Opportunities & Challenges for eCook Zambia

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Executive Summary

This report summarises the findings from a series of studies **carried out in Zambia**, 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 Zambia.

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, 2015a, 2015c). 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.

Zambia was identified as a high impact potential market through the Global Market Study (Leary *et al.*, 2018). The aim of this Zambia 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
- Prototyping
- Stakeholder workshops (Kick-off Meeting and Design Challenge)

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

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1.1 Key findings

1.1.1 Fuel choice, fuel stacking and the compatibility of Zambian cuisine with eCooking

The focus groups, cooking diaries and national policy and markets review showed that electricity is the aspirational fuel for most households in Zambia and that access, affordability (or perception of affordability) and reliability are the main barriers holding back wider adoption of electric cooking, all of which are addressed by the eCook concept. Whilst adding a battery into the system raises the upfront cost, breaking it down into manageable repayments on a par with how people currently pay for biomass using innovative financing mechanisms make it affordable.

They also showed that LPG is not yet popular in Lusaka, as it is currently expensive and is perceived as unsafe. If the LPG market is established, a fuel stacking scenario with LPG and energy-efficient electric appliances attractive to modern Zambians, as they could cook faster, multi-task and save money.

Electricity may be the aspirational cooking fuel for most Zambian households, however the national markets and policy review showed that charcoal use is deeply embedded within society. In 2013, 12% of Zambians (2 million) were already using electricity as their primary fuel, however recent load-shedding caused many of these people to revert back to charcoal. 37% of Zambians (6 million) use charcoal as their primary cooking fuel - globally, only Liberia, Haiti and Togo have higher proportions of their population cooking on charcoal.

The cooking diaries indicated that it is highly likely that many more than 2 million Zambians own an electric hotplate, as it is often used in a fuel stacking scenario with a charcoal mbaula. The Zambian mbaula is an extremely inefficient device constructed purely from thin sheet metal, allowing heat to escape into the surroundings rather than into the pot. It's appeal primarily relates to its extremely low purchase cost (just 1.5USD) and its familiarity.

The focus groups, kitchen laboratory experiments and cooking diaries showed cooking with electricity is highly compatible with Zambian cuisine and modern energy-efficient appliances are highly desirable to everyday Zambian cooks. Together with the choice modelling survey, they showed that urban Zambians typically fuel stack between charcoal and electricity. Charcoal is typically used for "long boilers" like beans, as hotplates consume a lot of units. However, there is now a much more efficient alternative to the hotplate: the Electric Pressure Cooker (EPC).

The Design Challenge showed that EPCs can already cook certain foods much faster and much cheaper than charcoal on ZESCO's grid; however, they require the cook to change their behaviour. Cleanliness and speed of cooking are therefore likely to be important selling points. Insulating cooking devices not only

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makes them more efficient, but also improves the experience for the cook on hot days who does not want to be heated any more. Emphasising safety will be important, as there is a perception that pressure cooking is dangerous.

The EPC is expected to play a key role in the development of future eCook systems, as it is the highly energy intensive "*long boilers*" such as beans or offals that are most likely to create spikes in demand that flatten the battery. Zambian cuisine is made up of a diverse range of dishes, however this can be simplified to facilitate practical system design by categorising them by their energy demand into:

- Long boilers – high energy demand on a hotplate, low energy demand on an EPC
- Medium boiler/fryers – medium energy demand on a hotplate or EPC
- Quick fryers – low energy demand on a hotplate or EPC

A concept prototype was assembled from locally available components to supply a total daily energy demand of 2.9kWh. 80% of respondents to the choice modelling surveys indicated that they cook 3 meals a day. Values obtained from experimentation in the kitchen laboratory were used to size the prototype for 1 day of typical Zambian cooking in a 5-person household. The Design Challenge and kitchen laboratory experiments showed that recharging an eCook device should be as simple as possible, or cooks may get to mealtime and be disappointed to find their battery is flat.

The Design Challenge highlighted that appliances are cheaper than batteries and therefore, carefully selecting the most efficient electric cooking appliances will reduce the size and therefore cost of the battery bank by significantly more than the cost of the appliance itself. The choice modelling surveys showed that half the people who reported cooking with electricity but did not fuel stack with any other fuel were 'appliance stackers', i.e. they cooked with multiple electric appliances. Energy-efficient appliances are often limited to a particular set of foods, however an eCooking solution with multiple energy-efficient appliances is likely to be cheaper than another with just one.

Figure ES-1: The evolution of the eCook concept: energy-efficient appliances are cheaper than batteries.

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These activities have highlighted 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**.**

1.1.2 Load shedding

Energy-efficient appliances can make a valuable contribution to demand side management of ZESCO's grid. Electricity is already the aspirational fuel; however, the grid is overloaded with inefficient hotplates and ovens, meaning there is an opportunity to promote off-the-shelf energy-efficient appliances, in particular, EPCs.

The national policy and markets review showed that ZESCO generate almost entirely from hydroelectric sources and that in recent years, late rainfall has forced ZESCO to implement load shedding to balance demand with supply. The choice modelling surveys showed that load shedding is most frequently experienced from September to December, which ties in with seasonal rainfall patterns, as when the rains come late, Zambia's hydropower-dominated grid is unable to keep up with demand.

ZESCO's Demand Side Management department have shown a keen interest in the eCook concept, however to date, there have been few clean cooking projects looking at electric cooking, as ZESCO are actively encouraging their users to switch to LPG in an attempt to reduce the loading on the grid and prevent further load shedding. In rural areas, firewood is the most widely used fuel for cooking, whilst in urban areas, most households fuel stack charcoal and electricity, depending on which foods they are cooking and whether there are blackouts at mealtimes or not.

During load shedding, charcoal production increased significantly to meet the growing demand, accelerating deforestation and stepping up the pressure on Zambia's already strained natural resources. During blackouts, households previously accustomed to the convenience of cooking on a hotplate were forced to light up their mbaulas even for 'lighter' foods.

Battery-supported appliances and LPG can enable everyday cooks to mitigate the effects of load shedding. Despite promotion by the government during load shedding, LPG is not yet popular in Zambia. There is a perception that it is dangerous due to the risk of a cylinder exploding, however this may well change, especially as the fuel becomes more popular in neighbouring nations. If it does, a fuel stacking scenario with LPG and energy-efficient eCook devices is likely to be highly attractive to everyday cooks.

The techno-economic modelling showed that for blackouts of up to 4 hours per day, a battery sized to meet half the daily cooking demand (0.42kWh) could enable ZESCO's customers to cook whenever they

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wanted. If they were able to develop an on-bill financing mechanism to break down the high upfront cost of efficient battery-supported appliances, their poorest customers could potentially cook for just 3-5 USD/month in 2020.

Household energy storage in the form of battery-supported eCooking systems are an attractive proposition for users, however they may exasperate ZESCO's problems further. If their hydropower grid already has storage, they may be limited by energy, not power, meaning that adding more loads at any time of day would be detrimental.

1.1.3 Affordability

The high upfront cost of battery-supported cooking was highlighted by key stakeholders as a major barrier at the Kick-off Meeting. The choice modelling survey showed that affordability is a key factor in making eCooking attractive to poorer households. Whilst almost half of charcoal users buy monthly, 20% buy daily in small quantities.

In fact, an opportunity exists today for the promotion of EPCs as a more efficient alternative to hotplates. This could be catalysed if ZESCO, Zambia's state-owned utility, offered an on-bill financing option, as the initial purchase cost and awareness of technology are both significant barriers. However, this would need to be accompanied by training for first time users on how to use them efficiently. The results of the bean boiling challenge indicate that they could actually increase demand if households who previously used charcoal to boil beans all suddenly switched to electricity without even putting the lid on!

The Kick-off Meeting identified micro-financing via pay-as-you-go business models, Village Banking, or cooperatives and targeted training/awareness raising were seen as key enablers. Peri-urban households were identified as the key target market segment, as people are more likely to be paying for their fuel, yet grid-connections are likely to be least reliable and many will not be connected at all.

The choice modelling highlighted that whilst some of the consumer preferences are likely to reduce the overall cost of eCook systems by reducing battery size (e.g. 2 hobs over 4, lid over open pot) others are likely to increase it, so compromises may have to be made (e.g. 2 hobs over 1, lid over sealed pot, lease-to-own over utility business model). The focus group participants prioritised several more energy-efficient features that can make future eCook products more affordable a separate food warmer, automatic control mechanisms & pressure cookers.

The choice modelling, focus groups and cooking diaries showed that there is a false perception that electricity is expensive and therefore, most Zambian households who own an electric hotplate will only use it to cook 'lighter' or 'quicker' foods, such as frying an egg. For 'heavier' or 'longer boiling' dishes such

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as beans, the mbaula would undoubtedly be lit. Although electricity prices have recently increased from 0.05 to 0.09USD/kWh, the cooking diaries have shown that cooking with an electric hotplate is still cost comparable with charcoal. In fact, electric cooking is much cheaper if energy efficient appliances and practices are employed. However, the kitchen laboratory experiments and bean boiling challenge showed that electric pressure cookers can cook beans in half the time and for a fraction of the cost of charcoal (under 1 ZMW). Overcoming the intangibility of electricity by clearly showing cooks how much has been used (or better, how much money has been spent) on each dish will be key to overcoming this false perception.

The techno-economic modelling showed that in Zambia, electricity is already by far the cheapest option for cooking, and LPG is not competitive at all. Even battery-supported cooking is cost comparable with charcoal, as ZESCO's tariffs are so low. A lifeline tariff of just 0.015USD/kWh is available for the first 200kWh in each month (equivalent to 6.6kWh/day) and the evidence from the cooking diaries has shown that most households use far less than this for cooking. However, the focus groups showed that poorer households often share electricity meters with their landlords/ladies, limiting their access to this lifeline tariff that was designed to support them.

1.1.4 Off-grid eCooking

The national policy & markets review showed that Zambia has a huge off-grid population and emerging mini-grid and solar markets. They are primarily focussed on lighting solutions, however, they are paving the way for PV-eCook and cooking on mini-grids. Several private companies are now offering pay-as-you-go solutions and Fenix have recently launched Zambia's first mobile-money enabled pay-as-you-go solar package. Zambia has very favourable environmental conditions for solar and some micro-hydro potential.

1.1.5 Supply chain

The challenges of finding lithium ion batteries and DC cooking appliances during prototyping highlight the need for further supply chain and technology development. Lithium ion batteries are available, but with a long lead time and a high cost. However, this was to be expected, as this is an emerging opportunity, which since 2013, we have predicted will not be commercially viable until 2020. 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. DC cooking appliances that can cook Zambian foods efficiently need to be developed to reduce the size of battery and bring down the overall cost of the system.

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1.1.6 Long-term stakeholder engagement and co-creation

It will be important to raise awareness of the solution and co-construct the emerging solutions with the Zambian Government. 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 Kick-off Meeting identified the Department of Energy, ZESCO (Zambia Energy Services Company), REA (Rural Electrification Authority), ERB (Energy Regulation Board), the private sector, NGOs, traditional leaders and academia as key actors. Finally, the Design Challenge and focus groups highlighted that empowering female entrepreneurs will be an important enabler for eCook.

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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 Zambia. In particular, this in country work aims to gain much greater insight into culturally distinct cooking practices and explore how compatible they are with battery-supported electric cooking. The report is rich with detail and is intended to provide decision makers, practitioners and researchers with new knowledge and evidence.

This report presents findings from the design, assembly and testing of a concept prototype to inform the future development of eCook within Zambia. It is one component of a broader study designed to assess the opportunities and challenges that lie ahead for eCook in high impact potential markets, such as Zambia, funded through Innovate UK's Energy Catalyst Round 4 by DfID UK Aid and Gamos Ltd. (https://elstove.com/innovate-reports/). 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, 2015b, 2015c). 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.

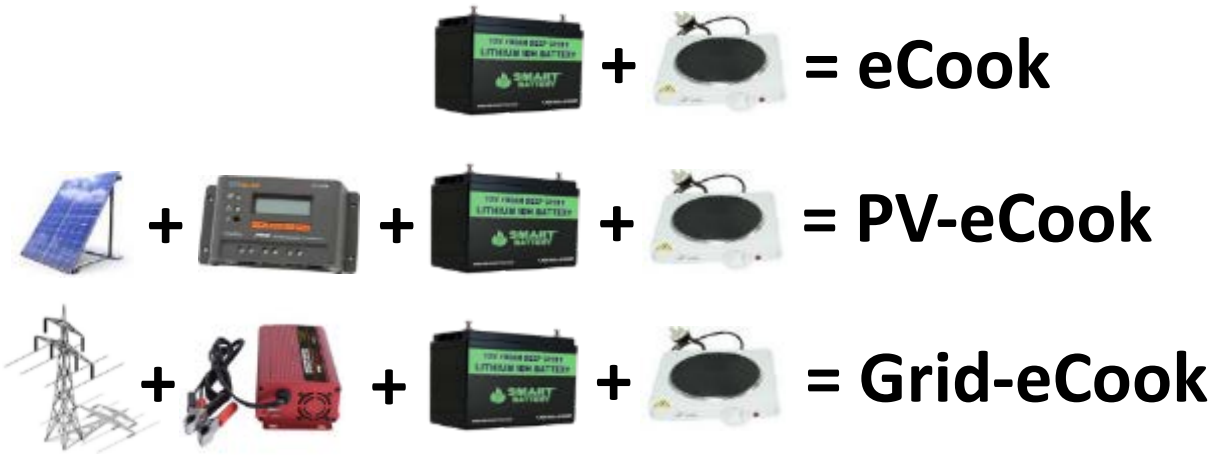

Figure 1: Pictorial definitions of 'eCook' terminology used in this report.

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3 Why Zambia?

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 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 2), such as Tanzania, Zambia and Uganda. For Grid-eCook, Asian nations sit at the forefront, with China and India both the biggest markets. Zambia still has a large target markets and also scores relatively highly for viability, however most importantly, over 10% of the population already cook with electricity.

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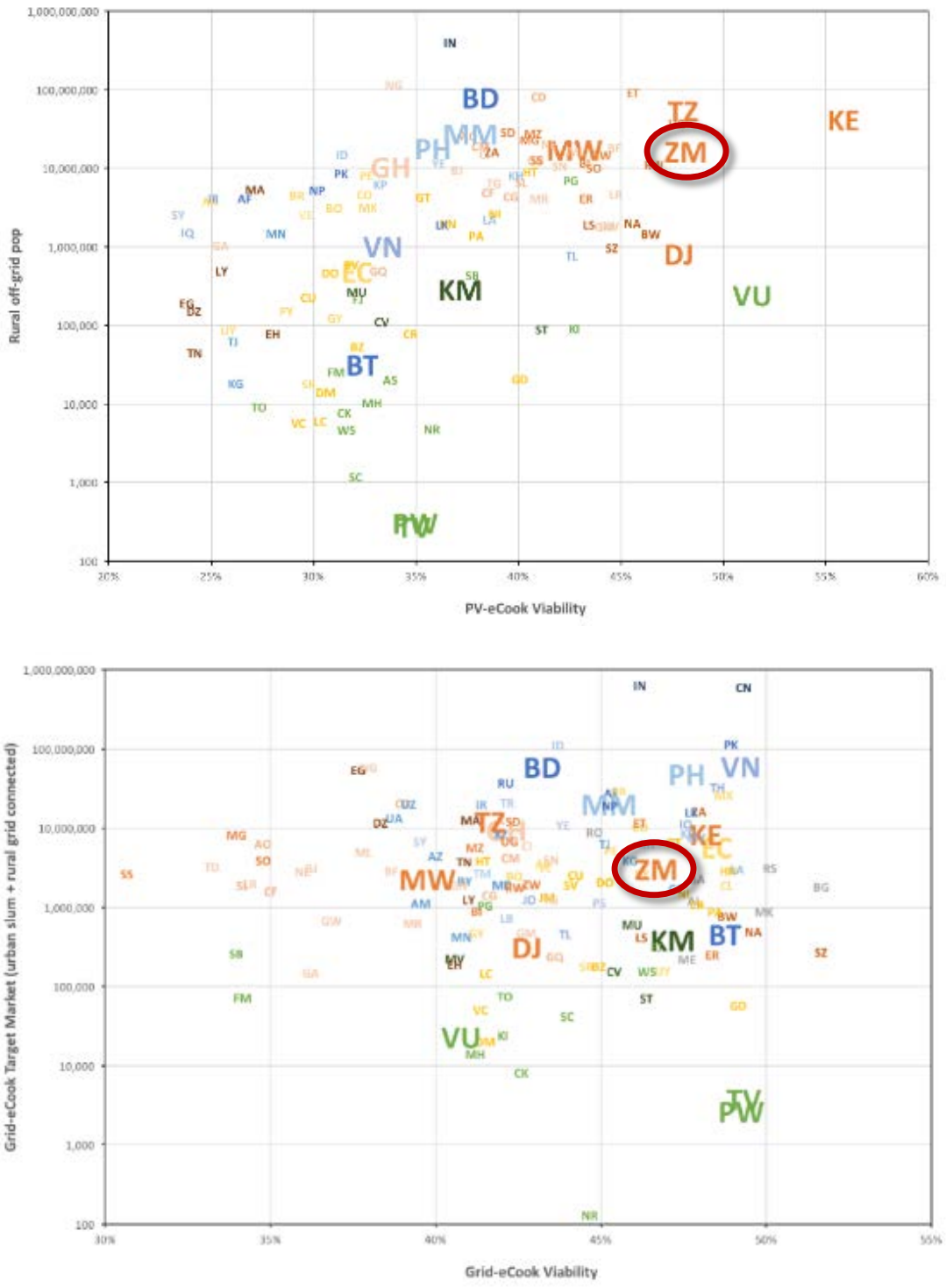

Figure 2: Comparison of size of PV-eCook (top) and Grid-eCook (bottom) target market segments by electrification and demographic status with ease of reaching these market segments.

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3.4 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 led 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 3 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. Zambia shows strong viability scores for both Grid-eCook and PV-eCook and has 6 million commercialised polluting fuels users.

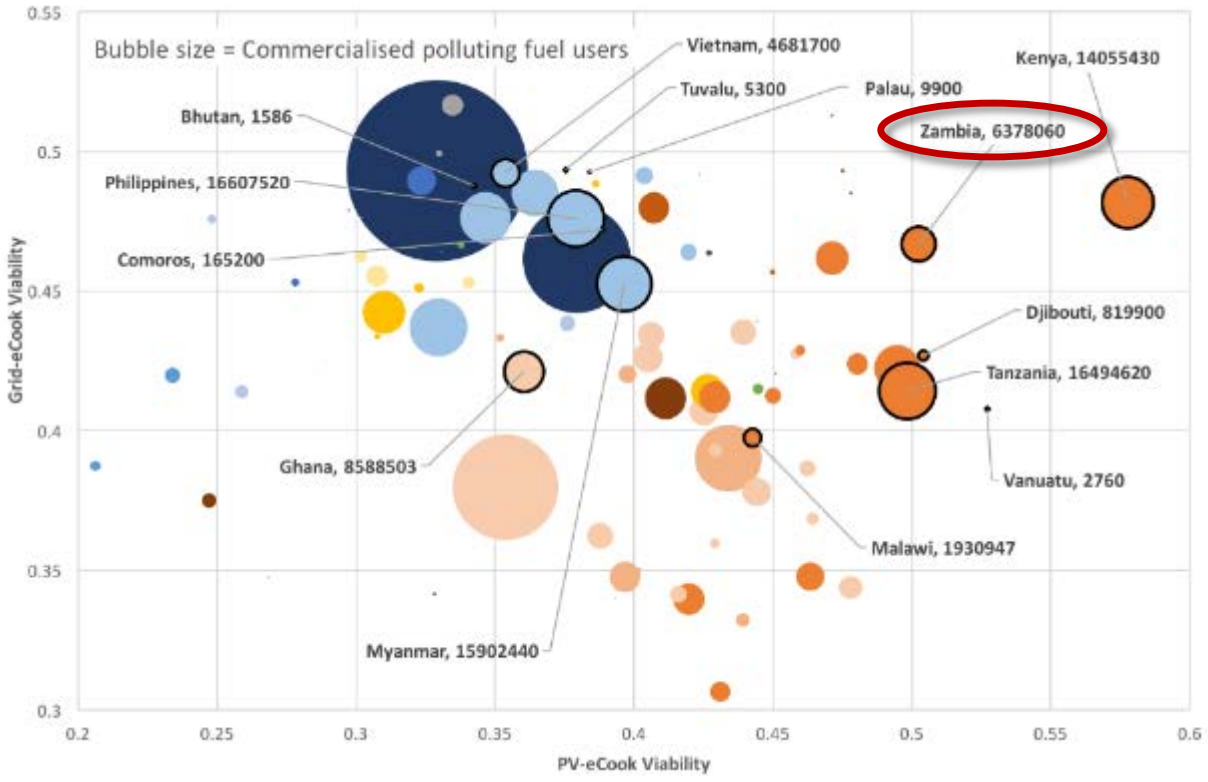

Figure 3 Size of commercialized polluting fuel (kerosene, charcoal, coal) users market segments and ease of reaching them with Grid-eCook or PV-eCook solutions.

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3.5 Introduction to the opportunity for eCook in Zambia

In 2013, 12% of Zambians (2 million) were already using electricity as their primary fuel (WHO 2017), however recent load-shedding caused many of these users to revert back to charcoal (Dlamini *et al.*, 2016). Charcoal production increased to meet this growing demand, accelerating deforestation and stepping up the pressure on Zambia's already strained natural resources (Dlamini et al. 2016). Neither LPG nor kerosene markets have yet emerged in Zambia, presumably due to the long overland supply chain that would need to be established to import these fuels into this landlocked Southern African nation. What is more, at 0.05USD/kWh, Zambia has one of the lowest grid electricity tariffs in the world, creating near ideal market conditions for Grid-eCook.

37% of Zambians (6 million) use charcoal as their primary cooking fuel - only Liberia, Haiti and Togo have higher market shares (WHO 2017). 24 responses were received to the GACC experts survey, indicating that prices are at moderate levels (0.18USD/kg in rural charcoal producing regions, rising to 0.27USD/kg in urban areas and reaching a maximum of 0.38USD/kg). **Error! Reference source not found.** shows that irrespective of whether a HH uses charcoal on an open fire, in an ICS or even in an advanced ICS, it is still cheaper to cook with grid electricity.

28% of Zambians (5 million) are connected to the national grid, meaning that even before load-shedding began, there were still 3 million grid-connected Zambians primarily cooking with other fuels. What is more, 3 million Zambians live at the fringes of the grid, in urban slums or rural grid-connected regions, where eCook can play a vital role in both strengthening and expanding the grid.

In fact, Zambia actually scores higher for PV-eCook viability than for Grid-eCook. 59% of Zambians (10 million) live in rural areas, 96% of whom are off-grid. The market for pico-solar products and SHS is expanding rapidly, with 15,000 sales made in Zambia in the second half of 2016 (GOGLA et al. 2016). Like neighbouring Malawi, Zambia has very favourable environmental conditions (monthly average solar irradiation: 4.4-5.8kWh/m2/day and temperatures: 17-25°C).

Analysis of the FAO's food consumption database suggests that Zambian cuisine requires relatively low energy input in the cooking process. The database suggests a predominantly vegetable-based diet, with maize, cassava, sweet potatoes and other roots & tubers creating the highest energy demand. Zambia's main staple, nshima, is a maize-based dish similar to Malawi's nsima and Kenya's ugali. It requires significant stirring throughout the cooking process, reducing the potential energy savings of insulated pots and even lids, however it can be carried out satisfactorily on relatively low power appliances (500W).

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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.'s (2018) global market assessment highlighted that over 10% of the population already cook with electricity, however recent load shedding caused a significant number of these users to revert back to charcoal, rapidly accelerating deforestation.

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

The aim of this Zambia 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 Zambia.

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.

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

- 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 Zambia. 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.

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

5.1 Cooking diaries

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

- ***Cooking with electricity is compatible with Zambian cuisine and modern energy-efficient appliances are highly desirable to everyday Zambian cooks.***
- ***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: 'heavy foods'.***
- ***Electricity is already the aspirational fuel; however, the grid is overloaded with inefficient hotplates and ovens, meaning there is an opportunity to promote off-the-shelf energy-efficient appliances, in particular, EPCs.***
- ***Battery-supported appliances and LPG can enable everyday cooks to mitigate the effects of load shedding.***
- ***LPG is not yet popular in Lusaka, as it is currently expensive, and it is perceived as unsafe.***
- ***If the LPG market is established, a fuel stacking scenario with LPG and EPCs attractive to modern Zambians, as they could cook faster, multi-task and save money.***

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

Figure 4: Training cooking diaries participants in Lusaka to complete the cooking diary forms.

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 this study is to gain a deeper understanding of how households in Zambia 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 solely with electricity, using a range of electric cooking appliances, including hotplates and Electric Pressure Cookers (EPCs), plus any electrical appliances they already owned. Fuel quantities were measured by weighing firewood, charcoal or LPG cylinders before and after each "*cooking event*"; plug-in electricity meters were used for the electric cooking appliances.

The study samples were drawn from a mixture of low-, middle- and high-income urban households Lusaka 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.

COOKING WITH ELECTRICITY IS COMPATIBLE WITH ZAMBIAN CUISINE AND MODERN ENERGY-EFFICIENT APPLIANCES ARE HIGHLY DESIRABLE TO EVERYDAY ZAMBIAN COOKS.

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: 'HEAVY FOODS'.

BATTERY-SUPPORTED APPLIANCES & LPG CAN ENABLE EVERYDAY COOKS TO MITIGATE THE EFFECTS OF LOAD SHEDDING.

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

The cooking diaries study in Zambia has shown that cooking with electricity is compatible with Zambian cuisine and that modern energy-efficient appliances are highly desirable to everyday Zambian 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: 'heavy foods'.

In Lusaka, electricity is already the aspirational fuel, however the grid is overloaded with inefficient hotplates and ovens, meaning there is an opportunity already on the table to promote off-the-shelf energy-efficient appliances, in particular, EPCs. However, battery-supported appliances are likely to make electric cooking much more attractive, as although load shedding was not occurring at the time of this study, it may well return in the not too distant future, which will cause users to revert back to charcoal. LPG is not yet popular in Lusaka, as it is currently expensive, and it is perceived as unsafe. However, if load shedding returns, it may well become an attractive option. If the LPG market is established, the ability to cook faster and multi-task, whilst also saving money are likely to make a fuel stacking scenario with EPCs extremely attractive for modern Zambians.

ELECTRICITY IS ALREADY THE ASPIRATIONAL FUEL; HOWEVER, THE GRID IS OVERLOADED WITH INEFFICIENT HOTPLATES AND OVENS, MEANING THERE IS AN OPPORTUNITY TO PROMOTE OFF-THE-SHELF ENERGY-EFFICIENT APPLIANCES, IN PARTICULAR, EPCS.

LPG IS NOT YET POPULAR IN LUSAKA, AS IT IS CURRENTLY EXPENSIVE AND IT IS PERCEIVED AS UNSAFE. IF THE LPG MARKET IS ESTABLISHED, A FUEL STACKING SCENARIO WITH LPG & EPCS ATTRACTIVE TO MODERN ZAMBIANS, AS THEY COULD COOK FASTER, MULTI-TASK AND SAVE MONEY.

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:

- ***Load shedding is most frequent from September to December, which ties in with seasonal rainfall patterns, as when the rains come late, Zambia's hydropower-dominated grid is unable to keep up with demand.***
- ***Half the people who reported cooking with electricity but did not fuel stack with any other fuel were 'appliance stackers', i.e. they cooked with multiple electric appliances.***
- ***The mean monthly expenditure on electricity (for cooking & other purposes) was roughly 200 ZMK (15 USD).***
- ***Almost half of the charcoal users buy monthly, however 20% buy daily in small quantities.***
- ***80% of respondents reported cooking 3 meals a day.***
- ***Respondents had a strong preference for a device that avoids wood fire smoke.***
- ***Affordability is a key factor in making eCooking attractive to poorer households***
    - ***Some consumer preferences are likely to reduce the overall cost of eCook systems, e.g. 2 hobs over 4, lid over open pot***
    - ***Others are likely to increase it, so compromises may have to be made, e.g. 2 hobs over 1, lid over sealed pot, lease-to-own over utility business model.***

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

Figure 5: Training enumerators for the choice modelling survey in Lusaka.

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

5.2.2 Key learning points

5.2.2.1 Overview of sample

Roughly three quarters of the sample were drawn from urban areas around Lusaka, and one quarter were drawn mostly from three rural towns located around 50 km from the capital. The sample was female biased, but this is not surprising, as there was no cash incentive offered & the focus on cooking likely attracted more female respondents. The mean household size was found to be 5.2 (including children).

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46% of the sample were deprived in at least one of the indicators relating to education, home construction materials & source of drinking water.

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

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

5.2.2.2 Load shedding

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

5.2.2.3 Fuel stacking & fuel choice

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

HALF THE PEOPLE WHO REPORTED COOKING WITH ELECTRICITY BUT DID NOT FUEL STACK WITH ANY OTHER FUEL WERE 'APPLIANCE STACKERS', I.E. THEY COOKED WITH MULTIPLE ELECTRIC APPLIANCES.

Half the people who reported cooking with electricity but did not fuel stack with any other fuel were 'appliance stackers', i.e. they cooked with multiple electric appliances. This shows that, just as each fuel has desirable & undesirable characteristics that make it better/worse for certain foods or

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occasions, so does each electric appliance. Just over half the sample (57%) reported using multiple cooking devices, with some households reporting owning up to 8 different cooking devices! For households with a single cooking device, the basic biomass stove was by far the most popular (83%).

THE MEAN MONTHLY EXPENDITURE ON ELECTRICITY (FOR COOKING & OTHER PURPOSES) WAS ROUGHLY 200 ZMK (15 USD).

Electricity & charcoal/firewood are useful for other things too. Almost all participants who cooked with electricity reported using it for lighting & refrigeration, whilst half reported using it for water heating. In contrast, charcoal was almost universally also used for water heating & by about a third for space heating.

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

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

5.2.2.4 Existing expenditures

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

ALMOST HALF OF THE CHARCOAL USERS BUY MONTHLY, HOWEVER 20% BUY DAILY IN SMALL QUANTITIES.

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

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

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

Cost is clearly an important issue. The belief that electricity is expensive appears to act as a driver for use of charcoal. 60% of participants thought that price was the major deciding factor for households considering transitioning to modern energy for cooking, which suggests that there are other important considerations to take into account, such as access, reliability & cultural preferences.

RESPONDENTS HAD A STRONG PREFERENCE FOR A DEVICE THAT AVOIDS WOOD FIRE SMOKE.

5.2.2.5 Health

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

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

5.2.2.6 Cooking time

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

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

80% OF RESPONDENTS REPORTED COOKING 3 MEALS A DAY.

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5.2.2.7 Gender

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

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

5.2.2.8 Financing

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

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

5.2.2.9 Consumer preferences – choice modelling results

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

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

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

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

The most important stove features are:

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

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

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

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

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

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

AFFORDABILITY IS A KEY FACTOR IN MAKING ECOOKING ATTRACTIVE TO POORER HOUSEHOLDS

- SOME CONSUMER PREFERENCES ARE LIKELY TO REDUCE THE OVERALL COST OF ECOOK SYSTEMS, E.G. 2 HOBS OVER 4, LID OVER OPEN POT
- OTHERS ARE LIKELY TO INCREASE IT, SO COMPROMISES MAY HAVE TO BE MADE, E.G. 2 HOBS OVER 1, LID OVER SEALED POT, LEASE-TO-OWN OVER UTILITY BUSINESS MODEL.

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

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5.3 Techno-economic modelling

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

- ***In Zambia, electricity is already by far the cheapest option and LPG is not competitive at all.***
- ***For blackouts of up to 4 hours per day, a battery sized to meet half the daily cooking demand (0.42kWh) could enable ZESCO's customers to cook whenever they wanted.***
- ***If they were able to develop an on-bill financing mechanism to break down the high upfront cost of efficient battery-supported appliances, their poorest customers could potentially cook for just 3-5 USD/month in 2020.***
- ***Household energy storage in the form of battery-supported eCooking systems are also an attractive proposition for users, however they may exasperate ZESCO's problems further. If their hydropower grid already has storage, they may be limited by energy, not power, meaning that adding more loads at any time of day would be detrimental.***

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

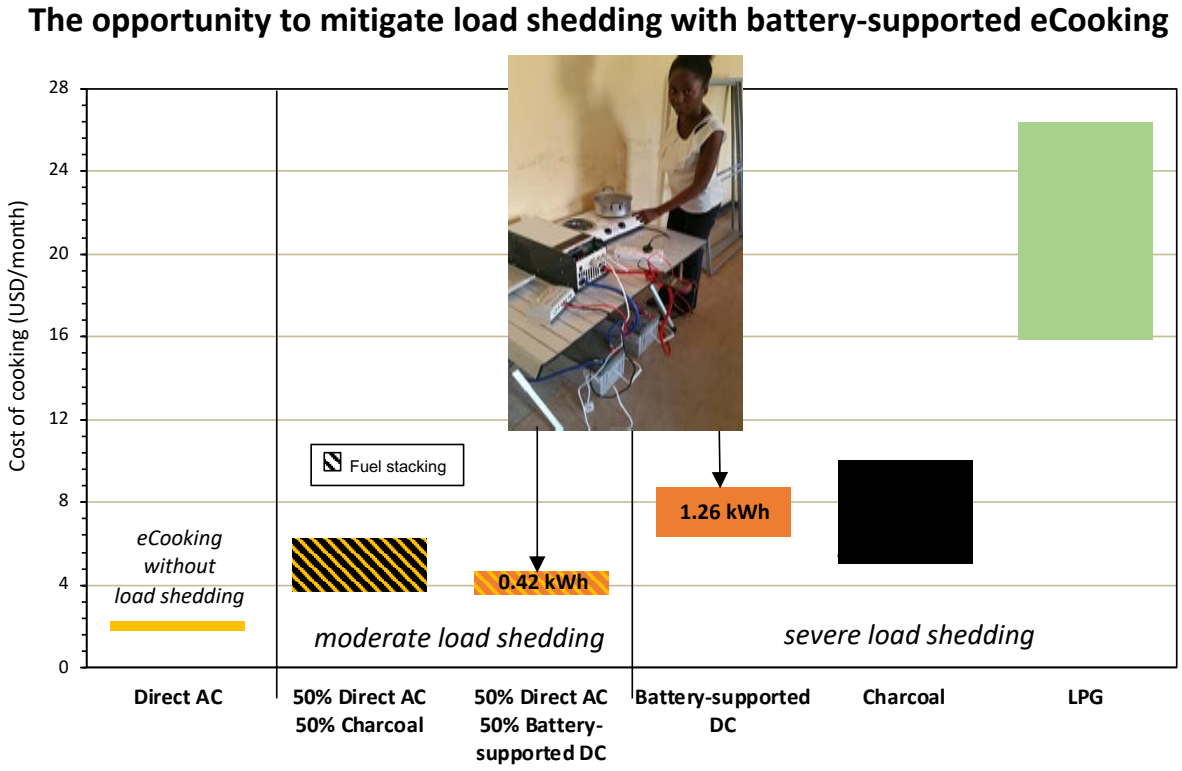

Figure 6: Selected modelling results for ZESCO national grid in Lusaka, Zambia in 2020 with a 5-year financing horizon for direct AC and 20-year financing horizon for battery-supported DC systems.

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.

FOR BLACKOUTS OF UP TO 4 HOURS PER DAY, A BATTERY SIZED TO MEET HALF THE DAILY COOKING DEMAND (0.42KWH) COULD ENABLE ZESCO'S CUSTOMERS TO COOK WHENEVER THEY WANTED.

IF THEY WERE ABLE TO DEVELOP AN ON-BILL FINANCING MECHANISM TO BREAK DOWN THE HIGH UPFRONT COST OF EFFICIENT BATTERY-SUPPORTED APPLIANCES, THEIR POOREST CUSTOMERS COULD POTENTIALLY COOK FOR JUST 3-5 USD/MONTH IN 2020.

5.3.2 Key learning points

This modelling case study explores the opportunity for ZESCO, which has a significant customer base already cooking on electricity, to optimise the loading on their grid. Efficient eCooking appliances can significantly reduce electricity demand and peak loading for households currently cooking on inefficient appliances, such as hotplates. Furthermore, supporting eCooking appliances with a battery can time shift energy demand for cooking and reduce peak loading, whilst also enabling customers to cook during blackouts or load shedding.

In Zambia, electricity is already by far the cheapest option and LPG is not competitive at all (Figure 6). Battery-supported cooking is already the cheapest way to mitigate load shedding in Lusaka. For blackouts of up to 4 hours per day, a battery sized to meet half the daily cooking demand

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(0.42kWh) could enable ZESCO's customers to cook whenever they wanted. If they were able to develop an on-bill financing mechanism to break down the high upfront cost of efficient battery-supported appliances, their poorest customers could potentially cook for just 3-5 USD/month in 2020.

The results of this second case study clearly show that in contexts with relatively low electricity tariffs, both direct AC and battery-supported eCooking can already offer considerable cost savings for charcoal users, even if charcoal is relatively cheap. In contexts with emerging LPG markets and low electricity tariffs, electricity is by far the cheapest option. Where direct AC cooking is made unworkable by unreliable grid supplies, adding in the battery does add cost, but is still less expensive than the charcoal or LPG alternatives.

IN ZAMBIA, ELECTRICITY IS ALREADY BY FAR THE CHEAPEST OPTION AND LPG IS NOT COMPETITIVE AT ALL.

Household energy storage in the form of battery-supported eCooking systems are also an attractive proposition for users, however they may exasperate ZESCO's problems further. Depending on how much of ZESCO's hydropower generation is run-of-the-river and how much has reservoir storage, they may well already have the ability to schedule generation at scale. If there are high levels of water storage already built into their system, it is therefore likely to be limited by energy, not peak power. Therefore, introducing more loads, even battery-supported loads, may be detrimental, as some energy is lost during the charge/discharge cycle, which may further reduce the amount of energy available on the grid. In contrast, if the system is power limited, adding battery-storage can help with reducing peak demand by time-shifting electricity demand for cooking.

HOUSEHOLD ENERGY STORAGE IN THE FORM OF BATTERY-SUPPORTED ECOOKING SYSTEMS ARE ALSO AN ATTRACTIVE PROPOSITION FOR USERS, HOWEVER THEY MAY EXASPERATE ZESCO'S PROBLEMS FURTHER. IF THEIR HYDROPOWER GRID ALREADY HAS STORAGE, THEY MAY BE LIMITED BY ENERGY, NOT POWER, MEANING THAT ADDING MORE LOADS AT ANY TIME OF DAY WOULD BE DETRIMENTAL.

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):

- ***Electricity is the aspirational fuel for most households in Zambia. Access, affordability (or perception of affordability) and reliability are the main barriers holding back wider adoption of electric cooking.***
- ***There is a general perception that cooking with electricity is expensive. However, the evidence from the cooking diaries shows that even cooking with inefficient electric hotplates is cheaper than charcoal and that electric pressure cookers can cook beans in half the time and for a fraction of the cost of charcoal (under 1 ZMW).***
- ***Overcoming the intangibility of electricity by clearly showing cooks how much has been used (or better, how much money has been spent) on each dish will be key to overcoming this false perception.***
- ***The FGD participants prioritised a separate food warmer, automatic control mechanisms & pressure cookers, all of which are all energy-efficient features that can make future eCook products more affordable by reducing battery size.***

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

Figure 7: Focus group participants in Shimbala discussing how compatible an EPC might be with their current and aspirational cooking practices.

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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.

ELECTRICITY IS THE ASPIRATIONAL FUEL FOR MOST HOUSEHOLDS IN ZAMBIA. ACCESS, AFFORDABILITY (OR PERCEPTION OF AFFORDABILITY) AND RELIABILITY ARE THE MAIN BARRIERS HOLDING BACK WIDER ADOPTION OF ELECTRIC COOKING.

Figure 8: Focus group participants with an EPC in Ng'ombe.

5.4.2 Key learning points

The evidence from these FGDs suggests that **electricity is the aspirational fuel** for most households in Zambia and confirms that **access, affordability (or perception of affordability) and reliability** are the **main barriers** holding back wider adoption of electric cooking.

There is a general **perception that cooking with electricity is expensive**, however the evidence from the cooking diaries shows that **even cooking with inefficient electric hotplates is cheaper than charcoal**. This false perception has led many landlords/ladies, whose tenants share their electricity meter, to ban cooking with electricity. Even if electric cooking is allowed, long boiling dishes such as beans are often specifically prohibited, forcing their tenants to pay more to cook with charcoal. The national utility, ZESCO,

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

offers a very generous lifeline tariff of 0.15 ZMW/kWh (just 0.015 USD/kWh) for the first 200 kWh/month. Whilst this is more than enough to cook with, even on inefficient hotplates, it is not accessible to many poorer households, who live in rented accommodation with a shared meter. Nonetheless, even at the standard tariff of 0.89 ZMW/kWh (0.089 USD/kWh), the evidence from the cooking diaries shows that electricity is still cheaper than charcoal, as almost all meals can be cooked for under 2kWh (1.78 ZMW or 0.178 USD), regardless of household size.

THERE IS A GENERAL PERCEPTION THAT COOKING WITH ELECTRICITY IS EXPENSIVE. HOWEVER, THE EVIDENCE FROM THE COOKING DIARIES SHOWS THAT EVEN COOKING WITH INEFFICIENT ELECTRIC HOTPLATES IS CHEAPER THAN CHARCOAL AND THAT ELECTRIC PRESSURE COOKERS CAN COOK BEANS IN HALF THE TIME AND FOR A FRACTION OF THE COST OF CHARCOAL (UNDER 1 ZMW).

Overcoming the intangibility of electricity by clearly showing cooks how much has been used (or better, how much money has been spent) on each dish will be key to overcoming this false perception. Most people have no idea how much electricity goes into cooking a typical dish and therefore how much it costs. In contrast, with charcoal and firewood it is physically very obvious. If future electric stoves included an energy meter, which clearly displayed how much money had been spent on the last dish, the comparison would be much clearer. PV-eCook (solar electric cooking) devices have a significant advantage here, as they do not rely on an external power supply, as a result, the size of the repayments should clearly communicate to the user just how much (or how little) it costs to cook with electricity.

Cooking beans is a major drain on the finances of poorer households. The evidence from the cooking diaries shows that **electric pressure cookers can cook beans in half the time and for a fraction of the cost of charcoal** (under 1 ZMW). Electricity & firewood are both already favoured for quick foods. Charcoal is harder to light, but burns steadily for several hours, making it the preferred fuel for longer boiling dishes, such as beans, trotters, game meat or village chicken. The electric pressure cooker yields the greatest time and cost savings of any appliance on long boiling dishes, positioning it well to take over from charcoal. Most households in the FGDs only had experience with hotplates, but were impressed with how quickly the electric pressure cooker could cook beans and how tasty they were.

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Many people say that food cooked on charcoal is tastier than electricity, as it cooks slowly. **Just because electricity can cook quickly, it doesn't mean it has to**. In fact, slow cookers cook even more slowly than charcoal, allowing meat to tenderise and flavours to combine over many hours. Cooking slowly is one way of allowing heat to penetrate all the way through food. Raising the temperature of the water that is boiling the food with a pressure cooker is another. Electric pressure cookers cook even faster than hotplates, but produce tender, flavoursome food like the slow cooker by raising the boiling point of water to 120°C. Many people assume that an electric pressure cooker can only cook long boiling foods with the lid on. In fact, it can also fry, steam or boil with the lid on or off (some baking is even possible), leading many to market them as 'multicookers'.

OVERCOMING THE INTANGIBILITY OF ELECTRICITY BY CLEARLY SHOWING COOKS HOW MUCH HAS BEEN USED (OR BETTER, HOW MUCH MONEY HAS BEEN SPENT) ON EACH DISH WILL BE KEY TO OVERCOMING THIS FALSE PERCEPTION.

The FGD participants prioritised a separate food warmer, automatic control mechanisms & pressure cookers, **all of which are all energy-efficient features that can make future eCook products more affordable by reducing battery size**. They also highlighted **affordable monthly payments**, **powering other appliances** and **safe design to avoid shocks** - all of which are integral features of any eCook product/service. In addition, many mentioned the critical role of **user training**, especially if incorporating appliances that require significant changes in cooking habits, such as electric pressure cookers. Surprisingly, **baking was found to be relatively important**, however in a conventional oven, this is the most energy intensive cooking process. Fortunately, many electric pressure cookers come with a 'cake' button that could provide an aspirational purchasing trigger. Interestingly, **portability was generally seen as negative**, due to durability & safety concerns. This bodes well for bulky energy storage technologies such as sodium ion batteries.

THE FGD PARTICIPANTS PRIORITISED A SEPARATE FOOD WARMER, AUTOMATIC CONTROL MECHANISMS & PRESSURE COOKERS, ALL OF WHICH ARE ALL ENERGY-EFFICIENT FEATURES THAT CAN MAKE FUTURE ECOOK PRODUCTS MORE AFFORDABLE BY REDUCING BATTERY SIZE.

In peri-urban contexts, many households that used to collect firewood are now forced to purchase it, as access to the bush becomes harder as population density increases. Charcoal is the next step, as it is more energy dense, so it can be transported from further afield. This creates an opportunity for eCook, because this commercialisation of polluting fuels is an existing expenditure that can be redirected into repayments on an eCook system. Existing expenditures on a blend of firewood and charcoal

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among FGD participants seem to be in the order of 80-200 ZMW/month. At 100 ZMW/month (10 USD), the economic proposition of eCook becomes viable with a 4-5 year payback period. At 200 ZMW/month (20 USD), 2-3 year payback periods become possible.

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

5.5 Prototyping

This section summarises the findings from the eCook prototyping:

- ***Urban Zambians typically fuel stack between charcoal and electricity. Charcoal is typically used for "long boilers" like beans, as hotplates consume a lot of units. However, there is now a much more efficient alternative to the hotplate: the Electric Pressure Cooker (EPC).***
- ***The EPC is expected to play a key role in the development of future eCook systems, as it is the highly energy intensive "long boilers" such as beans or offals that are most likely to create spikes in demand that flatten the battery.***
- ***Zambian cuisine is made up of a diverse range of dishes, however this can be simplified to facilitate practical system design by categorising them by their energy demand into:***
    - ***Long boilers***
    - ***Medium boiler/fryers***
    - ***Quick fryers***
- ***A concept prototype was assembled from locally available components to supply a total daily energy demand of 2.9kWh. Values obtained from experimentation in the kitchen laboratory were used to size the prototype for 1 day of typical Zambian cooking in a 5-person household.***

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

Figure 9: Cooking meat stew on a battery-supported EPC at the eCook Zambia Design Challenge.

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

5.5.1 Overview

The prototyping carried out in Zambia used experimental '*ethno-engineering'* methodologies to create a kitchen laboratory where current and aspirational Zambian cooking practices and the trade-offs between energy-efficiency and behavioural change could be explored. A concept prototype was assembled from locally available components to demonstrate the concept of cooking on battery-supported electricity.

5.5.2 Key learning points

The kitchen laboratory experiments showed that today, urban Zambians typically fuel stack between charcoal and electricity. Charcoal is typically used for "long boilers" like beans, however recent advancements in electric cooking appliance technology now offers a much more time and energy efficient alternative to the conventional electric hotplate: the Electric Pressure Cooker (EPC). This appliance is expected to play a key role in the development of future battery-supported cooking systems (eCook), as it is the highly energy intensive "*long boilers*" such as beans or offals that are most likely to create peaks in demand that flatten the battery.

URBAN ZAMBIANS TYPICALLY FUEL STACK BETWEEN CHARCOAL AND ELECTRICITY. CHARCOAL IS TYPICALLY USED FOR "LONG BOILERS" LIKE BEANS, AS HOTPLATES CONSUME A LOT OF UNITS. HOWEVER, THERE IS NOW A MUCH MORE EFFICIENT ALTERNATIVE TO THE HOTPLATE: THE ELECTRIC PRESSURE COOKER (EPC).

THE EPC IS EXPECTED TO PLAY A KEY ROLE IN THE DEVELOPMENT OF FUTURE ECOOK SYSTEMS, AS IT IS THE HIGHLY ENERGY INTENSIVE "LONG BOILERS" SUCH AS BEANS OR OFFALS THAT ARE MOST LIKELY TO CREATE SPIKES IN DEMAND THAT FLATTEN THE BATTERY.

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THE MBAULA

- Ubiquitous across urban Zambia today.
- Inefficient, expensive fuel, unhealthy & environmentally destructive
- Popular for "*long boilers*"

THE HOTPLATE

- Aspirational
- Popular for quicker cooking dishes

- Efficient for quick dishes, healthier & less environmentally destructive.
- Still expensive & unpopular for "*long boilers*"

THE ELECTRIC PRESSURE COOKER (EPC)

- Available, but not yet popularised.
- Far more energy efficient, quicker & easier for "*long boilers*"
- Can also cook "*medium boiler/friers*" & "*quick friers*"

Figure 10: Comparison of the EPC with popular cooking devices in Zambia today.

Zambian cuisine is made up of a diverse range of dishes, however this can be simplified to facilitate practical system design by categorising them by their energy demand. The three key categories proposed from this study are:

- "**Long Boilers**" – High energy demand, require boiling for more than an hour. High impact opportunity for EPCs.
- "**Medium Boiler/Fryer**" – Medium energy demand, typically 15 mins to 1 hour of boiling and/or frying. Possible to cook on an EPC with moderate energy savings.
- "**Quick Fryers**" – Low energy demand, typically less than 15 mins of frying. Most dishes possible to cook on an EPC, but with limited to no energy savings.

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

ZAMBIAN CUISINE IS MADE UP OF A DIVERSE RANGE OF DISHES, HOWEVER THIS CAN BE SIMPLIFIED TO FACILITATE PRACTICAL SYSTEM DESIGN BY CATEGORISING THEM BY THEIR ENERGY DEMAND INTO:

- LONG BOILERS
- MEDIUM BOILER/FRYERS
- QUICK FRYERS

Figure 11: Saving time and energy by boiling the water for nshima in the kettle and putting a lid on the pan.

The promising results shown by EPCs in the kitchen laboratory lead to the inclusion of EPCs alongside hotplates in the cooking diaries study.

Values obtained from experimentation in the kitchen laboratory were used to size the demonstration prototype for a typical Zambian day of cooking in a 5-person household:

- A single "*quick fryer*" on a hotplate for breakfast= 0.2kWh
- 2 "*medium boiler/friers*" on a kettle/hotplate or EPC for lunch = 0.5+0.5kwh = 1kWh
- A "*long boiler*" on an EPC with 2 "*medium boiler/friers*" on a kettle/hotplate or EPC for dinner = 0.7+0.5+0.5kwh = 1.7kWh

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

A concept prototype was assembled from locally available components to supply a total daily energy demand of 2.9kWh. Lithium ion batteries and DC cooking appliances were not available, so an oversized 5.5kWh lead acid battery bank with a 1.5kW inverter/charger had to be substituted. The prototype was capable of charging either from 600W of PV or the grid. The prototype was successfully demonstrated at the eCook Zambia Kick off Meeting and Design Challenge and is now installed at the CEEEZ office. Subsequently, the much more portable and affordable eCookBucket was transported to Zambia, which paired a LiFePO4 battery with a DC rice cooker to create the solar lantern of solar electric cooking.

A CONCEPT PROTOTYPE WAS ASSEMBLED FROM LOCALLY AVAILABLE COMPONENTS TO SUPPLY A TOTAL DAILY ENERGY DEMAND OF 2.9KWH. VALUES OBTAINED FROM EXPERIMENTATION IN THE KITCHEN LABORATORY WERE USED TO SIZE THE PROTOTYPE FOR 1 DAY OF TYPICAL ZAMBIAN COOKING IN A 5-PERSON HOUSEHOLD.

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

5.6 Review of National Policy & Markets

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

- ***ZESCO generate almost entirely from hydroelectric sources. In recent years, late rainfall has forced ZESCO to implement load shedding to balance demand with supply. ZESCO's Demand Side Management department have shown a keen interest in the eCook concept.***
- ***To date, there have been few clean cooking projects looking at electric cooking, as ZESCO are actively encouraging their users to switch to LPG in an attempt to reduce the loading on the grid and prevent further load shedding.***
- ***In rural areas, firewood is the most widely used fuel for cooking, whilst in urban areas, most households fuel stack charcoal and electricity, depending on which foods they are cooking and whether there are blackouts at mealtimes or not.***
- ***Zambia has a huge off-grid population and emerging mini-grid and solar markets, primarily focussed on lighting solutions.***

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

Figure 12: A mock-up of a potential future business model that tackles the invisible divisibility of electricity by enabling users to buy a voucher for just enough units to cook a meal on an energy-efficient electric cooking appliance for a fraction of the cost of a small bag of charcoal sized to cook the same meal.

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

5.6.1 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. The study had two dimensions:

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

5.6.2 Key findings

This study has confirmed that there is a strong market for eCook products and services in Zambia, however there are a number of regulatory challenges that need to be addressed. Grid electricity is managed by a single state-owned company, ZESCO, and generation is almost entirely from hydroelectric sources. In recent years, late rainfall has forced ZESCO to implement load shedding to balance demand with supply. ZESCO now has a Demand Side Management department, who have shown a keen interest in the eCook concept.

Zambia has a huge off-grid population and emerging mini-grid and solar markets, primarily focussed on lighting solutions. In rural areas, firewood is the most widely used fuel for cooking, whilst in urban areas, most households fuel stack charcoal and electricity, depending on which foods they are cooking and whether there are blackouts at mealtimes or not.

Zambia has seen a range of clean cooking initiatives, the majority focussed on improved biomass stoves. Zambia's most popular stove, the mbaula, is extremely inefficient, as it is entirely constructed from metal, with no insulation to focus the heat onto the pot. However, to date, there have been few clean cooking projects looking at electric cooking, as ZESCO are

ZESCO GENERATE ALMOST ENTIRELY FROM HYDROELECTRIC SOURCES. IN RECENT YEARS, LATE RAINFALL HAS FORCED ZESCO TO IMPLEMENT LOAD SHEDDING TO BALANCE DEMAND WITH SUPPLY. ZESCO'S DEMAND SIDE MANAGEMENT DEPARTMENT HAVE SHOWN A KEEN INTEREST IN THE ECOOK CONCEPT.

TO DATE, THERE HAVE BEEN FEW CLEAN COOKING PROJECTS LOOKING AT ELECTRIC COOKING, AS ZESCO ARE ACTIVELY ENCOURAGING THEIR USERS TO SWITCH TO LPG IN AN ATTEMPT TO REDUCE THE LOADING ON THE GRID AND PREVENT FURTHER LOAD SHEDDING.

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

actively encouraging their users to switch to LPG in an attempt to reduce the loading on the grid and prevent further load shedding.

IN RURAL AREAS, FIREWOOD IS THE MOST WIDELY USED FUEL FOR COOKING, WHILST IN URBAN AREAS, MOST HOUSEHOLDS FUEL STACK CHARCOAL AND ELECTRICITY, DEPENDING ON WHICH FOODS THEY ARE COOKING AND WHETHER THERE ARE BLACKOUTS AT MEALTIMES OR NOT.

ZAMBIA HAS A HUGE OFF-GRID POPULATION AND EMERGING MINI-GRID AND SOLAR MARKETS, PRIMARILY FOCUSSED ON LIGHTING SOLUTIONS.

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

5.7 eCook Zambia Kick-off Meeting

This section summarises the findings from the eCook Zambia Kick-off Meeting:

- ***Lack of awareness and high upfront cost were identified as two key barriers, whist deforestation and load shedding were two main drivers.***
- ***Micro-financing, pay-as-you-go business models and targeted training/awareness raising were seen as key enablers.***
- ***The Department of Energy, ZESCO (Zambia Energy Services Company), REA (Rural Electrification Authority), ERB (Energy Regulation Board), the private sector, NGOs, traditional leaders and academia were identified as the key actors.***
- ***Peri-urban households were identified as the key target market segment, with pay-as-you-go, Village Banking and cooperatives seen as the best marketing strategies to reach them.***

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

Figure 13: Attendees from across the electrification and clean cooking sectors at the eCook Zambia Kick-off Meeting in Lusaka.

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

5.7.1 Overview of event

The eCook Zambia Kick-off Workshop brought together key stakeholders from the solar lighting, clean cookstoves and utility sectors to discuss the proposition of battery-supported cooking. The Centre for Energy, Environment and Engineering Zambia (CEEEZ) in partnership with a UK research consortium (Gamos Ltd., University of Surrey and Loughborough University), are collaborating on an initial exploratory study to investigate the opportunity for this potentially transformative technology, which is designed to extend access to electricity access and clean cooking facilities to poorer households (PV-eCook.org).

Prof. Yamba opened the event, highlighting the fact that whilst the rapid spread of solar PV across Africa has already transformed millions of lives, it has yet to have an impact on the main energy need of poor households: cooking. However, in the context of falling global PV prices, recent advancements in battery technology and rising charcoal/fuelwood prices in severely deforested regions, the door is opening for a potentially transformative alternative - solar electric cooking (PV-eCook). eCook also has a role to play in enhancing mini-, micro- and nano- grids, as well as unreliable national grid infrastructure as smart household level energy storage offers grid operators a new demand side management mechanism and households the ability to ride through blackouts.

Dr. Jon Leary of Gamos Ltd. and Loughborough University noted that their recently completed global market assessment highlights Zambia's enormous potential for eCook. Load shedding, relatively cheap grid electricity and an established electric cooking market create an attractive market for Grid-eCook, whilst the vast off-grid population and an emerging SHS industry offer huge potential for PV-eCook.

A prototype eCook device was demonstrated by cooking popcorn on an electric hotplate and beans on an electric pressure cooker. The prototype is capable of charging from both solar PV and ZESCO's grid and was built using off-the-shelf components already available in Zambia. The system is

LACK OF AWARENESS & HIGH UPFRONT COST WERE IDENTIFIED AS KEY BARRIERS; WHIST DEFORESTATION & LOAD SHEDDING WERE TWO MAIN DRIVERS.

THE DEPARTMENT OF ENERGY, ZESCO (ZAMBIA ENERGY SERVICES COMPANY), REA (RURAL ELECTRIFICATION AUTHORITY), ERB (ENERGY REGULATION BOARD), THE PRIVATE SECTOR, NGOS, TRADITIONAL LEADERS AND ACADEMIA WERE IDENTIFIED AS THE KEY ACTORS.

MICRO-FINANCING, PAY-AS-YOU-GO BUSINESS MODELS AND TARGETED TRAINING/AWARENESS RAISING WERE SEEN AS KEY ENABLERS.

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

sized for a small family doing most of their cooking on a mixture of efficient appliances and the electric hotplate.

Figure 14: Demonstrating the eCook Zambia prototype during the Kick-off Meeting.

5.7.2 Key learning points

Small group discussions revealed the key opportunities and challenges that eCook is likely to face in Zambia. Lack of awareness and the high upfront cost were identified as two of the key barriers, whist deforestation and load shedding were two of the main drivers. Micro-financing, pay-as-you-go business models and targeted training and awareness raising were seen as key enablers. The Department of Energy, ZESCO (Zambia Energy Services Company), REA (Rural Electrification Authority), ERB (Energy Regulation Board), the private sector, NGOs, traditional leaders and academia were identified as the key actors in this transition. Peri-urban households were identified as the key target market segment, with pay-as-you-go, Village Banking and cooperatives seen as the best marketing strategies to reach them.

PERI-URBAN HOUSEHOLDS WERE IDENTIFIED AS THE KEY TARGET MARKET SEGMENT, WITH PAY-AS-YOU-GO, VILLAGE BANKING AND COOPERATIVES SEEN AS THE BEST MARKETING STRATEGIES TO REACH THEM.

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

5.8 eCook Zambia Design Challenge

This section summarises the findings from the Design Challenge:

- ***The development of DC cooking appliances, empowering female entrepreneurs, LPG-eCook hybrids and building upon successful financing models (e.g. pay-as-you-go solar lighting and Village Banking) will be key enablers for eCook.***
- ***eCook can make a valuable contribution to demand side management of ZESCO's grid***
- ***Electric Pressure Cookers are already cheaper than charcoal on ZESCO's grid; however, they require the cook to change their behaviour. Cleanliness and speed of cooking are likely to be important selling points. Emphasising safety will be important.***
- ***Insulating cooking devices not only makes them more efficient, but also improves the experience for the cook on hot days who does not want to be heated any more.***
- ***Appliances are cheaper than batteries. Carefully selecting the most efficient electric cooking appliances will reduce the size and therefore cost of the battery bank by significantly more than the cost of the appliance itself.***
- ***Recharging an eCook device should be as simple as possible, or cooks may get to mealtime and be disappointed to find their battery is flat.***

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

Figure 15: Comparing a range of biomass cookstoves with an Electric Pressure Cooker (EPC) at the eCook Zambia Design Challenge in Lusaka.

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

5.8.1 Overview of event

The eCook Zambia Design Challenge aimed to facilitate the participatory design of eCook (a battery-supported electric cooking concept), allowing the generic concept to evolve around Zambian cooking practices. Entrepreneurs from the Zambian cookstove, solar lighting and utility sectors worked with everyday cooks to guide the evolution of eCook around their needs and aspirations. In the morning, the cooks used a variety of stoves to prepare typical Zambian dishes, offering feedback to the entrepreneurs on what design features they would like to see on a future eCook product. In the afternoon, groups of entrepreneurs presented their visions for eCook in Zambia. They presented the market segments they planned to target and the marketing strategies they would use to reach them; the business models they would use to make it affordable to poorer households; and the innovation needed to make it all work.

THE DEVELOPMENT OF DC COOKING APPLIANCES, EMPOWERING FEMALE ENTREPRENEURS, LPG-ECOOK HYBRIDS, & BUILDING UPON SUCCESSFUL FINANCING MODELS (E.G. PAY-AS-YOU-GO SOLAR LIGHTING AND VILLAGE BANKING) WILL BE KEY ENABLERS FOR ECOOK.

5.8.2 Key learning points

To summarise, this event has shown that efficient electric cooking appliances, such as electric pressure cookers, have significant potential for reducing the size of the battery and therefore the overall cost of an eCook system. They are particularly well suited to the foods that Zambians who fuel stack between charcoal and electricity use, i.e. charcoal for long boiling dishes such as beans and offals. However, there are significant challenges to be overcome in relation to behavioural change. Understanding how people cook, how they aspire to cook and what can motivate them to change their practices will be as important as further technical research to develop DC appliances that are more intuitive and can cook a wider range of foods.

ECOOK CAN MAKE A VALUABLE CONTRIBUTION TO DEMAND SIDE MANAGEMENT OF ZESCO'S GRID.

The eCook Zambia Design Challenge was an important step forward in the evolution of the generic eCook concept (cooking on battery-supported electricity) to the needs and aspirations of Zambian cooks. To continue this evolution, further work should focus on the key learning points identified here:

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Appliances are cheaper than batteries. Carefully selecting the most efficient electric cooking appliances will reduce the size and therefore cost of the battery bank by significantly more than the cost of the appliance itself. The result is a cheaper overall solution that will be affordable to even poorer consumers.

APPLIANCES ARE CHEAPER THAN BATTERIES. CAREFULLY SELECTING THE MOST EFFICIENT ELECTRIC COOKING APPLIANCES WILL REDUCE THE SIZE AND THEREFORE COST OF THE BATTERY BANK BY SIGNIFICANTLY MORE THAN THE COST OF THE APPLIANCE ITSELF.

Empowering women to lead this transition will be key. New livelihood opportunities will emerge at all stages of the value chain and women are best placed to take these on. This is both from the perspective of accelerating uptake (for example, women are much more likely to buy a product marketed to them by other women) and ensuring the broadest developmental impact by contributing to gender equity.

Building upon successful financing models will be key to unlocking the poorer and harder to reach rural markets. For example, pay-as-you-go solar lighting and Village Banking.

The development of DC cooking appliances will be a key enabler for eCook. AC appliances require an inverter, which adds cost, bulk, unreliability and inefficiency to the system.

Demand side management. eCook can make a valuable contribution to demand side management of ZESCO's grid, reducing the likelihood that load shedding will return. Especially if the devices can be controlled remotely with a SIM card so that the battery can be charged when surplus power is available instead of at mealtimes when demand is already peaking.

Electric pressure cookers are already cost competitive with charcoal; however, they require the cook to change their behaviour. Further research is required on how the design could be made more intuitive. Initially, they would need to be packaged with an instruction manual, dedicated cookbook for Zambian foods, and/or training for first time users.

INSULATING COOKING DEVICES NOT ONLY MAKES THEM MORE EFFICIENT, BUT ALSO IMPROVES THE EXPERIENCE FOR THE COOK ON HOT DAYS WHO DOES NOT WANT TO BE HEATED ANY MORE.

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

An electric pressure cooker alone may not be enough for a household to do all their cooking, as some foods require special pots and constant monitoring. Manually adjusting the heat in the pot is also an important feature that is not available on most models available on the market today.

Insulating cooking devices not only makes them more efficient, but also improves the experience for the cook on hot days who does not want to be heated any further!

Recharging an eCook device should be as simple as possible, or cooks may get to mealtime and be disappointed to find their battery is flat.

LPG-eCook hybrids. The perception of LPG as dangerous by many Zambian households may well change in the future. Investigating the strengths and weaknesses of electric cooking appliances and LPG and considering the value offered by hybrid systems would be wise.

Safety of pressure cookers. Pressure cookers also considered by many to be unsafe, so awareness raising about their safety features may well be necessary.

Cleanliness and speed of cooking are likely to be important selling points for electric pressure cookers.

ELECTRIC PRESSURE COOKERS (EPCS) ARE ALREADY CHEAPER THAN CHARCOAL ON ZESCO'S GRID; HOWEVER, THEY REQUIRE THE COOK TO CHANGE THEIR BEHAVIOUR.
CLEANLINESS AND SPEED OF COOKING ARE LIKELY TO BE IMPORTANT SELLING POINTS. EMPHASISING SAFETY WILL BE IMPORTANT.

RECHARGING AN ECOOK DEVICE SHOULD BE AS SIMPLE AS POSSIBLE, OR COOKS MAY GET TO MEALTIME AND BE DISAPPOINTED TO FIND THEIR BATTERY IS FLAT.

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

6 Conclusion

Electricity is the aspirational cooking fuel for most Zambian households, however charcoal use is deeply embedded within society. In 2013, 12% of Zambians (2 million) were already using electricity as their primary fuel, however recent load-shedding caused many of these users to revert back to charcoal. 37% of Zambians (6 million) use charcoal as their primary cooking fuel - globally, only Liberia, Haiti and Togo have higher proportions of their population cooking on charcoal. In fact, it is highly likely that many more than 2 million Zambians own an electric hotplate, as it is often used in a fuel stacking scenario with a charcoal mbaula. The Zambian mbaula is an extremely inefficient device constructed purely from thin sheet metal, allowing heat to escape into the surroundings rather than into the pot. It's appeal primarily relates to its extremely low purchase cost (just 1.5USD) and its familiarity.

There is a false perception that electricity is expensive and therefore, most Zambian households who own an electric hotplate will only use it to cook 'lighter' or 'quicker' foods, such as frying an egg. For 'heavier' or 'longer boiling' dishes such as beans, the mbaula would undoubtedly be lit. Although electricity prices have recently increased from 0.05 to 0.09USD/kWh, this study has shown that cooking with an electric hotplate is still cost comparable with charcoal. In fact, electric cooking is much cheaper if energy efficient appliances and practices are employed. What is more, a lifeline tariff of just 0.015USD/kWh is available for the first 200kWh in each month (equivalent to 6.6kWh/day) and the evidence from the cooking diaries has shown that most households use far less than this for cooking. However, the focus groups showed that poorer households often share electricity meters with their landlords/ladies, limiting their access to this lifeline tariff that was designed to support them.

During load shedding, charcoal production increased significantly to meet the growing demand, accelerating deforestation and stepping up the pressure on Zambia's already strained natural resources. During blackouts, households previously accustomed to the convenience of cooking on a hotplate were forced to light up their mbaulas even for 'lighter' foods. Despite promotion by the government during load shedding, LPG is not yet popular in Zambia. There is a perception that it is dangerous due to the risk of a cylinder exploding, however this may well change, especially as the fuel becomes more popular in neighbouring nations. If it does, a fuel stacking scenario with energy-efficient eCook devices is likely to be highly attractive to everyday cooks.

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

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stoves**.** In fact, an opportunity exists today for the promotion of electric pressure cookers as a more efficient alternative to hotplates. This could be catalysed if ZESCO, Zambia's state-owned utility, offered an on-bill financing option, as the initial purchase cost and awareness of technology are both significant barriers. However, this would need to be accompanied by training for first time users on how to use them efficiently. The results of the bean boiling challenge indicate that they could actually increase demand if households who previously used charcoal to boil beans all suddenly switched to electricity without even putting the lid on!

The emerging solar home system and mini-grid markets in Zambia are paving the way for PV-eCook. Several private companies are now offering pay-as-you-go solutions and Fenix have recently launched Zambia's first mobile-money enabled pay-as-you-go solar package. Zambia has very favourable environmental conditions for solar and some micro-hydro potential.

However, the challenges of finding lithium ion batteries and DC cooking appliances during prototyping highlight the need for further supply chain and technology development. Lithium ion batteries are available, but with a long lead time and a high cost. However, this was to be expected, as this is an emerging opportunity, which since 2013, we have predicted will not be commercially viable until 2020. 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. DC cooking appliances that can cook Zambian foods efficiently need to be developed to reduce the size of battery and bring down the overall cost of the system.

The detailed findings from each of the activities carried under the eCook Zambia 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, 2015c; 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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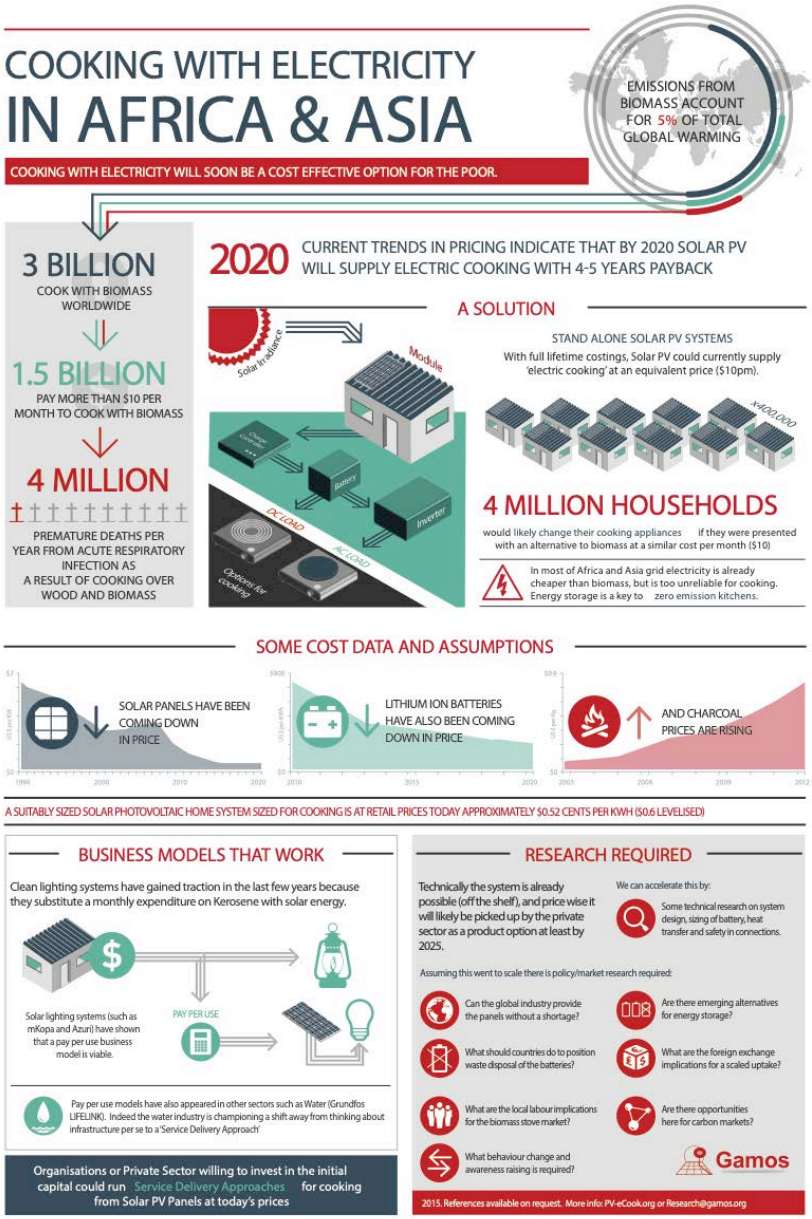

Figure 16 Infographic summarising the concept in order to lobby research and policy actors.

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

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[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.

[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.

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[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.

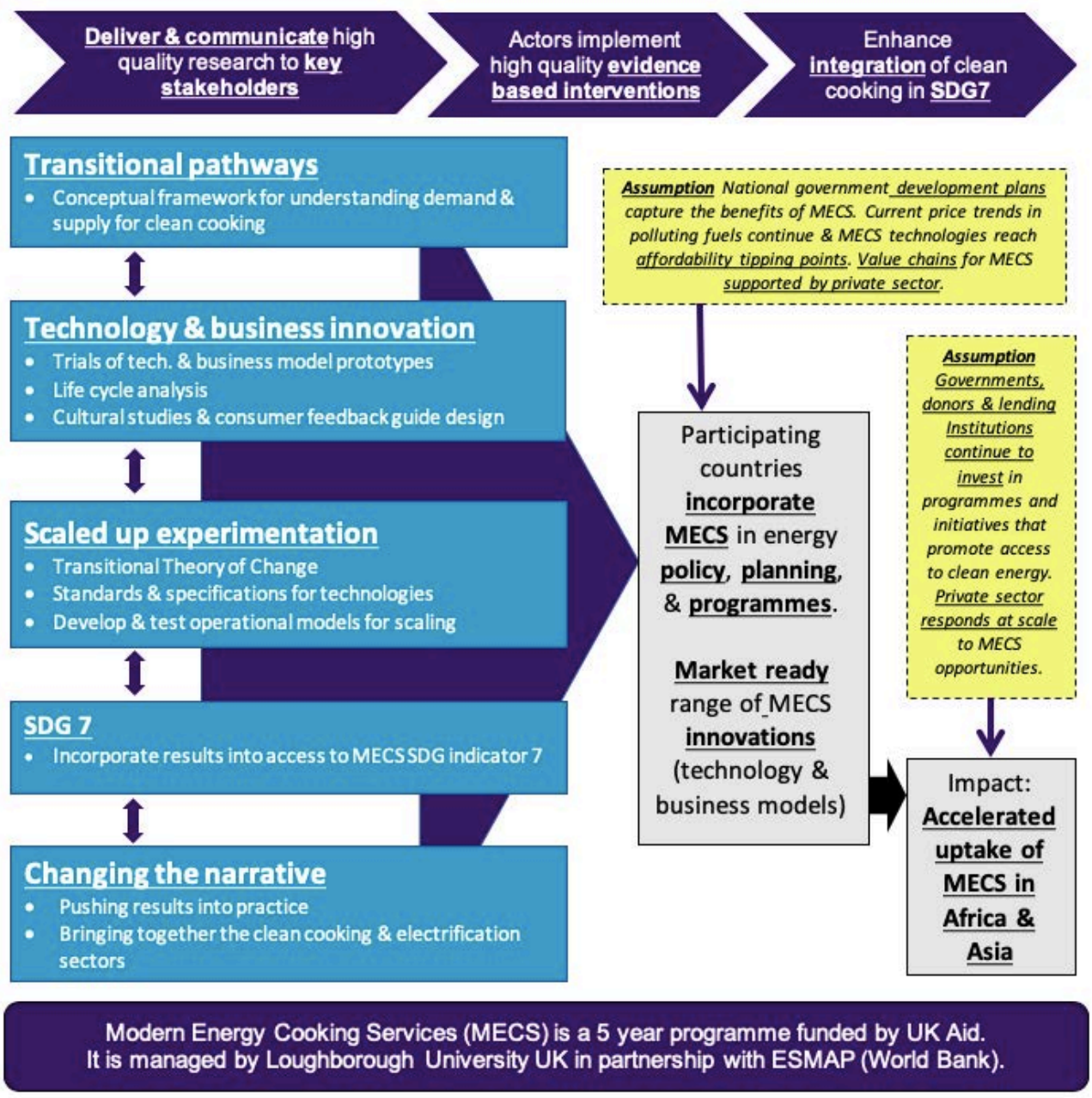

Figure 17: Overview of the MECS programme.

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