Modern Energy Cooking Services Electric Cooking Outreach (MECS-ECO) Background Research – A Review of Current Thinking

1 Introduction

The Modern Energy Cooking Services Electric Cooking Outreach (**MECS ECO) competition will be launched on 11th December 2019 and seeks to fund projects which will support**

- **Community-Scale pilot studies to accelerate the uptake of efficient electric cooking appliances.**
- **Market assessments to gather intelligence on the opportunities emerging in DFID priority countries for efficient electric cooking appliances.**

The **Modern Energy Cooking Services Electric Cooking Outreach** (MECS-ECO) is a challenge fund that enables the Modern Energy Cooking Services programme (and thus Department for International Development (DFID)) to fund research projects to facilitate a transition to modern energy cooking services in countries supported by DFID.

This document provides a background to the current thinking on the electrification of cooking. Applicants are advised to consider this research along with the Guidance and Competition Specification documents to ensure the questions within the Grant Application Form are addressed appropriately.

The number and scope of the MECS Challenge Fund competitions varies with each round to remain in line with the MECS programme's needs. This challenge fund is formed of two targeted calls in specific thematic areas.

These will be:

- **Theme One: Community-Scale pilot studies to accelerate the uptake of efficient electric cooking appliances.**
- **Theme Two: Market assessments**

All competitions will use a Grant Application Form and assessment criteria. Priority will be given to Applications that collaborate with individuals or organisations in countries supported by DfID (see section 28 of the FAQ's).

In MECS-ECO each individual application must be specific to one of the two themes. If applying to more than one call, applicants will need to demonstrate an ability to deliver the projects. There is a limit of two applications by a company in total with one from each of the themes

Applicants should consider and incorporate accessibility (needs for access of those with impairments or disabilities) within their project specifications.

2 Introduction to Modern Energy Cooking Services (MECS) – the programme

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 have had limited impact on development outcomes. The multiple problems caused by biomass-based cooking, which affect 3 billion people in low income countries, result in 4 million premature deaths annually (which is more than the combined deaths by Malaria, HIV and TB, WHO 2018[i]), contribute to climate change and cause loss of economic opportunity.

According to the World Bank a 'business-as-usual' approach will not deliver on SDG Global Goal 7 and will result in more people using biomass for cooking in 2030 than is the case now (World Bank 2015[ii]). A different strategy that supports the transition of low-income economies to the use of modern energy cooking services, creating access to genuinely clean cooking is needed to change this situation. Using emerging innovations and technologies could potentially **leapfrog existing harmful practices in cooking with significant development benefit**.

This programme, Modern Energy Cooking Services (MECS) 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). A key driver is the trajectory of costs that show 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 (Figure 1). For this programme, any research related to biomass cooking is out of scope.

Whilst the overall MECS programme will focus on cooking with genuinely clean modern fuels - including gas (both LPG and Biogas), the main technology of focus for this challenge fund is Electric Cooking Appliances (particularly pressure cookers) and their acceptance both to users and to those managing loads and delivery of grid and off-grid electricity.

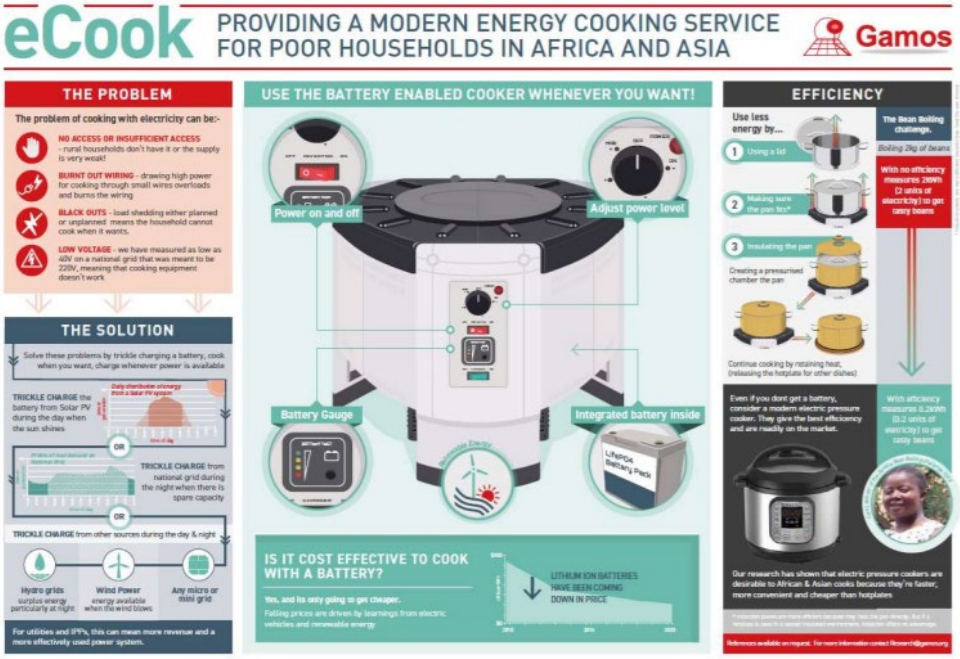

Figure 1. Research by the UK universities and innovators is laying the groundwork for a different approach to the enduring problem of cooking

Lessons learned about transitioning markets to electricity are likely to be applicable to gas, and vice versa. Beyond the technologies, research will capture other drivers for transition including understanding and optimisation of fuel stacking; cooking demand and behaviour adaptation; and establishing the evidence base to support a policy enabling environment that will underpin a pathway to scale and support well understood markets and enterprises.

More details can be found on the website www.mecs.org.uk

3 MECS-ECO – The challenge fund

3.1 Why focus on electricity?

Definitions of energy access are often synonymous with electricity access, even though SDG 7 aspires to ensure access to affordable, reliable, sustainable and modern energy for all, clearly defining that households require both access to electricity and clean cooking. Figure 2 shows that if we continue on the 'business as usual' trajectory, the world will fall well short of this aspirational target in both respects. The access gap for clean cooking is predicted to be far bigger than that for electricity.

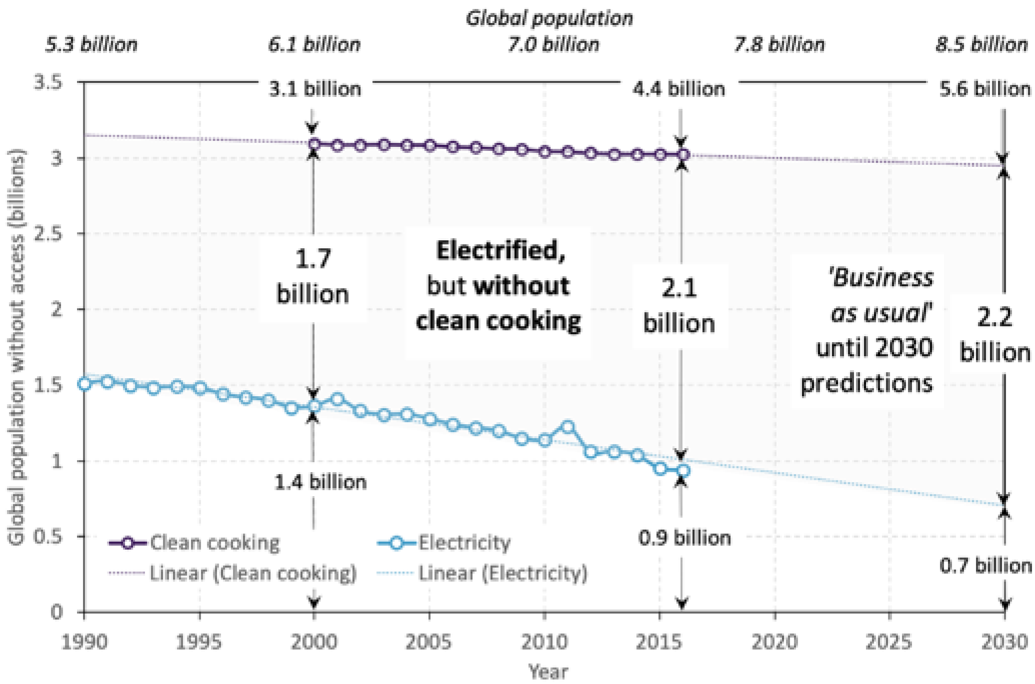

Figure 2: Trends in global access to electricity and clean cooking (Batchelor et al., 2019). Historical electrification, clean cooking and global population data sourced from the World Bank's World Development Indicators (WDI) (World Bank, 2019b). Future population predictions sourced from United Nations World Population Prospectus (United Nations, 2017). Linear forecasting used to predict global access beyond 2016.

In 2017 the number of people without electricity access fell below 1 billion, a fall of 97 million compared to 2016. However, three-quarters of the 570 million people who gained access since 2011 are concentrated in Asia (IEA 2018). Sub Saharan Africa has major challenges, but nevertheless is making gains.

The proposition that electricity could be used for clean cooking is deeply integrated with the progress on electrification. The increase in grid and off grid capacity has been significant over the last few years and created contexts whereby the idea of electric cooking could be considered. Indeed, its affordability particularly in urban areas suggests an easy gain in the challenge of clean cooking.

Providing universal access to affordable, reliable, sustainable and modern energy for all is not an easy target. The population of sub-Saharan Africa (SSA) is expected to double by 2050; by 2030, electricity supply across Africa will need to triple to meet the demand from demographic growth in these economies and their changing lifestyles and expectations. At current investment rates the SSA population without electricity is projected to stabilise at around 585 million people in 2030 – however, that is not to ignore that 1 billion will be connected. Africa currently has 80 GW of new electricity capacity under construction, while the Africa Renewable Energy Initiative aims to mobilise investment for at least 300 GW of renewable energy generation by 2030. Energy trade through regional power pools is a core part of the long-term strategy in terms of distributed generation and to increase the share of renewable energies.

Renewable energy generation itself has the advantage of a relatively short design and build cycle, compared to major hydropower installations. Utility-scale renewable energy projects in particular solar PV and wind, have grown in recent years and thanks to appropriate frameworks, power procurements have achieved record-low prices for new generation in many African countries. Changes in the policy environment have opened up generation to private investment for renewable technologies to make additions to national grids. 83% of new independent power producer (IPP) procurements are for renewables. From 2015 to 2016, Africa-focused investments were $4.3 billion, although about 26% of those power sector commitments in Africa were in just four countries. Nevertheless, there are about 270 utility scale projects currently commissioned in more than 30 African countries totalling over 27 GW of new capacity and representing about $47 billion of investment.

The landscape of thinking about electricity distribution is also changing conceptually and in practice, both globally and in Africa and Asia. Decentralised generating capacity, and 'prosumer' (where the consumer becomes their own producer of electricity) are two key concepts beginning to change the landscape. These concepts include stand-alone mini grids and (solar) home systems. Cost reductions of renewable technologies and improved reliability enable these off-grid solutions to provide timely alternatives to centralised power infrastructure for different end-users. While grid extension-based electrification has long been perceived as the reference model in developing economies, private sector is spearheading the design of innovative electricity supply models based on off-grid technologies.

According to a recent World Bank report about **half a billion people in Africa and Asia could be cost-effectively supplied with electricity through mini-grids**. At least 154 million people in the world were estimated to have benefitted from electricity services from off-grid renewable energy technologies through 2017. These solutions hold the potential to successfully address peri-urban and rural contexts that are characterised by limited, sparse demand as well as lower ability to pay among customers. 57% of planned mini-grids are based on solar-hybrid technologies, and they aim to connect more than 27 million people globally at an investment cost of €11 billion. At present, mini-grid investments in sub-Saharan Africa alone are about $3.6 billion. Mini-grid models are evolving, from providing only basic electricity services for households, to providing electricity services for income generating activities.

In 2010, building on mature solar and mobile money technologies there were a number of start-ups offering **a new generation of solar home systems (SHS) to remote rural markets with sustainable, affordable and safe electricity on market terms.** Most of these started by providing basic lighting and phone charging utilising the system as a service with prepaid mobile payments or on a pay-as-you-go (PAYG) basis. The role of mobile money was to enable companies to reduce the costs associated with bill recovery in remote rural areas, while maximising affordability and responding to the customers need to pay by small regular payments. According to GOGLA, more than 3,000 PAYG SHS are sold every day by nearly 30 companies operating in at least 32 countries in SSA. The number of PAYG SHS sold in Kenya alone is about to reach 300,000 kits per year,[1] which is about equivalent to the annual growth in new rural households. The resilience of current PAYG business models is still undecided. The acquisition of new customers is a significant expense, and to get the return based on a low load consumption of a simple light makes profitability challenging.

There is then the prospect of integration between the three modes of electrification – stand-alone systems, mini-grids and grid. The commercial, technological, and regulatory development of the three delivery modes is currently poorly coordinated, if at all. Distribution planning will likely

[1] Ibid

become more coordinated with transmission and large generation planning, and even with regional or multinational power sector planning. This should also integrate climate change and environmental factors and forecasts. Electrification is not a static process, but rather a dynamic one. Mini-grids and stand-alone systems are crucial solutions to deliver initial electricity access relatively faster than grid-based solutions. They can unlock latent community demand for sustainable electricity.

Mitigating upfront payments. A transition to and uptake of electric cooking depends not only on the affordability to the household per se, but to the mechanisms by which a household may spread payments. The requirements are to mitigate the upfront cost of devices to the consumer. Utilities, with excess generating capacity and wanting to encourage more demand, could offer the initial cost of an EPC on a lease basis, or a pay as you go through perhaps on bill financing. The same is true for off-grid solutions including mini grids and solar home systems. However, in the case of these latter options, the developer themselves need finance to mitigate the upfront capital expenditure of investment in renewable energy, with enough flexibility in terms of debt, equity or grant financing that they can pass the benefits on to the consumer in terms of mitigating the household upfront expenditure on appliances.

By introducing a 'single investment strategy', incorporating clean cooking into the growth of renewable energy technology for grid and off-grid development, the various financial instruments currently in play to encourage renewable technologies come to the foreground. By inclusion in planning for larger projects, clean cooking could leverage long-term loans associated with a special purpose vehicle (SPV), typically involving guarantees, loans and project bonds. Auctions have brought the costs of development and construction of RE down, the availability of a feed-in-tariff has been a win-win for development of distributed electric generating capacity based on RE, tax incentives have enabled greater revenue generation. A key point is that as renewable energy investments grow over the coming ten years, clean cooking has an opportunity to leverage such larger investments and to use power purchase agreements to bridge the current shortfall in SDG7 clean cooking requirements.

Within this context, load management for cooking needs to be deeply embedded in all planning of electrification. The challenge fund is designed to gain greater understanding of how efficient cooking appliances may affect the load management and design of grid and off-grid electricity supplies.

3.2 Why a focus on electric pressure cookers?

The competition is restricted to electrical energy efficient cooking appliances; the following section presents some data and findings on electric pressure cookers (EPCs), rice cookers (and slow cookers) each of which can considered an energy efficient appliance.

The electric appliance commonly found in retailers in sub Saharan Africa and Asia, is a hotplate. The cheaper hotplates have a heating element exposed to the air, and a pan sits on top of it. The heat transfer between hotplate and pan has considerable losses, and for this reason some people suggest induction stoves. While induction stoves improve the heating up of the pan, the sides of the pan still radiate heat, and for longer term cooking such as simmering beans for an hour or more, the losses are considerable.

Batchelor et al explain that unlike other cooking fuels that rely on combustion, electricity does not need air flow to create heat. It therefore opens up the possibility of the food being cooked in a highly insulated environment. This principle is used in many popular electric cooking appliances, such as rice cookers, slow cookers and thermo pots. Having raised the temperature of the device to the cooking temperature, the insulation reduces heat loss, meaning that little to no extra energy is required to continue to cook the food (see Figure 3). Indeed this is the basis of the 'fireless' cooker, sometimes called Wonderbag or jiko. A pot of beans, for instance, is cooked for some minutes to remove toxins, and then taken off (any) stove and placed in the fireless cooker. With the highly insulated bag keeping the temperature high, the beans continue to cook – thus saving fuel.

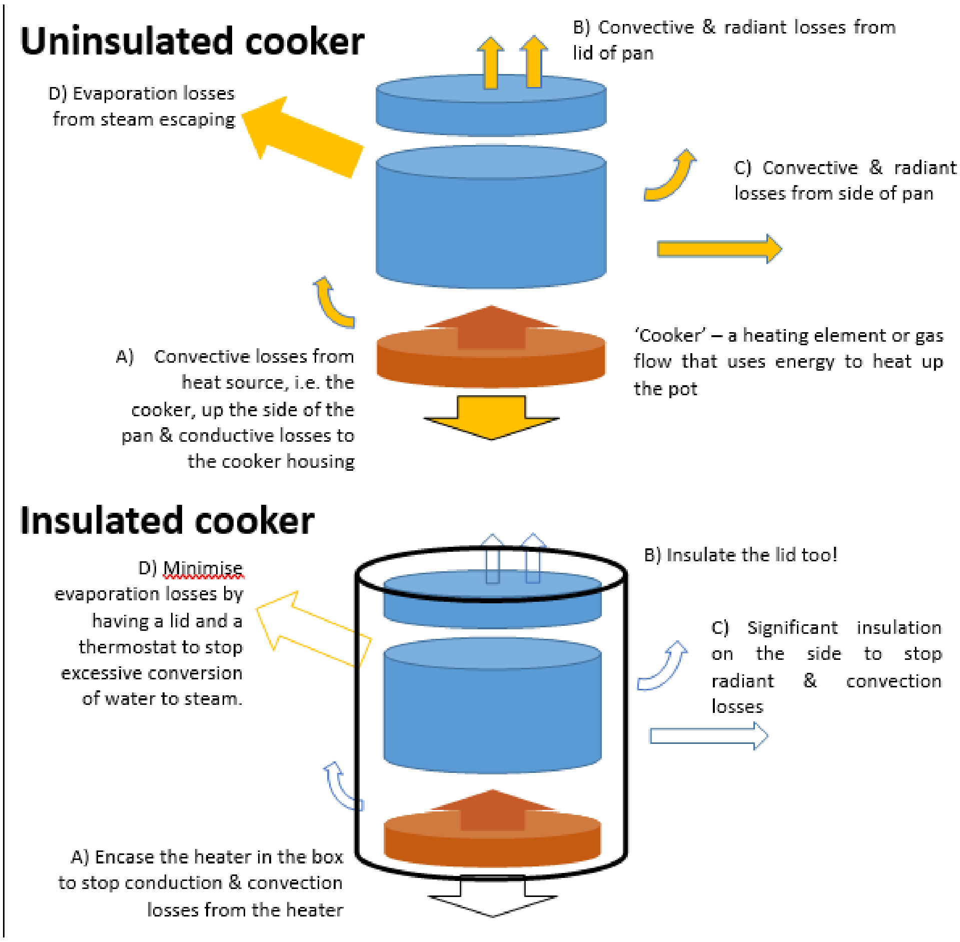

Figure 3: Heat loss mechanisms mitigated by insulating the cooking pot and heating device. Adapted from Batchelor et al.[iii].

Whilst rice cookers are also insulated and automated, they are not sealed and their control system is much simpler, merely dumping full power into the pot until all the water has been vaporised. However, they are much more useful than their name suggests, as one participant noted: "I have learnt that rice cookers are badly named – they can cook so much more than rice!" It should also be noted that because of the insulation, 'full power' on a rice cooker is generally much lower than on a hotplate, which has important implications for systems where peak power is a constraint, such as battery-supported cookers or mini-grids.

In addition to minimising heat losses through insulation, the Electric pressure cooker (EPC) adds the option to pressurise. This raises the boiling point of water and enables the food to be cooked faster. Figure 4 shows that after the initial pressurisation, the hotplate in an EPC only comes on periodically to maintain the temperature in the sealed environment inside and resulting in considerable energy savings. As Prof. R. Khan states: "*it is temperature that cooks food, not energy per se*". The EPC (or multicooker) simply combines an electric hotplate, a pressure cooker, an insulated box and a fully automated control system (Figure 5).

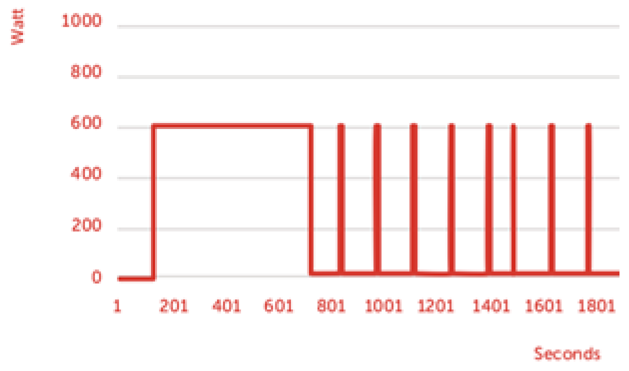

Figure 4: Typical load profile for a 700W rated EPC on a half hour cooking cycle

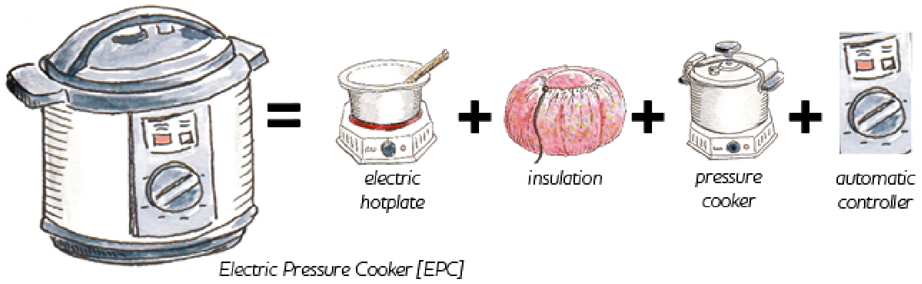

Figure 5: The fundamental components of an EPC.

As stated above, the EPC goes further by pressurising the system; during this stage the boiling point of water is raised up from 100°C to around 120°C. The increased temperature enables the food to cook faster, resulting in shorter cooking times and therefore reduced energy consumption. 'Manual' stove-top pressure cookers (heated by charcoal and gas) are common in East Africa, although their safety is of concern to many users. EPCs integrate an array of safety and control features, offering multiple redundancies if any one were to fail (see Figure 6). It controls the energy input into the device, such that the cook can walk away and leave the device cooking autonomously.

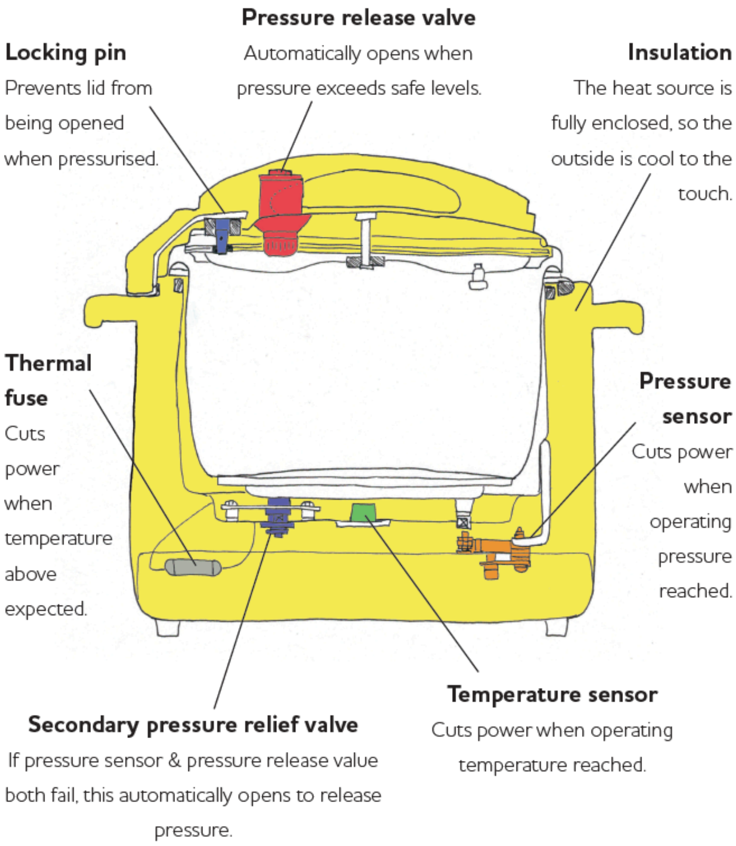

Figure 6: Automatic control and safety features of a typical EPC.

While the sealed environment has a positive effect on energy consumption, the sealed, blind, nature of pressure cooking can make inexperienced cooks nervous. They believe that more stirring is required, or they need to see the food to make sure it is cooking or has not overcooked. Such responses hold back many cooks from utilising the EPC. In fact, much less stirring is needed, as no water escapes from the sealed environment during pressure cooking and the temperature is automatically limited to 120°C, so it is almost impossible to burn the food. In the data below we identify whether these beliefs are an insurmountable barrier to using EPCs in East and Southern Africa or whether the other benefits might outweigh this particular challenge.

3.3 How energy efficient are EPCs at cooking East/Southern African foods under controlled conditions?

Controlled tests in a 'kitchen laboratory' for the eCookBook in Kenya revealed that EPCs can save up to 85% of the cost of cooking 'heavy foods' on charcoal. 'Heavy foods' typically involve boiling for an hour or more on conventional stoves. They include beans, tripe, githeri (beans and maize stew) and stews with tougher cuts of meat.

A fireless cooker utilises the principles of insulation (but not pressurisation) as a means to save fuel on any conventional cooking device during the simmering section of a recipe. For beans, the pot is heated until they are partially cooked (there is a need to cook until the toxins are removed) and then the pot is transferred into the fireless cooker and sealed in an insulated environment. Because the temperature is maintained with minimal heat losses, the food continues to cook with no further input of energy. Figure 7 shows that judicious use of the fireless cooker can save between 10 to 15 KSh (0.10-0.15 USD) on fuel for charcoal, kerosene, LPG or an electric hotplate.

As it is an insulated appliance, a fireless cooker is effectively inbuilt into every EPC, allowing it to prevent heat from escaping from the pot throughout the entire recipe (not just the simmering stage). As a result, Figure 7 shows that whilst cooking on LPG or an electric hotplate works out roughly the same cost as charcoal, the pressurisation and automatic control features of the EPC make it an order of magnitude cheaper. Kerosene is slightly cheaper than charcoal, LPG or an electric hotplate, however still several times more than the EPC.

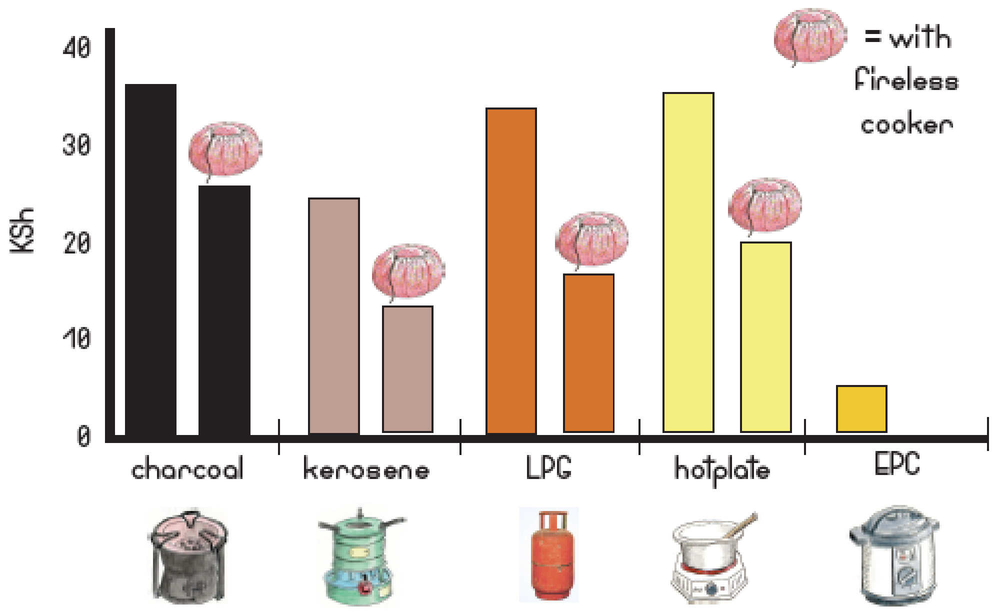

Figure 7: Cost comparison for ½kg dried yellow beans on the most popular fuels in urban Kenya (Nairobi costs, July 2018) [27]**.**

Energy savings on 'heavy foods' are clearly substantial in controlled and semi-controlled conditions; however, it is important to understand how they fit into the kitchen routines of everyday cooks. This is part of the competition brief. The evidence from the cooking diaries shows that 'heavy foods' comprise approximately one third of all dishes on a typical urban East African household's menu (see Table 1). In fact, many other dishes can also be cooked on an EPC: some are intuitive (e.g. rice), whilst others require some behaviour change (e.g. using a heatproof glove to hold the pot still whilst stirring ugali), however there are several that are extremely challenging on most models of EPC available on the market today (e.g. chapati).

A typical East/Southern African menu can be understood as composing of a set of categories of dishes, each with varying degrees of compatibility with EPCs. Table 1 proposes the following categories:

- 'Heavy' foods – usually require boiling the main ingredient (e.g. beans) for over an hour on a conventional stove and may also contain a frying stage with extra ingredients to add flavour (e.g. a tomato and onion sauce).

- Staples – normally boiled for approximately half an hour. Some require stirring (e.g. ugali, porridge), but others are simply left to boil (e.g. rice).
- Quick fryers – usually fried for 5-15 minutes, a shallow pan and high heat is often preferred, but not essential. Access to the pan is usually required to stir the food and prevent burning.
- Deep fryers – food is completely submerged in oil at 175-190°C.
- Flat breads – medium heat, evenly distributed across a shallow pan is required to cook the whole of the flat bread at the same rate. Access to the pan is required to turn the bread frequently.

The data suggests that it is actually possible for urban Kenyan households to cook over 90% of their menu on an EPC.

Table 1: Categorisation of typical Kenyan foods by their compatibility with EPCs.

Food category	Frequency on urban Kenyan menu	Typical dishes	Compatibility with EPCs	Energy savings with EPCs	Enablers
'Heavy foods'	32%	Beans, matumbo (tripe), meat stews	Users instinctively use EPCs	High (50-90%)	Cooking times & water quantities for popular local foods
Staples	39%	Ugali (maize meal), rice	Users use EPCs if encouraged	Moderate (20-50%)	Demonstrations, extra EPC
Quick fry	20%	Sukuma wiki (kales), eggs	Users use EPCs if encouraged	Low (5-20%)	Demonstrations, manual heat control, extra EPC, shallow pan
Deep fry	2%	Mandazi (donut), fried chicken, chips	Users cannot currently use EPCs	Low (5-20%)	Manual heat control or deep fry settings (175-190°C)
Flat breads	4%	Chapati (flat bread)	Users cannot currently use EPCs	Low (5-20%)	Manual heat control & shallow pan
Other	3%	Unknown			

Table 2: Measured and modelled energy consumption for 100% electric cooking on a mixture of inefficient and efficient appliances.

	Median daily energy consumption (kWh/ household/ day)	Mean Household size (no. ppl)	Median per capita daily energy consumption (kWh/person/day)
Zambia			
100% electricity measured, median	1.63	7.9	0.21
Total consumption if EPC at 90% of menu	*1.1*		*0.14*
Tanzania			
100% electricity measured	2.06	4.2	0.49
Total consumption if EPC at 90% of menu, modelled	*1.44*		*0..34*
Kenya			
100% electricity measured, (with EPC proportion	1.4	3.1	0.46
Total consumption if EPC at 90% of menu	*0.96*		*0.30*

3.4 User experience of EPCs

Whilst cost, driven by energy efficiency, may be a strong driver, if the cooker is not easy to use and the food is not as tasty as usual, households will be unlikely to adopt it. This section presents insights from the exit survey from the Kenya cooking diaries, which asked the households who had been using EPCs (plus rice cookers and hotplates) for a month, about their experience with this new cooking device.

'Heavy foods' such as beans or matumbo (tripe) that usually require boiling for an hour or more to soften are unsurprisingly rated as much easier to cook on the EPC than the hotplate (Figure 8). In contrast, foods that require manual heat control &/or a shallow pan, such as chapati or mandazi, are rated much easier on the hotplate.

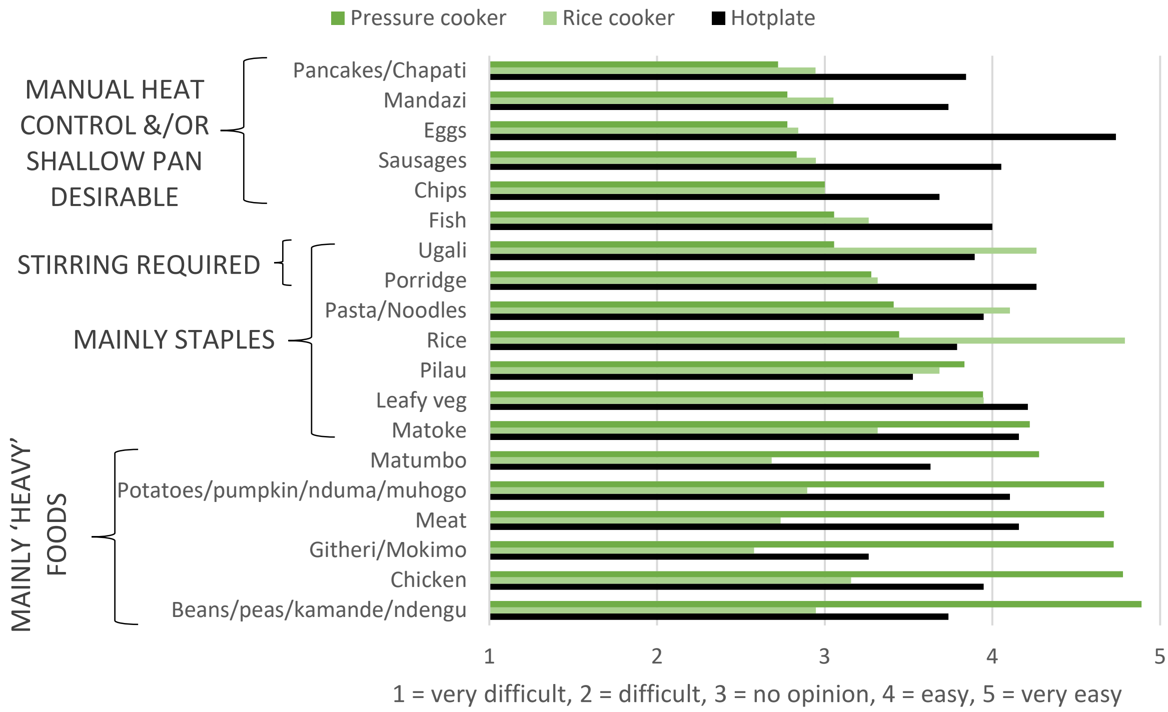

Figure 8: Average responses to the question from 20 trial households in Kenya: "how easy is it to cook each food on the eCookers?" Ranked by ease of cooking on an EPC.

Perhaps surprisingly to some, food cooked on electricity was rated as the tastiest, just ahead of LPG & charcoal (Figure 9). Wood & kerosene lag far behind. Figure 10 shows that whist some respondents missed the smokey flavour in specific foods, many did not miss it at all.

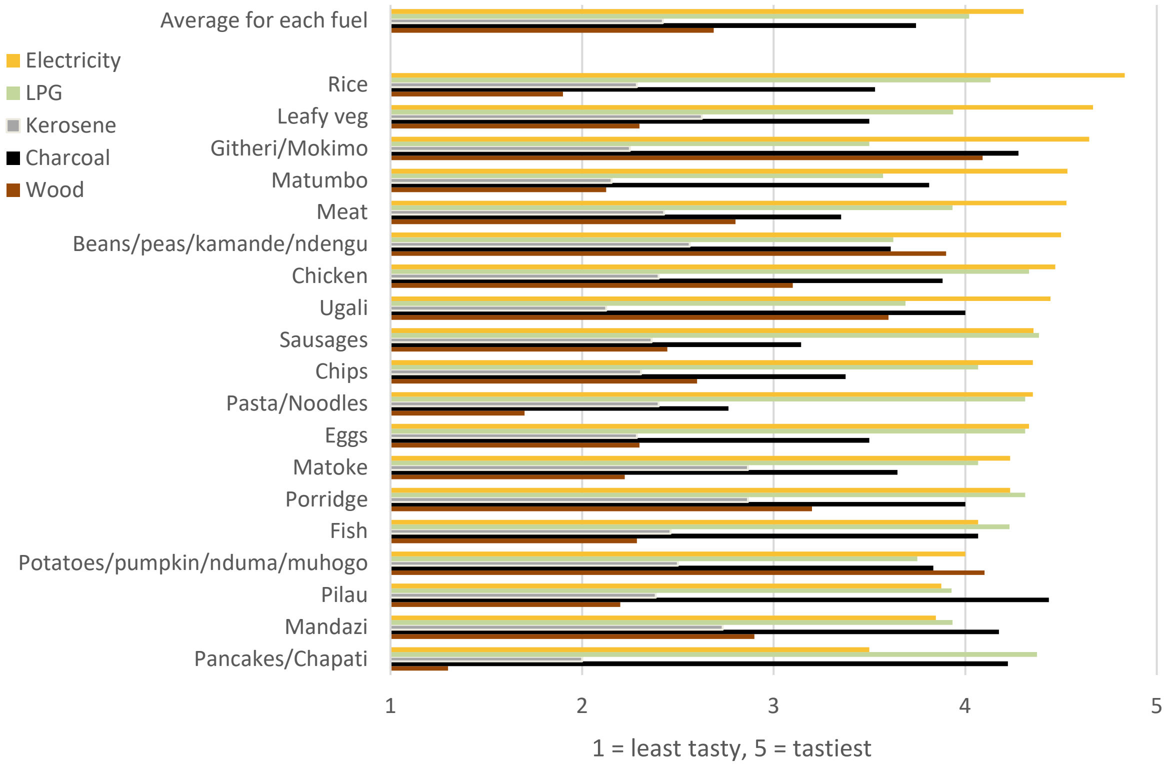

Figure 9: Average responses to the question from 20 trial households in Kenya: "Do foods taste different when cooked on different fuels? If so, please rank each fuel for each food." Foods ranked by tastiness when cooked with electricity.

Figure 1: Responses to the question from 20 trial households in Kenya : "Do you miss the smokey flavour of food? If so, for which dishes in particular?". Words sized according to the number of responses.

The automated control systems of the EPC & rice cooker makes cooking easier, enabling multi-tasking & preventing food from burning. Being able to cook faster & keep the kitchen clean are also both highly valued by the urban participants of the Kenya cooking diaries study, however, priorities may well be different in rural areas (Figure 11). Figure 12 shows that the rice cooker & EPC have clearly found a place in almost every participant's home.

Figure 2: Responses to the question from 20 trial households in Kenya: "What were the best/worst things about cooking with electricity?"

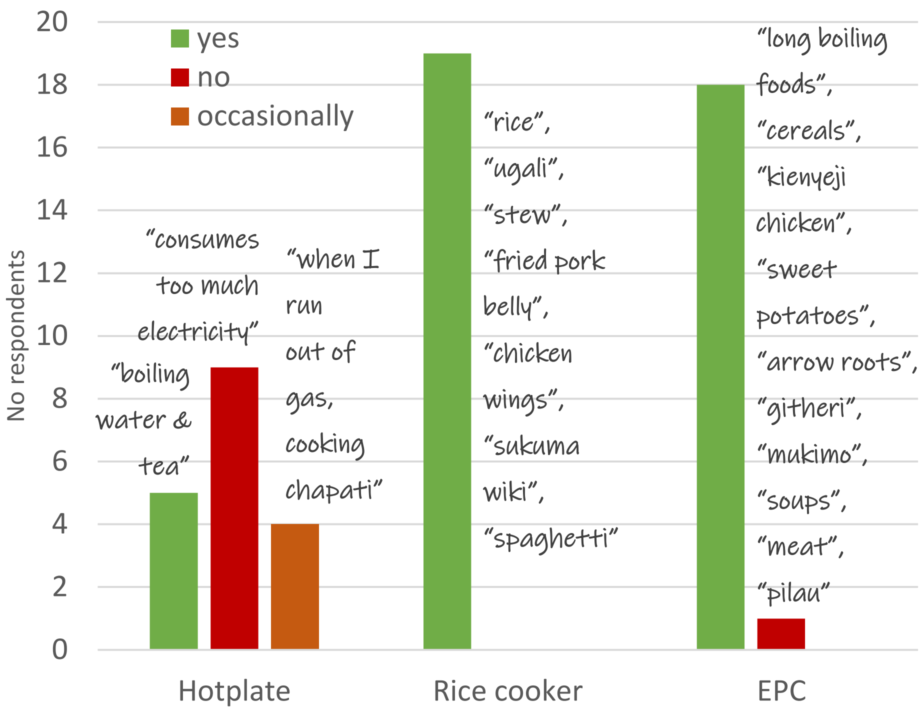

Figure 3: Responses to the question from 20 trial households in Kenya: "We are done with our survey and are leaving the cookers with you. Will you continue using the e-cookers or will you switch back to your old stove?"

The evidence to date shows that EPCs are significantly more energy efficient than electric hotplates in both laboratory and real kitchen environments. The empirical data from the kitchen laboratory shows that EPCs can cook the most energy intensive dishes with just one fifth of the energy of electric hotplates. This is complimented by results which show that everyday cooks choose EPCs for about half of their cooking and that across the full range of dishes they were used for, they use approximately half the energy of electric hotplates. Cooking with both hotplates and EPCs was found to use approximately 2kWh per household per day, with the cook choosing to cook 50% of the menu on an EPC. Analysis of the range of dishes that make up a typical menu and experimentation in the kitchen laboratory has shown that EPCs are capable of cooking over 90% of the typical urban Kenyan menu. Training and experience are likely to move the proportion of EPC use from 50% nearer to 90%. In poorer households which are used to only having one 'device' for cooking, the EPC is likely to be used for a greater proportion of the menu.

3.5 Is the call restricted to just EPCs/rice cookers?

You may suggest using other electrical energy efficient cooking appliances. We acknowledge that in some markets and some specific cultural cooking task specific appliances may be an appropriate step in the transition to modern energy like the kettle or bread making machine. For instance, lighting a charcoal stove just to boil water for tea is much more expensive than boiling the water in an electric kettle. As such kettles could be a first step in a transition.

You may suggest other appliances, but there needs to be a reasoned presentation on why the device might assist in a transition to electrical use for cooking, and there will be a weighting in the scores based on the known efficiency of the proposed appliance.

3.6 Global LEAP

The Global LEAP Awards will launch the first-ever competition for appropriately designed, highly energy efficient electric pressure cookers suitable for use in off- and weak-grid settings in January 2020. Winners and Finalists of the 2020 Global LEAP Awards Electric Pressure Cooker competition will be eligible for up to $200,000 in innovation prizes as well as results-based financing to support bulk procurement. Find out more at: https://globalleapawards.org/electric-pressure-cookers

A key output of the Global LEAP process is a buyers guide, highlighting the most energy-efficient, user-friendly, durable and safe EPCs available on the market today. Given that contracts for this challenge fund will be issued at around the same time as the buyers' guide is published, applicants for the challenge fund will be able to refine and determine the appliance make and purchase at the time of contracting, in order to make use of the findings of the Global LEAP.

[i] WHO 2018 http://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

[ii] World Bank (2015); Atur, Varadarajan; Jammi, Ramachandra. 2015. World Bank Group support to electricity access, FY2000-2014: an independent evaluation. Washington, D.C. : World Bank Group.

[iii] Leary, J., Scott, N., Numi, A., Chepkurui, K., Hanlin, R., Chepkemoi, M., Batchelor, S., Leach, M., Brown, E. 2019 "eCook Kenya Cooking Diaries – September 2019 Working Paper". ACTS, Gamos Ltd., University of Sussex and UIU supported by UK Aid, EPSRC, RCUK & DECC. Available from: www.mecs.org.uk