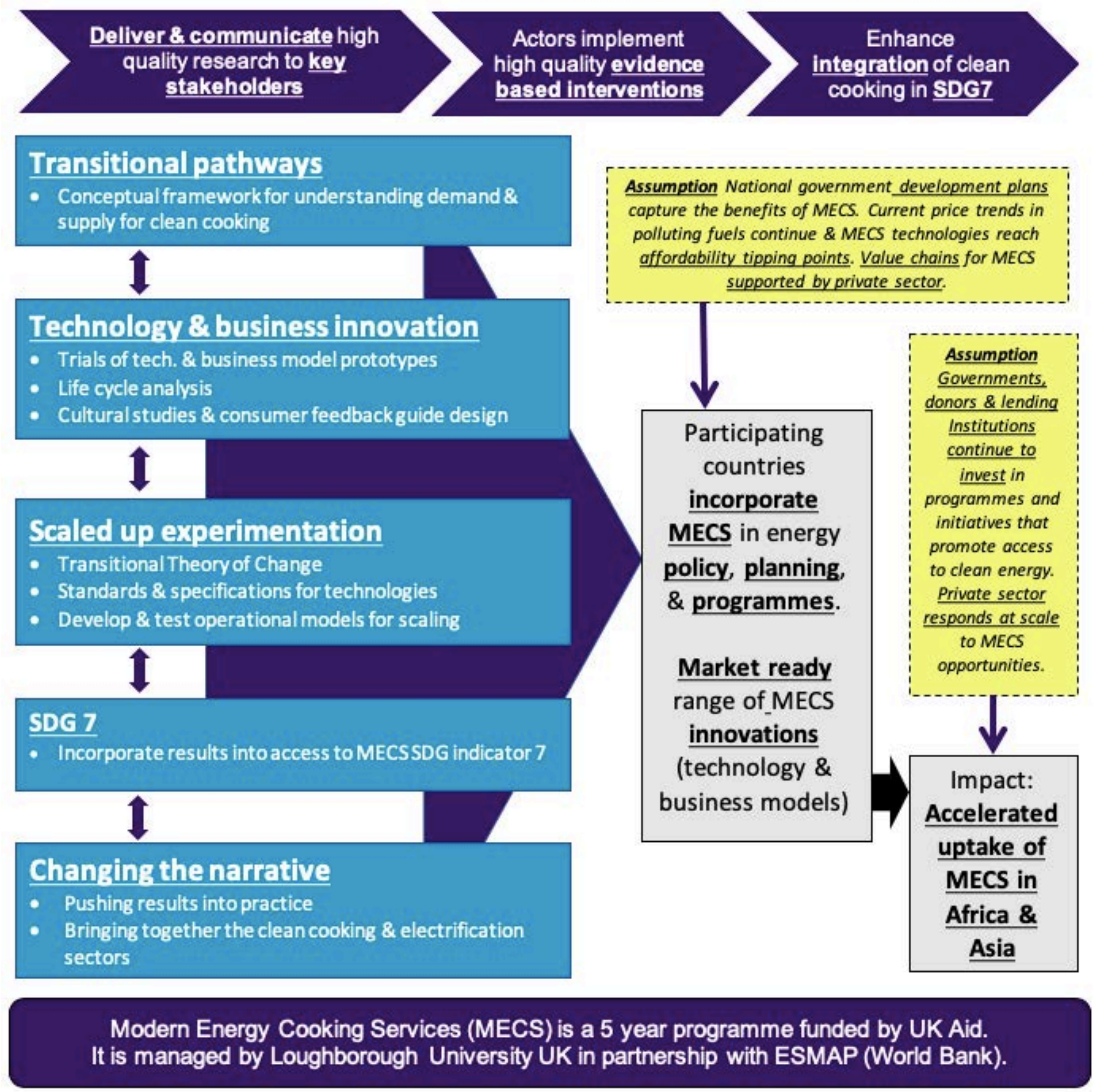

Figure 17: Overview of the MECS programme.