Opportunities & Challenges for eCook Myanmar

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Executive Summary

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

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.

Myanmar had been identified as a high impact potential market through the Global Market Study (Leary *et al.*, 2018). The aim of this Myanmar 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 workshop

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1.1 Key findings

This study has shown that there is a strong market for eCook products and services in Myanmar, as electricity is already the aspirational cooking fuel for most households in Myanmar, with access and reliability the major barriers holding back further adoption. There is an emerging LPG market, however challenges in formalizing what was previously a black-market commodity have limited its development. Myanmar cuisine highly compatible with battery-supported electricity, with many energy-efficient appliances that fit well with Myanmar cuisine already available on the market. Grid electricity in Myanmar is among the cheapest in the world, however, awareness of relative fuel costs and the health impacts of biomass cooking low.

There are clear indications, particularly from the diaries and focus group exercises, that households would adopt eCook products/services,– if the price and other conditions were 'right'. Cooking with battery-supported electricity can address both the reliability and access concerns, making it an attractive proposition, if this can be successfully communicated to potential users. Where the grid is available, Grid-eCook offers greater reliability; where it is not, PV-eCook can make sufficient reliable electricity for cooking available anywhere. Whilst affordability is less of a challenge for grid connected systems than in other contexts due to the very low grid tariff, battery-supported devices will add significantly to the cost, but will also add significantly to the value proposition by enabling reliable electricity access. Myanmar's ageing electrical generation & distribution infrastructure is in need of major investment. eCook systems can offer decentralised energy storage that can strengthen weak-grids without having to wait for upgrades to the centralised system.

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

This work in Myanmar has shown that moving directly to insulated energy-efficient appliances such as rice cookers, insulated red electric frying pans and Electric Pressure Cookers (EPCs) is more attractive than hotplates. Many households in urban areas already have access to grid electricity, that is reliable enough to cook with (especially if a voltage stabiliser is available), given that insulated appliances such as the rice cooker and EPC mitigate this unreliability to a certain extent.

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The price point may not yet been reached for battery-supported eCooking, however the evidence from the cooking diaries shows that it is already cost effective to cook with off-the-shelf energy-efficient electric cooking appliances. The cost and challenges involved in building the demonstration prototype highlight the current situation – challenges in sourcing key components locally (higher capacity lithium ion batteries and DC cooking appliances) and a high cost for what is available (batteries at $400/kWh). This comes as no surprise to us. Our premise since 2013 has been that components will become cheaper and more available as learning rates kick in for lithium ion batteries in particular. If adequate supply chains are established, by 2020 eCook systems will be affordable in Myanmar.

1.1.1 Policy support

At the stakeholder meeting in Yangon hosted by the Department for Research and Innovation, representatives from key government ministries confirmed that eCook has the potential to address several of Myanmar's interlinked developmental challenges. The policy review and stakeholder meeting confirm that there is a hunger within the government and other decision makers for a solution to the enduring problem of biomass cooking. Existing policies tend to support eCook, however coordinated action is required to overcome the key barriers highlighted during this research.

It will be important to raise awareness of the solution and co-construct the emerging solutions with the Myanmar 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.

1.1.2 Deforestation

Deforestation is greatly reducing the quantity & quality of woodfuel available across Myanmar, forcing many to start paying for their fuel and to look for alternatives to biomass. This creates an emerging opportunity to capture these new expenditures on polluting fuels with clean & modern eCook products/services. In fact, the choice modelling survey showed that there was greatest agreement that firewood is expensive for cooking, less so for LPG, and electricity appears to be regarded as the cheapest fuel.

Charcoal production and sale was officially banned 5 years ago, limiting its use, however it is still available across the country. The hot climate means that cookstoves are rarely needed for space heating in most of the country.

Households in Yangon switching from charcoal to LPG & electricity for cooking has slowed deforestation in the Ayeyarwady delta region's mangroves. eCook could build upon this success story by extending access to reliable electricity for cooking to many more households.

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1.1.3 Supply chain

Establishing a supply chain for larger scale (>10Ah) lithium ion batteries and DC cooking appliances in Myanmar will be key to achieving affordability. Myanmar's border with China means that obtaining key components will be much easier than in Africa. Higher capacity Li-ion batteries not yet available through local suppliers, however they can be obtained with a month's lead time directly from the factory.

In fact, many electrical components are manufactured in Myanmar, including transformers, micro-hydro turbines and electric hotplates. As a result, the local manufacture of eCook components may well also be possible. However, the quality and efficiency of these components will likely be a major issue.

1.1.4 Fuel stacking

The policy and national markets review showed that LPG is not yet popular in Myanmar, however if the market develops, a fuel stacking scenario with LPG and electric appliances could be attractive for modern cooks wanting to mitigate the highly unstable nature of grid electricity. Myanmar has gas reserves, but they are either used for electricity generation or exported, leaving little spare capacity for domestic LPG production.

1.1.5 Energy-efficient electric cooking appliances and Myanmar cuisine

The cooking diaries study, participatory cooking sessions at the stakeholder workshop, kitchen laboratory experiments at the REAM office and focus groups have shown that cooking with electricity is compatible with Myanmar cuisine and that modern energy-efficient appliances are highly desirable to everyday cooks. Rice & curry is the most popular meal in Myanmar, which matches well with rice cookers & insulated electric frying pans - automated energy-efficient appliances that make cooking much easier.

We can now see that the motivations to change behaviour to adopt an aspirational product that offers more than what a charcoal stove can (or even LPG) are an alternative and seemingly more viable pathway than creating something that mimics as closely as possible the slow and inefficient nature of charcoal stoves. Myanmar has it all – from hand-wound electric coils with no-doubt a terrible efficiency, up to induction stoves and electric pressure cookers. By identifying the most efficient off-the-shelf appliances and pairing eCook with these instead of a hotplate, we can significantly increase affordability by reducing the size of the battery and at the same time create a product that is much more attractive to consumers.

In particular, insulated appliance such as the rice cooker, electric frying pan, thermo-pot and Electric Pressure Cooker (EPC) are prime candidates for future eCook products. Insulated pots are traditionally used to keep tea warm in Myanmar, which significantly reduces demand for reheating. The thermo-pot is a modern evolution of this, essentially a kettle combined with a thermos flask. Insulation not only

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significantly reduces the energy demand for cooking, but also mitigates the impact of short blackouts and low voltage, simply by stopping heat from escaping from the cooking pot.

Factories in China are already mass-producing DC cooking appliances, which can greatly reduce the size, cost, efficiency and reliability of eCook products. Currently this is limited to rice cookers and hotplates, but it surely will not be long before other appliances follow. In fact, rice cookers don't just cook rice – many Myanmar households regularly prepare soup in them and with the lid closed, they are even capable of frying.

The choice modelling surveys showed that there was a clear preference for a device that did not make food taste smoky, which can only achieved with LPG and electricity. A participatory design exercise with live cooking demonstrations at the stakeholder workshop showed that food cooked on energy-efficient electric cooking appliances was just as delicious as food cooked on other fuels.

The choice modelling survey showed that some consumer preferences (e.g. 2 hobs over 4, lid over open pot) are likely to also be attractive to system designers, as they will decrease overall system costs. The survey showed that affordability is unsurprisingly 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, whist 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 prototyping revealed several key design features for future eCook devices. Future battery-supported eCook devices should aim to incorporate similar state of charge indicators to mobile phones or laptops. Voltage has a massive impact on power and therefore heat delivered by a cooking appliance, however batteries can stabilise the voltage to give consistent performance or vary the voltage to offer the user control.

If eCook can be partnered with appropriate social marketing & training designed to enable users to cook efficiently with energy-efficient electric appliances, battery banks can be much smaller & costs can be significantly reduced

1.1.6 Business models

Two optimised systems have been proposed, based upon combining the data obtained during the stakeholder workshop with comparable tests carried out in the REAM office:

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1. The first of which was designed to meet all of a small/medium household's everyday needs, with an optimised all electric system with monthly costs ranging from 6,000-10,000 MMK (4-6.5 USD) for Grid-eCook and 8,500-19,000 MMK (5.5-12.5 USD) for PV-eCook.
2. The second optimised system was designed to cook just rice two times a day and has monthly costs ranging from 1,500-2,500 MMK (1-1.5 USD) for Grid-eCook and 2,500-6,000 MMK (1.5-4 USD) for PV-eCook. This single appliance-based 'rice-eCook' system could be a gradual first step for many towards cooking entirely on battery electric systems, with the user adding more appliances as they gain more confidence in the technology and/or as more money becomes available.

Pay-as-you-go business models have not yet taken off in Myanmar to the same extent as they have in Africa. However, the choice modelling survey showed that most respondents owned mobile phones and as they are relatively new in Myanmar, most have leapfrogged straight to the smartphone. Mobile money is not yet mainstream; however, mobile banking is gaining in popularity and could offer an attractive mechanism for collecting regular repayments from future users of leased or rented eCook products.

The buy-as-you-go business model presents an attractive alternative to pay-as-you-go. Buy-as-you-go involves packaging eCook products in discrete units so that households can buy what they can with the money they have available. Rice-eCook is likely to be the first step on this ladder for many households, as a rice cooker is usually the first cooking appliance a newly grid-connected household will buy. This fits well with the battery-integrated appliance concept, as each new appliance could come with an appropriately sized battery, allowing users to gradually transition onto an all-electric battery-supported cooking system.

1.1.7 Opportunities & challenges for PV-, Mini-grid- and Grid-eCook

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.

1.1.7.1 PV-eCook

In Myanmar, pioneering households are already cooking on solar home systems. Two innovative end-users were visited during the research and there are surely more, as household solar systems proliferate and low power energy-efficient cooking appliances are already available on the

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market. By empowering these pioneers to optimise the products they have developed, we can create efficient and replicable solutions tailored to the needs of rural people.

Table 1: Opportunities & Challenges for PV-eCook in Myanmar.

Opportunities	Challenges
• Pioneers already assembling PV-eCook systems • 18 million in rural off-grid regions (World Bank 2017) • Many HH PV systems already in use across the country • No. SHS unknown, but estimated at > 10 million • DRD SHS programme broadens this base • Strong solar resource	• Mobile money & pay-as-you-go business models only recently launched • Most rural HHs cook on firewood because its free • Quality of available equipment low, as often factory rejects • Short-term donor-lead projects hindering local market development

1.1.7.2 Grid-eCook

In Myanmar, electricity is already the aspirational fuel, however the grid is heavily overloaded, placing severe restrictions on how people cook with electricity. Participants in the focus groups were willing to get up as early as 2am to begin cooking before the voltage starts to sag as the grid is loaded up throughout the day. What is more, the manual voltage transformers used by many households in Myanmar require as much attention as tending a fire - certainly not modern or convenient access to energy. Integrating battery-storage into cooking appliances is likely to be beneficially from both a user and grid-stability perspective, as many participants could only cook at certain times of the day, as at peak times, the voltage regularly sags below 150V.

Low voltage can affect cooking just as much as blackouts. The power produced by cooking appliances proportional to V^2, which means that halving the voltage leaves just a quarter of the power - at 115V, a 1kW hotplate (rated at 230V) becomes a 250W hotplate. Extreme voltage fluctuations were observed on the government grid across the country; however, this was extreme in rural areas, at times sagging to below 20V on a grid designed for 230V! As a result, users are accustomed to purchasing additional hardware to be able to use the electricity from a government grid. Voltage stabilisers and safeguards that disconnect power when the voltage is too high/low are standard issue in households across the country. This creates a significant opportunity for Grid-eCook, as most battery chargers can accept a much wider

voltage range (typically 100-250V) and can therefore store variable voltage grid electricity and deliver constant voltage battery-supported electricity when required.

Table 2: Opportunities & Challenges for Grid-eCook in Myanmar.

Opportunities	Challenges
• Energy-efficient electric cooking appliances already widely adopted • 0.03USD/kWh (40MMK) - one of the lowest tariffs in the world • Many towns with electricity available only during set hours • Extreme voltage fluctuations	• Load shedding no longer occurring in Yangon (but still an issue in other parts of the country) • Planned coal & existing gas generation reduces effectiveness of Grid-eCook from environmental & energy efficiency perspectives • Tariff set to increase

1.1.7.3 *Mini-grid-eCook*

There are an estimated 6,000 mini-grids in operation across the country, some of which have already enabled electric cooking for their customers. With an average of 100 HH connected to each, making a total potential market of 600,000 HHs. Many of the mini-grids are community owned and the reliability is often much better than national grid, however the unit cost is usually also higher. There was little international investment during military regime, so local developers set up robust self-financed business models. Most of the equipment is locally manufactured and several mini-grids already allow users to cook, although peak loading is a major challenge limiting who can cook, how they can cook and when they can cook. However, several options now exist to mitigate this, including centralised or decentralised battery storage, smart metering, distributed load control and collaborative agreements, can decouple electricity demand from supply.

The techno-economic modelling case study of a micro-hydro mini-grid in Shan State highlights the opportunity for mini-grid developers to enable their customers to do all of their cooking with electricity without overloading the grid by using household battery storage. Mini-grid-eCook presents a significant opportunity in Myanmar and is particular attractive on run-of-the-river hydropower systems. The abundance of hydropower resources has enabled the establishment of mini-grids with very low unit costs. For run of the river hydro, distributed HH storage is extremely valuable. Batteries can be charged at off-peak times to enable cooking at peak times. Running generators at low load factors is extremely inefficient, so many biomass gasifier and diesel mini-grids only run for set hours of the day. This creates

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an opportunity to charge batteries whenever the generator is on, to enable HHs to have 24h access to electricity 24h. Storage is already available on solar mini-grids, so to add cooking, the developer can simply increase size of system components (PV, charge controllers, centralised battery bank & inverters). Distributed HH storage can be useful on solar mini-grids if the cable runs long and/or blackouts are frequent.

Table 3: Opportunities & Challenges for Mini-Grid-eCook in Myanmar.

Opportunities	Challenges
• Many mini-grid users already able to cook with electricity • Strong domestic biomass gasifier and micro-hydro mini-grid market • Stronger grids already incorporating cooking • Weaker grids in need of strengthening to enable cooking • Emerging PV mini-grid market	• Lack of legal status for mini-grids • Lack of financing options for mini-grid developers to replicate their successful projects

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Table of Contents

ACKNOWLEDGEMENT **2**

RIGHTS, PERMISSIONS & DISCLAIMER **2**

EXECUTIVE SUMMARY **3**

1.1 KEY FINDINGS 4

1.1.1 Policy support *5*

1.1.2 Deforestation *5*

1.1.3 Supply chain *6*

1.1.4 Fuel stacking *6*

1.1.5 Energy-efficient electric cooking appliances and Myanmar cuisine *6*

1.1.6 Business models *7*

1.1.7 Opportunities & challenges for PV-, Mini-grid- and Grid-eCook *8*

2 INTRODUCTION **14**

2.1 BACKGROUND 14

2.1.1 Context of the potential landscape change by eCook *14*

2.1.2 Introducing 'eCook' *15*

3 WHY TANZANIA? **16**

3.1 TARGET MARKET SEGMENTS 16

3.2 VARIABLES USED 16

3.3 ELECTRIFICATION AND DEMOGRAPHICS 17

3.4 COMMERCIALISED POLLUTING FUELS 19

3.5 INTRODUCTION TO THE OPPORTUNITY FOR ECOOK IN MYANMAR 20

4 AIMS, OBJECTIVES & METHODOLOGY **21**

5 KEY FINDINGS **22**

5.1 COOKING DIARIES 23

5.1.1 Overview of methodology *24*

5.1.2 Key learning points *25*

5.2 CHOICE MODELLING SURVEYS 27

5.2.1 Overview of methodology *28*

5.2.2 Key learning points *28*

5.3 TECHNO-ECONOMIC MODELLING 32

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5.3.1 Overview of methodology ... *33*
5.3.2 Key learning points ... *33*
5.4 Focus group discussions ... 35
5.4.1 Overview of methodology ... *36*
5.4.2 Key learning points ... *36*
5.5 Prototyping ... 40
5.5.1 Overview ... *41*
5.5.2 Key learning points ... *41*
5.6 Review of National Policy & Markets ... 44
5.6.1 Overview of methodology ... *45*
5.6.2 Key findings ... *45*
5.7 Stakeholder workshop ... 47
5.7.1 Overview of workshop ... *48*
5.7.2 Key outcomes ... *48*
6 CONCLUSION ... 52
7 REFERENCES ... 54
8 APPENDIX ... 55
8.1 Appendix A: Problem statement and background to Innovate eCook project ... 55
8.1.1 Beyond business as usual ... *55*
8.1.2 Building on previous research ... *57*
8.1.3 Summary of related projects ... *61*
8.1.4 About the Modern Energy Cooking Services (MECS) Programme ... *62*

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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 Myanmar. 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 Myanmar. 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 Myanmar, 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.

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.

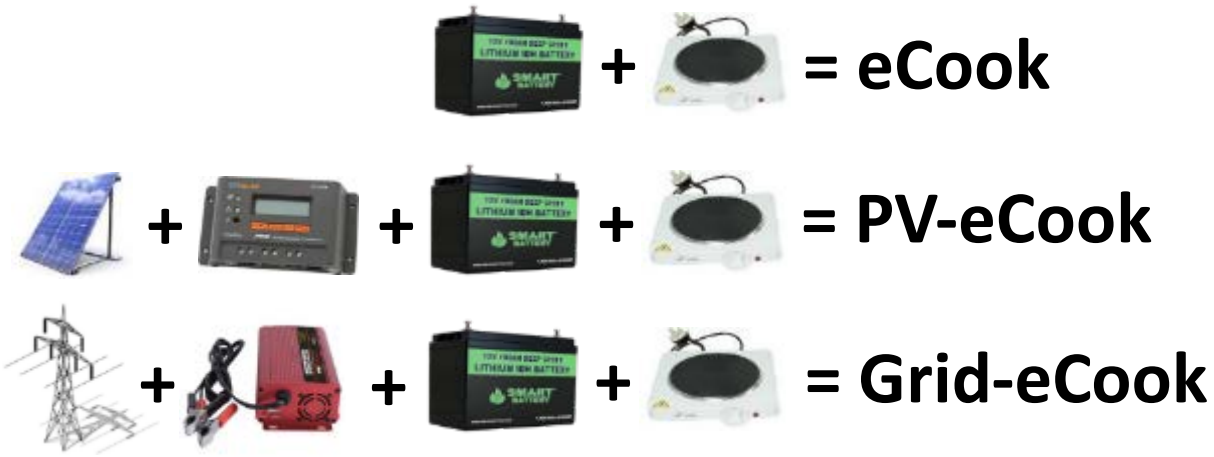

Figure 1: Pictorial definitions of 'eCook' terminology used in this report.

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3 Why Tanzania?

3.1 Target market segments

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

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

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

3.2 Variables used

Brown & Sumanik-Leary (2015) carried out a review of the behavioural change challenges that are likely to enable and constrain the uptake of eCook. The global study (Leary & Batchelor 2018) compared actual country contexts with Brown & Sumanik-Leary (2015) generic typology to evaluate the viability of eCook in each place. Table 1 shows how each of Brown & Sumanik-Leary (2015) factors are represented by an

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indicator. Indicators are grouped into sub-categories, which themselves are grouped into categories. In brief it was hypothesized that the market for eCook may be influenced by:-

- The alternative fuel options – that includes the availability and cost of electricity, and the attractiveness of alternatives such as kerosene and LPG.
- The finance available to consumers – both in terms of incomes, repayment mechanisms (i.e. presence of mobile money) and ability to (and cost of) borrow the upfront capital.
- The solar resource and ambient temperatures - which affect energy generation/storage options.
- Governance – the markets will be strongly affected by the rule of law.
- Skills and capacity availability – is the institutional environment in place to train technicians?
- The size of the market - both in proportional terms and absolute numbers.
- Ease of doing business – will it be possible for private sector to set up new markets?
- Policy environment – is it favourable towards renewable energy technologies?
- The national grid – how many people it reaches, affordability and the quality of the supply.

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

3.3 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. However, Myanmar sits at the front of the pack for Asian nations in terms of viability score and globally in terms of market size. For Grid-eCook, Asian nations sit at the forefront, with China and India both the biggest markets and China in particular is one of the more viable contexts. However, globally, Myanmar has one of the largest target markets and also scores relatively highly for viability.

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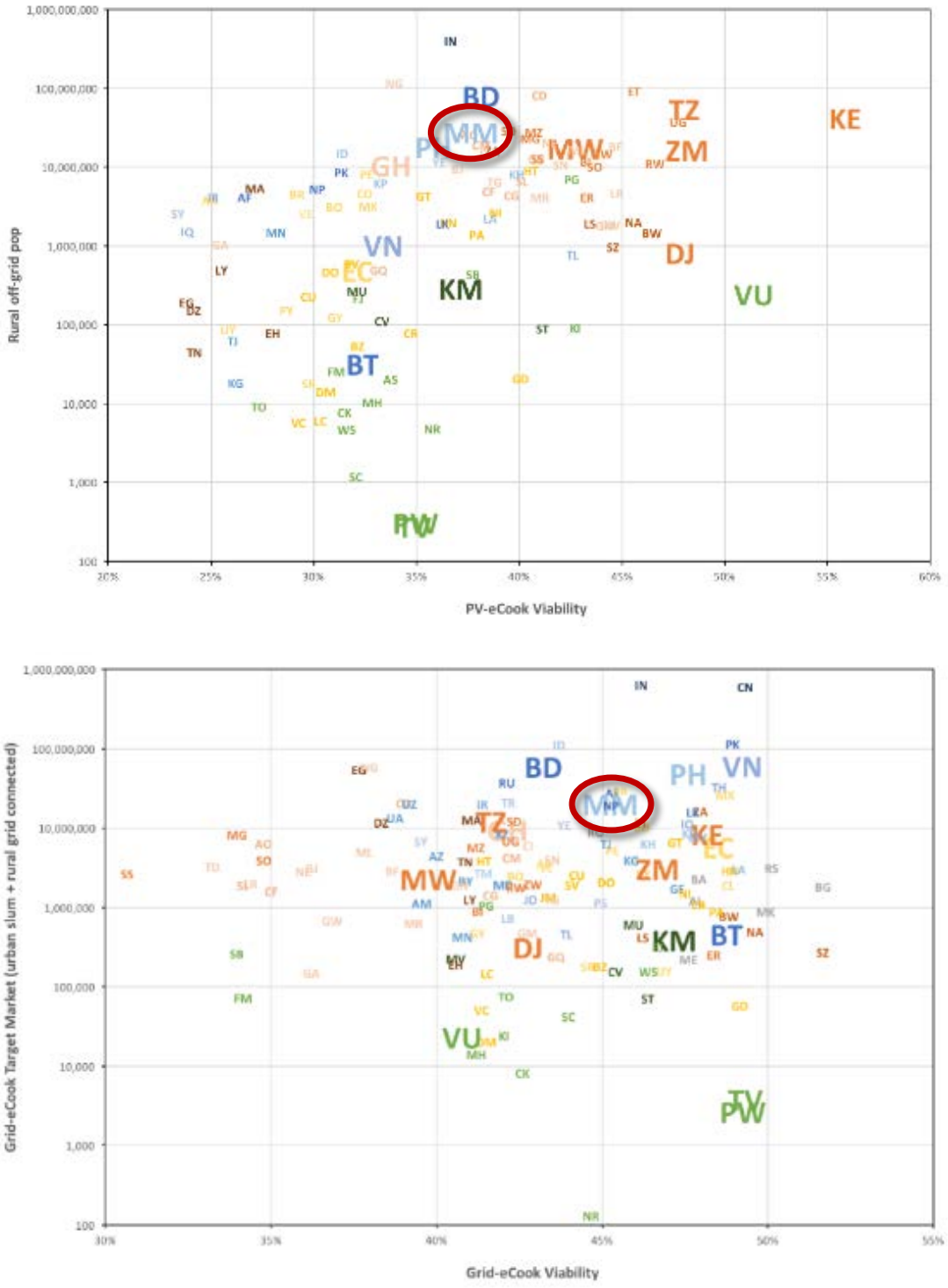

Figure 2: Comparison of size of PV-eCook (top) and Grid-eCook (bottom) target market segments by electrification and demographic status with ease of reaching these market segments.

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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 lead the WHO to create a new classification of 'polluting fuels' (WHO, 2014), which also includes kerosene. The global study focused on three of these kerosene, charcoal and coal, as these three commercialised polluting fuels present the greatest opportunity to divert an existing expenditure to increase quality of life.

Figure 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. However, Myanmar has 16 million commercialised polluting fuels users, exceeding Kenya's 14 million. However, Myanmar's viability scores are more moderate, indicating that there will be more challenges to address in order to reach this population.

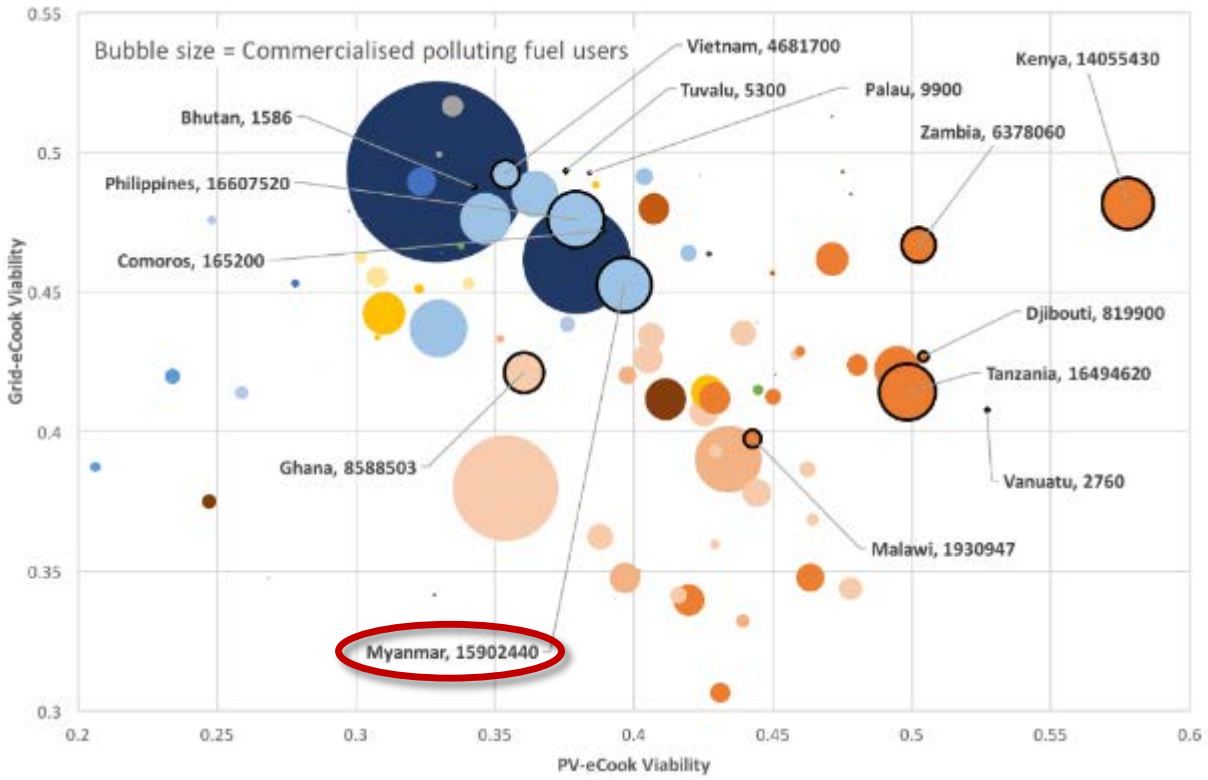

Figure 3 Size of commercialized polluting fuel (kerosene, charcoal, coal) users market segments and ease of reaching them with Grid-eCook or PV-eCook solutions.

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

3.5 Introduction to the opportunity for eCook in Myanmar

After decades of military rule, Myanmar began a gradual transition towards democracy in 2010. After years of neglect, the country's crumbling infrastructure was in desperate need of investment. Myanmar is a gas exporting nation, with an emerging local market (Naing & Surachatte 2017). According to the latest HH survey data just 500,000 people (1%) cook using LPG, however it should be noted that this survey was conducted in 2013. Under military rule, LPG was highly subsidized, but only available to government officials. For everyone else, the only alternative was black market LPG, smuggled over the border from Thailand (Myanmar Times, 2011). The civilian government is still in the process of formalizing the market, by issuing licenses and introducing price regulation (Myanmar Business Today, 2016). At the current price of 0.55USD/kg, cheap LPG is likely to persuade many more to transition away from charcoal or firewood.

Myanmar is the second biggest charcoal market in the world, after DRC. 95% of the population (52 million) cook on pollution fuels, with 29% (16 million) using charcoal as their primary cooking fuel. The GACC experts survey results suggested a low charcoal price of 0.37USD/kg in Yangon, however this should be treated with caution, as it is based on a single respondent and FAO import/export data.

52% of the country (28 million) has access to the national grid and at 0.06USD/kWh the unit cost is very low. As a result, both charcoal and LPG are above the parity line, meaning that it would be cost-effective for these users to transition to electricity for cooking. What is more, a lifeline tariff of 0.04USD/kWh for the first 100kWh is available, yet just 4% (2 million people) reportedly use electricity as their primary fuel for cooking. Regular blackouts (an average of 15 per month) may be a significant contributing factor.

The market for PV-eCook also has significant potential, as 51% of the rural population (18 million people) do not have grid access and a recent government-led SHS programme has reportedly been relatively successful in offering access to lighting and basic energy services to thousands of HHs.

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

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 the liberalisation of Myanmar opens the door to a significant charcoal market, with a small percentage of users already cooking on electricity, paving the way for eCook.

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

The aim of this Myanmar 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 Myanmar.

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.
- 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.

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

5 Key findings

The following section presents the key findings from the activities carried out in Myanmar. 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:

- ***The cooking diaries study in Myanmar has shown that cooking with electricity is compatible with Myanmar cuisine and that modern energy-efficient appliances are highly desirable to everyday cooks.***
- ***In particular, the rice cooker, electric frying pan, thermo-pot and Electric Pressure Cooker (EPC) are prime candidates for future eCook products. Insulation not only significantly reduces the energy demand for cooking, but also mitigates the impact of short blackouts and low voltage, simply by stopping heat from escaping from the cooking pot.***
- ***In Myanmar, electricity is already the aspirational fuel, however the grid is heavily overloaded, placing severe restrictions on how people cook with electricity.***
- ***Integrating battery-storage into cooking appliances is likely to be beneficially from both a user and grid-stability perspective, as many participants could only cook at certain times of the day, as at peak times, the voltage regularly sags below 150V.***
- ***LPG is not yet popular in Myanmar, however if the market develops, a fuel stacking scenario with LPG and electric appliances could be attractive for modern cooks wanting to mitigate the highly unstable nature of grid electricity.***

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

Figure 4: Experimenting with different cooking stoves and appliances in a kitchen laboratory setting to select which appliances to trial in the cooking diaries study in Myanmar.

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 Myanmar cook and how compatible this is with electricity. This mixed methods approach gathers data from various sources: cooking diary forms, energy measurements, a registration survey an exit survey.

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

22 households (HHs) were asked to keep detailed cooking diaries, recording exactly what they cooked, when and how for six weeks. For the first two weeks they were asked to cook as they would normally, using their usual fuels and stoves. For the remaining four weeks, they were asked to transition to cooking with electricity, using a range of electric cooking appliances, including rice cookers, Electric Pressure Cookers (EPCs), induction stoves and thermo-pots, 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 rural and per-urban households in the Dry Zone and Ayeyarwady Delta regions and urban households in Yangon 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.

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

IN PARTICULAR, THE RICE COOKER, ELECTRIC FRYING PAN, THERMO-POT AND ELECTRIC PRESSURE COOKER (EPC) ARE PRIME CANDIDATES FOR FUTURE ECOOK PRODUCTS. INSULATION NOT ONLY SIGNIFICANTLY REDUCES THE ENERGY DEMAND FOR COOKING, BUT ALSO MITIGATES THE IMPACT OF SHORT BLACKOUTS AND LOW VOLTAGE, SIMPLY BY STOPPING HEAT FROM ESCAPING FROM THE COOKING POT.

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 Myanmar has shown that cooking with electricity is compatible with Myanmar cuisine and that modern energy-efficient appliances are highly desirable to everyday cooks. In particular, the rice cooker, electric frying pan, thermo-pot and Electric Pressure Cooker (EPC) are prime candidates for future eCook products. Insulation not only significantly reduces the energy demand for cooking, but also mitigates the impact of short blackouts and low voltage, simply by stopping heat from escaping from the cooking pot.

In Myanmar, electricity is already the aspirational fuel, however the grid is heavily overloaded, placing severe restrictions on how people cook with electricity. Many of the participants from the cooking diaries study could only cook at certain times of the day, as at peak times, the voltage regularly sags to levels where it is unusable without a voltage stabiliser (<150V). As a result, integrating battery-storage into cooking appliances is likely to be beneficially from both a user and grid-stability perspective. For the user, it would enable cooking throughout the day and predictable performance, as the voltage would be much more stable. Plus, it would also allow them to use other low power appliances by also connecting them to the battery. For the grid operator, it would smooth out the load profile, as the battery could be trickle charged at off-peak times and discharged at mealtimes, effectively time shifting cooking loads into times when spare generating capacity is available.

LPG is not yet popular in Myanmar, as the market was extremely restricted under military rule. However, if the market develops, it may well become an attractive option to consumers. Nonetheless, as grid electricity is so cheap in Myanmar and electric appliances such as the rice cooker and electric frying pan are already so embedded within kitchen routines, it is unlikely that many households would completely switch over from electricity to LPG. Instead, a fuel stacking scenario with LPG and electric appliances seems much more attractive for modern cooks in Myanmar wanting to mitigate the highly unstable nature of electricity from

IN MYANMAR, ELECTRICITY IS ALREADY THE ASPIRATIONAL FUEL, HOWEVER THE GRID IS HEAVILY OVERLOADED, PLACING SEVERE RESTRICTIONS ON HOW PEOPLE COOK WITH ELECTRICITY.

INTEGRATING BATTERY-STORAGE INTO COOKING APPLIANCES IS LIKELY TO BE BENEFICIALLY FROM BOTH A USER AND GRID-STABILITY PERSPECTIVE, AS MANY PARTICIPANTS COULD ONLY COOK AT CERTAIN TIMES OF THE DAY, AS AT PEAK TIMES, THE VOLTAGE REGULARLY SAGS BELOW 150V.

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

the national grid. This scenario would have the additional advantage of combining the manual control of LPG and automatic control of electricity to enable both fine control for specific dishes and multi-tasking.

LPG IS NOT YET POPULAR IN MYANMAR, HOWEVER IF THE MARKET DEVELOPS, A FUEL STACKING SCENARIO WITH LPG AND ELECTRIC APPLIANCES COULD BE ATTRACTIVE FOR MODERN COOKS WANTING TO MITIGATE THE HIGHLY UNSTABLE NATURE OF GRID ELECTRICITY.

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:

- ***Most respondents owned mobile phones and as they are relatively new in Myanmar, most have leapfrogged straight to the smartphone.***
- ***There was greatest agreement that firewood is expensive for cooking, less so for LPG, and electricity appears to be regarded as the cheapest fuel.***
- ***Taste – there was a clear preference for a device that did not make food taste smoky.***
- ***Affordability is a key factor in making eCooking attractive to 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: Carrying out a choice modelling survey in rural Myanmar.

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 REAM, 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

Most respondents (89%) owned mobile phones, indicating high levels of technical proficiency & possibly a greater willingness to adopt new innovations. Mobile phones are relatively new in Myanmar, so most people have leapfrogged straight to the smartphone.

MOST RESPONDENTS OWNED MOBILE PHONES AND AS THEY ARE RELATIVELY NEW IN MYANMAR, MOST HAVE LEAPFROGGED STRAIGHT TO THE SMARTPHONE.

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

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.

58% of respondents were connected to the national grid, 13% to a mini-grid, 7% to solar home systems & 4% to a generator. Only 1% had no electricity at all. The mean household size was found to be 4.6 (including children). 73% of the sample were deprived in at least one of the indicators relating to education, home construction materials & source of drinking water.

Respondents spend an average of 3.2 hours/day cooking. Breakfast is typically prepared at 5:00, lunch at 10:00 & dinner at 16:00.

THERE WAS GREATEST AGREEMENT THAT FIREWOOD IS EXPENSIVE FOR COOKING, LESS SO FOR LPG, AND ELECTRICITY APPEARS TO BE REGARDED AS THE CHEAPEST FUEL.

Unsurprisingly, participants reported that women are usually responsible for cooking (85%), however, in 5% of households, men do the majority of cooking & in 11% 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.

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. Interestingly, many rural firewood users also reported paying for it.

Electricity & charcoal/firewood are useful for other things too. Almost all participants who cooked with electricity reported using it for lighting (99%) & most for refrigeration (59%). Roughly half of all fuel users reported also using them for water heating, however almost nobody used them for space heating.

There was greatest agreement that firewood is expensive for cooking, less so for LPG, and electricity appears to be regarded as the cheapest fuel (out of these three only). However, LPG users believe LPG to be cheap and electricity to be expensive, indicating they are cost sensitive. People using wood tend to believe that both electricity and LPG are expensive.

LPG users tend to regard it as a safe fuel, unlike everybody else, suggesting that negative perceptions on safety act as a barrier to use of LPG.

TASTE – THERE WAS A CLEAR PREFERENCE FOR A DEVICE THAT DID NOT MAKE FOOD TASTE SMOKY.

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

People who use wood only weakly agree that it is inconvenient, whereas charcoal users feel most strongly that charcoal is not convenient, suggesting high levels of dissatisfaction with aspects of charcoal use (these are not specified but might include dirty, storage, time to light etc.).

Most respondents were aware that firewood is harmful to health, but they were less likely to feel that charcoal is harmful to health. While smoke was almost universally regarded as a health problem, there was also strong opinion that it was beneficial in controlling insects.

The features of the cooking process that are most important to consumers are:

- Boil and fry - to be able to do both
- Lid – people have a strong preference for a lid, but not for a sealed pot
- Hobs – people prefer double hobs, but interestingly people did not appear to have a preference for 4 hobs over a single hob.
- Taste – there was a clear preference for a device that did not make food taste smoky.
- Cost.

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.

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.

The features of the stove that are most important to consumers are:

- Portable – people would like a device that can be carried in/out of the house
- Capacity – people want to be able to do all their cooking on the device, and they want to be able to cook for larger numbers of people (8 people).
- Smoke – people would prefer a device that avoids generating any kind of smoke.
- Cost.

The functionality features most important to consumers were:

- Availability – people had a strong preference for a system that could cook reliably regardless of the weather.
- Having a device that was easy to clean.

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.

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

- Finance – people have a strong preference for leasing over utility models. There was a preference for a 6-year lease period over a 3-year period. These findings are potentially difficult to interpret, as people were not given any detail on the relative magnitudes of payments.

People have a strong preference lease-to-own over utility models, where the user simply makes regular payments for as long as they use the system, without ever gaining ownership. However, product/service designers may 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.

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

5.3 Techno-economic modelling

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

- ***Cooking on mini-grids is already happening in Myanmar.***
- ***Rice is the major staple across much of the region and electric rice cookers are both very easy to use and energy-efficient.***
- ***The abundance of hydropower resources has enabled the establishment of mini-grids with very low unit costs.***
- ***Peak loading is a major concern on power-limited mini-grids, but centralised or decentralised battery storage, smart metering, distributed load control and collaborative agreements, can decouple electricity demand from supply.***
- ***The case study of a micro-hydro mini-grid in Shan State highlights the opportunity for mini-grid developers to enable their customers to do all of their cooking with electricity without overloading the grid by using household battery storage.***

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

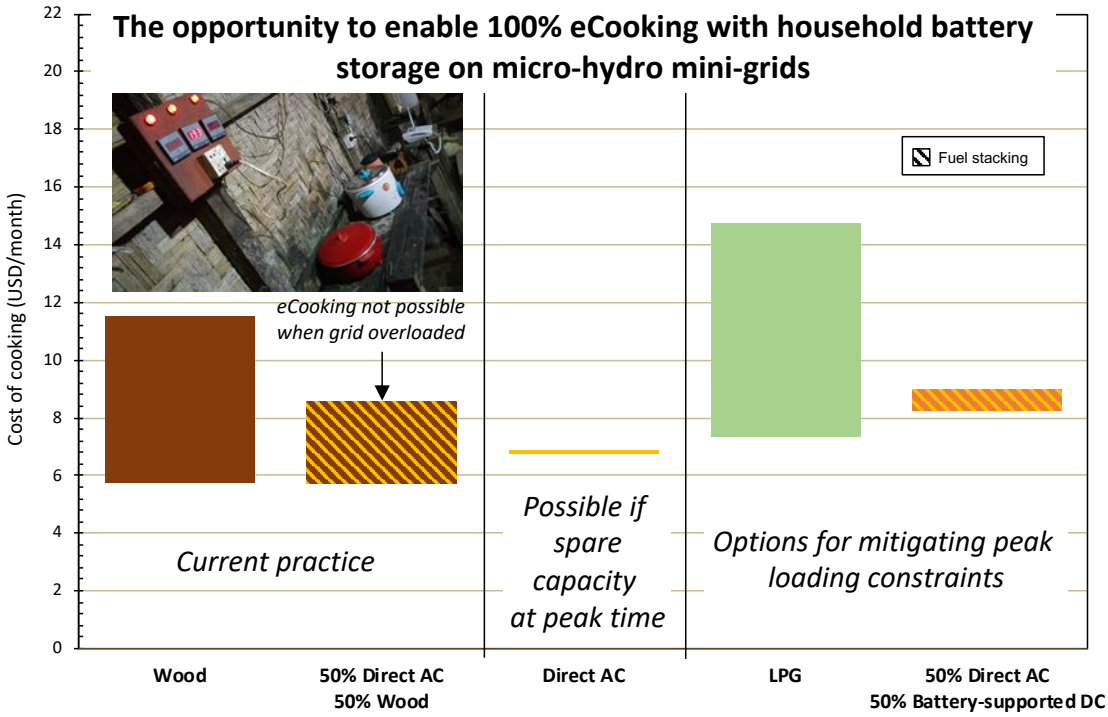

Figure 6: Selected modelling results for micro-hydro mini-grid in Naung Pain Lay, Pyin Oo Lwin, Myanmar, with 5 year financing horizon for direct AC *and 20 year for battery-supported DC systems.*

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.

COOKING ON MINI-GRIDS IS ALREADY HAPPENING IN MYANMAR.

RICE IS THE MAJOR STAPLE ACROSS MUCH OF THE REGION. ELECTRIC RICE COOKERS ARE BOTH VERY EASY TO USE & ENERGY-EFFICIENT.

THE ABUNDANCE OF HYDROPOWER RESOURCES HAS ENABLED THE ESTABLISHMENT OF MINI-GRIDS WITH VERY LOW UNIT COSTS.

5.3.2 Key learning points

Cooking on mini-grids is not a new idea – its already happening in many South and Southeast Asian countries. Rice is the major staple across much of the region and electric rice cookers are both very easy to use and energy-efficient. The abundance of hydropower resources has enabled the establishment of mini-grids with very low unit costs. However, with the rapidly falling prices of batteries and solar PV, new opportunities are opening up for the integration of energy-efficient eCooking in a broader range of systems, in particular solar and solar/diesel hybrid mini-grids, and for electricity to be used for a greater proportion of the day's cooking.

Peak loading is a major concern for electric cooking on power-limited mini-grids, but a variety of time-shifting techniques can decouple electricity

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

demand from supply, smoothing out the load profile and bringing down the Levelised Cost of Electricity (LCoE). These include centralised or decentralised battery storage, smart metering, distributed load control and collaborative agreements.

This case study of a micro-hydro mini-grid in Shan State highlights the opportunity for mini-grid developers who have already enabled cooking on their systems, to allow their customers to do all of their cooking with electricity (Figure 6). At peak times, the grid reaches capacity and the voltage dips, however, the users agreed to only cook with electricity when the voltage is high enough (indicated by a voltmeter installed by the mini-grid developer in every kitchen). Supporting the entire cooking load with a battery would not be cost effective versus purchased firewood, however it is also not necessary. A battery is only required when the grid is overloaded, therefore a much smaller (and cheaper) battery can still enable 100% eCooking. This is already cost competitive with LPG in 2020 and by 2025 is also projected to be cost-comparable with firewood. In fact, by 2025, even supporting the whole day's cooking with a battery becomes cost effective with tariffs below 0.13 USD/kWh. For other mini-grids with spare capacity at peak times in communities with similar firewood prices, direct AC eCooking is already cheaper than stacking firewood/electricity with tariffs below 0.20 USD/kWh in 2020.

PEAK LOADING IS A MAJOR CONCERN ON POWER-LIMITED MINI-GRIDS, BUT CENTRALISED OR DECENTRALISED BATTERY STORAGE, SMART METERING, DISTRIBUTED LOAD CONTROL AND COLLABORATIVE AGREEMENTS, CAN DECOUPLE ELECTRICITY DEMAND FROM SUPPLY.

THE CASE STUDY OF A MICRO-HYDRO MINI-GRID IN SHAN STATE HIGHLIGHTS THE OPPORTUNITY FOR MINI-GRID DEVELOPERS TO ENABLE THEIR CUSTOMERS TO DO ALL OF THEIR COOKING WITH ELECTRICITY WITHOUT OVERLOADING THE GRID BY USING HOUSEHOLD BATTERY STORAGE.

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 currently the aspirational fuel for most households in Myanmar.***
- ***Rice & curry is the most popular meal in Myanmar, matches well with rice cookers & insulated electric frying pans - automated energy-efficient appliances that make cooking much easier.***
- ***Reliability and access are major concerns, which make cooking with battery-supported electricity an attractive proposition, if this can be successfully communicated to potential users.***
- ***Whilst affordability is less of a challenge than in other contexts due to the very low grid tariff, battery-supported devices will add significantly to the cost but will also add significantly to the value proposition by enabling reliable electricity access.***
- ***Participants were willing to get up as early as 2am to begin cooking before the voltage starts to sag as the grid is loaded up throughout the day.***
- ***Manual voltage transformers used by many households in Myanmar require as much attention as tending a fire - certainly not modern or convenient access to energy.***

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

Figure 7: Discussing the how well modern energy-efficient electric cooking appliances fit with traditional cooking practices in Myanmar as the lights flicker on and off due to extreme voltage instabilities in Maw Gyun.

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 CURRENTLY THE ASPIRATIONAL FUEL FOR MOST HOUSEHOLDS IN MYANMAR.

Figure 8: Explaining how the battery-supported cooking prototype works to focus group participants in Nat Mauk.

5.4.2 Key learning points

The evidence from these FGDs suggests that **electricity is currently the aspirational fuel** for most households in Myanmar, as automated energy-efficient appliances such as the **rice cooker and insulated electric frying pan can make cooking much easier**. Reliability and access are major concerns, which make cooking with battery-supported electricity an attractive proposition, if this can be successfully communicated to potential users. Whilst affordability is less of a challenge than in other contexts due to the very low grid tariff, **battery-supported devices will add significantly to the cost, but will also add significantly to the value proposition by enabling reliable electricity access**.

RICE & CURRY IS THE MOST POPULAR MEAL IN MYANMAR, MATCHES WELL WITH RICE COOKERS & INSULATED ELECTRIC FRYING PANS - AUTOMATED ENERGY-EFFICIENT APPLIANCES THAT MAKE COOKING MUCH EASIER.

Rice & curry is the most popular meal in Myanmar, which explains why the most popular electric cooking appliances are **rice cookers & electric frying pans**. Rice is one of the easiest

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

staples to cook with electricity. Although there is some behaviour change from cooking on other fuels, it is a lot easier, so rice cookers are understandably one of the first electric appliances that many people in Myanmar buy. The cheap red electric frying pans that are popular across Myanmar are surprisingly energy-efficient, as the heating element is stuck to the bottom of the pan & there is insulation around it. This creates extremely efficient heat transfer into the pan, just like with an induction stove.

Space heating is often an important dual use for cookstoves, meaning that supposedly more efficient cookstoves are often not adopted as they are less efficient space heaters. However, the climate in much of Myanmar is warm enough that focussing the heat onto the pot rather than the cook is desirable.

Electricity is the aspirational cooking fuel, despite the **incredibly poor quality of electricity** available on Myanmar's national grid. In Nat Mauk, participants were so desperate to use it that they were willing to **get up as early as 2am to begin cooking before the voltage starts to sag** as the grid is loaded up throughout the day. The voltage on the government grid is so unstable that the **manual voltage transformers** used by many households in Myanmar to bring the voltage up to a usable level require constant adjusting as the lights begin to flicker to prevent them from going out completely. It requires **as much attention as tending a fire, so it's certainly not modern or convenient access to energy**. In Maw Gyun, **the voltage frequently dipped below 50V** just in the few hours we were there & sometimes reportedly dips as low as 20V.

RELIABILITY AND ACCESS ARE MAJOR CONCERNS, WHICH MAKE COOKING WITH BATTERY-SUPPORTED ELECTRICITY AN ATTRACTIVE PROPOSITION, IF THIS CAN BE SUCCESSFULLY COMMUNICATED TO POTENTIAL USERS.

WHILST AFFORDABILITY IS LESS OF A CHALLENGE THAN IN OTHER CONTEXTS DUE TO THE VERY LOW GRID TARIFF, BATTERY-SUPPORTED DEVICES WILL ADD SIGNIFICANTLY TO THE COST, BUT WILL ALSO ADD SIGNIFICANTLY TO THE VALUE PROPOSITION BY ENABLING RELIABLE ELECTRICITY ACCESS.

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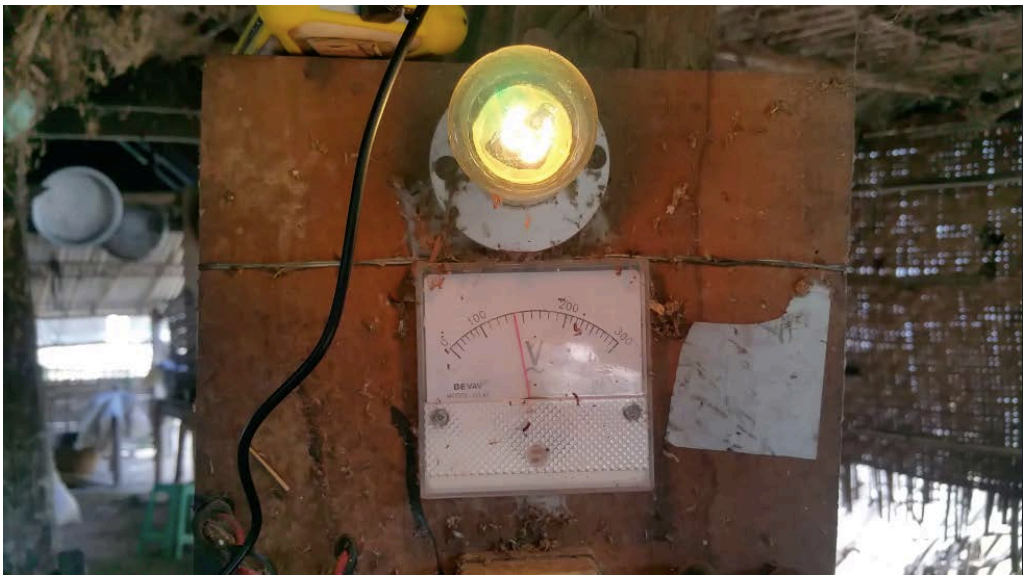

Figure 9: Most households in Myanmar have a voltmeter somewhere visible, as it dictates the daily routine. If the voltage is above 150V, life becomes significantly easier. If it surpasses 200V – make hay whilst the sun shines!

PARTICIPANTS WERE WILLING TO GET UP AS EARLY AS 2AM TO BEGIN COOKING BEFORE THE VOLTAGE STARTS TO SAG AS THE GRID IS LOADED UP THROUGHOUT THE DAY.

The popularity of **insulated electric cooking appliances** such as rice cookers & red electric frying pans in Myanmar can partly be explained by the fact that they are able to **maintain cooking performance during blackouts and voltage dips simply by preventing heat from leaving the pot**. However, low quality appliances have created the perception that electricity is unsafe to cook with as it is likely to shock the cook.

Cooking is cheap in Myanmar, with participants reporting expenditures around 10,000 MMK (7 USD) for a month of cooking on firewood, charcoal, gas or grid electricity. However, it may be possible for eCook systems with longer financing horizons to be competitive, especially as the cost of battery storage continues to fall. Mini-grids usually have higher tariffs than the government grid and at participants in Hlaine Bone reported paying 30,000 MMK (20 USD) per month to cook with electricity. At this price point, a PV-eCook system with a 5-year financing horizon may even be competitive today.

Unsurprisingly, innovative financing mechanisms will be needed to break down the high upfront cost of battery-supported devices into manageable repayments. **Pay-as-you-go financing mechanisms have not yet taken off in Myanma**r, so there is a need to find creative business models that can break down the high upfront cost of future eCook devices. Interestingly, people were willing to pay considerably more for

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a reliable power supply than an eCook device, implying that leveraging the additional functionality of eCook devices as enablers of reliable access to electricity for other domestic applications is likely to be a key marketing strategy.

MANUAL VOLTAGE TRANSFORMERS USED BY MANY HOUSEHOLDS IN MYANMAR REQUIRE AS MUCH ATTENTION AS TENDING A FIRE - CERTAINLY NOT MODERN OR CONVENIENT ACCESS TO ENERGY.

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5.5 Prototyping

This section summarises the findings from the eCook prototyping:

- ***The most compatible appliances include rice cookers, insulated red electric frying pans and Electric Pressure Cookers (EPCs).***
- ***Several Chinese factories are already producing DC cooking appliances, the most common of which is the DC rice cooker.***
- ***Pioneers are already using battery-supported cooking devices. Several solar electric cooking systems have already been assembled by end users and technical experts looking to find a way to enable cooking with electricity in off-grid regions.***
- ***Establishing a supply chain for larger scale (>10Ah) lithium ion batteries and DC cooking appliances in Myanmar will be key to achieving affordability.***
- ***Future prototypes should aim to incorporate similar state of charge indicators to mobile phones or laptops.***
- ***Voltage has a massive impact on power and therefore heat delivered by a cooking appliance, however batteries can stabilise the voltage to give consistent performance or vary the voltage to offer the user control.***

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

Figure 10: Showcasing the first eCook prototype in Myanmar at an ADB workshop on mini-grids in Yangon.

5.5.1 Overview

This report summarises the findings **from the prototyping carried out in Myanmar**, 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 Myanmar.

A range of methodologies were employed, including kitchen laboratory testing, observational field visits, reverse engineering and prototype assembly. The appliances tested and prototypes assembled were showcased on several occasions:

- ADB (Asian Development Bank) mini-grids workshop – raise awareness amongst key stakeholders that cooking on battery-supported electricity is possible.
- Focus Group Discussions – solicit feedback from future potential end users on the compatibility of battery-supported electricity with their current and aspirational cooking practices.
- eCook Myanmar Stakeholder Workshop – raise awareness amongst key stakeholders that cooking on battery-supported electricity is possible and catalyse discussion on the role this might play in enhancing access to electricity and clean cooking in Myanmar.

PIONEERS ARE ALREADY USING BATTERY-SUPPORTED COOKING DEVICES. SEVERAL SOLAR ELECTRIC COOKING SYSTEMS HAVE ALREADY BEEN ASSEMBLED BY END USERS AND TECHNICAL EXPERTS LOOKING TO FIND A WAY TO ENABLE COOKING WITH ELECTRICITY IN OFF-GRID REGIONS.

THE MOST COMPATIBLE APPLIANCES INCLUDE RICE COOKERS, INSULATED RED ELECTRIC FRYING PANS AND ELECTRIC PRESSURE COOKERS (EPCS).

5.5.2 Key learning points

The key findings of the prototyping activities are that electric cooking appliances are highly compatible with Myanmar cooking practices; DC cooking appliance are now available and that the pioneers are already using battery-supported cooking devices. The most compatible appliances include rice cookers, insulated red electric frying pans and

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Electric Pressure Cookers (EPCs). Several Chinese factories are already producing DC cooking appliances, the most common of which is the DC rice cooker. Several solar electric cooking systems have already been assembled by end users and technical experts looking to find a way to enable cooking with electricity in off-grid regions.

Establishing a **supply chain for larger scale (>10Ah) lithium ion batteries and DC cooking appliances in Myanmar will be key to achieving affordability**. Currently the only options are importing directly from the factory in China. Inverters are expensive and bulky, adding another point of failure and making the whole system less efficient. They also limit the maximum power that can be drawn, therefore defining which appliances can be used and whether they can be used simultaneously or not. DC cooking appliances eliminate the need for an inverter, however currently very few models are available and those that are generally are of poorer quality. Nonetheless, **a broad range of durable and affordable AC electric cooking appliances were available on the market** and insulated appliances were selected as they offer substantial energy savings, which can greatly reduce the size of the battery.

Future prototypes should aim to incorporate **similar state of charge indicators to mobile phones or laptops** (likely coulombic counting and learning algorithms to detect capacity from full cycles), which also use lithium ion batteries. Clearly communicating to users how much energy is left in the battery is vital to reduce the frustration of the battery running out halfway through cooking. Measuring the state of charge of a lithium ion battery is more complicated than lead acid, as the voltage/stage-of-charge curve is much flatter.

ESTABLISHING A SUPPLY CHAIN FOR LARGER SCALE (>10AH) LITHIUM ION BATTERIES AND DC COOKING APPLIANCES IN MYANMAR WILL BE KEY TO ACHIEVING AFFORDABILITY.

SEVERAL CHINESE FACTORIES ARE ALREADY PRODUCING DC COOKING APPLIANCES, THE MOST COMMON OF WHICH IS THE DC RICE COOKER.

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

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

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

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

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5.6 Review of National Policy & Markets

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

- ***There is a strong market for eCook products and services in Myanmar, as electricity is the aspirational cooking fuel.***
- ***Myanmar has gas reserves, but they are either used for electricity generation or exported, leaving little spare capacity for domestic LPG production.***
- ***Many fuelwood users are now paying for wood, as collecting has become more challenging due to dwindling forest reserves. This creates an emerging opportunity to capture these new expenditures on polluting fuels with clean & modern eCook products/services.***
- ***Households in Yangon switching from charcoal to LPG & electricity for cooking has slowed deforestation in the Ayeyarwady delta region's mangroves. eCook could build upon this success story by extending access to reliable electricity for cooking to many more households.***
- ***Myanmar's ageing electrical generation & distribution infrastructure is in need of major investment. eCook systems can offer decentralised energy storage that can strengthen weak-grids without having to wait for upgrades to the centralised system.***

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

Figure 11: REAM discussing the compatibility of a range of energy-efficient electric cooking appliances with Myanmar cuisine with representatives of Myanmar's Department for Research and Innovation.

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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. 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 Myanmar. The study had two dimensions:

1. to review the **current regulatory framework** in Myanmar 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 Myanmar, as electricity is without doubt the aspirational source of energy for cooking. However, cooking fuel in Myanmar is currently overwhelmingly from unsustainable sources (primarily charcoal, firewood, & LPG). Firewood dominates rural cooking, whilst electricity & charcoal are both much more popular in peri-urban and urban areas.

Myanmar has gas reserves, but they are either used for electricity generation or exported, meaning there is little to no spare capacity for domestic LPG production. Ironically, LPG is imported from Thailand and china, much of which was originally exported from Myanmar, refined and then reimported as LPG.

Many fuelwood users are now paying for wood, as collecting has become more challenging due to dwindling forest reserves. This creates an emerging opportunity to capture these new expenditures on polluting fuels with clean & modern eCook products/services.

Households in Yangon switching from charcoal to LPG & electricity for cooking has slowed deforestation in the Ayeyarwady delta region's

ELECTRICITY IS THE ASPIRATIONAL COOKING FUEL.

MYANMAR HAS GAS RESERVES, BUT THEY ARE EITHER USED FOR ELECTRICITY GENERATION OR EXPORTED, LEAVING LITTLE SPARE CAPACITY FOR DOMESTIC LPG PRODUCTION.

MANY FUELWOOD USERS ARE NOW PAYING FOR WOOD, AS COLLECTING HAS BECOME MORE CHALLENGING DUE TO DWINDLING FOREST RESERVES. THIS CREATES AN EMERGING OPPORTUNITY TO CAPTURE THESE NEW EXPENDITURES ON POLLUTING FUELS WITH CLEAN & MODERN ECOOK PRODUCTS/SERVICES.

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mangroves. eCook could build upon this success story by extending access to reliable electricity for cooking to many more households.

Charcoal prices vary considerably throughout the country – the same sack of charcoal sells for half the price in the charcoal producing regions of Magway and Tanitharyi than it does in Yangon. In fact, it is even more expensive in Shan State, showing that the opportunity to capture existing expenditures on commercialised polluting fuels is much more attractive in certain parts of the country.

Myanmar's ageing electrical generation & distribution infrastructure is in need of major investment. eCook systems can offer decentralised energy storage that can strengthen weak-grids without having to wait for upgrades to the centralised system.

HOUSEHOLDS IN YANGON SWITCHING FROM CHARCOAL TO LPG & ELECTRICITY FOR COOKING HAS SLOWED DEFORESTATION IN THE AYEYARWADY DELTA REGION'S MANGROVES. ECOOK COULD BUILD UPON THIS SUCCESS STORY BY EXTENDING ACCESS TO RELIABLE ELECTRICITY FOR COOKING TO MANY MORE HOUSEHOLDS.

MYANMAR'S AGEING ELECTRICAL GENERATION & DISTRIBUTION INFRASTRUCTURE IS IN NEED OF MAJOR INVESTMENT. ECOOK SYSTEMS CAN OFFER DECENTRALISED ENERGY STORAGE THAT CAN STRENGTHEN WEAK-GRIDS WITHOUT HAVING TO WAIT FOR UPGRADES TO THE CENTRALISED SYSTEM.

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5.7 Stakeholder workshop

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

- **Representatives from key government ministries confirmed that eCook has the potential to address several of Myanmar's interlinked developmental challenges, however coordinated action is required to overcome the key barriers highlighted during this research.**
- **A participatory design exercise with live cooking demonstrations showed that food cooked on energy-efficient electric cooking appliances was just as delicious as food cooked on other fuels.**
- **An optimised system designed to meet the needs of a household of six was designed with monthly costs of 6,000-19,000 MMK (4-12.5 USD).**
- **If eCook can be partnered with appropriate social marketing & training designed to enable users to cook efficiently with energy-efficient electric appliances, battery banks can be much smaller & costs can be significantly reduced**
- **A streamlined ecook device with a single dc appliance was found to costs 1,500-6,000 MMK/month (1-4 USD/month). This could cook rice twice a day & could be the first step for many towards an all-electric cooking solution.**

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

Figure 12: Setting the timer on the EPC at the stakeholder workshop hosted by the Department for Research & Innovation (DRI) and REAM in Yangon.

5.7.1 Overview of workshop

The national stakeholders' workshop '*Innovative Research on Electric Cooking and Beyond*' took place at the Department for Research and Innovation, Yangon, Myanmar from the 29th to the 31st January 2018. The main objective of for workshop was to explore the opportunity for eCook in Myanmar. The workshop targeted government stakeholders, with representatives from key ministries attending.

REPRESENTATIVES FROM KEY GOVERNMENT MINISTRIES CONFIRMED THAT ECOOK HAS THE POTENTIAL TO ADDRESS SEVERAL OF MYANMAR'S INTERLINKED DEVELOPMENTAL CHALLENGES.

The workshop was conducted for three days; on the first day participants were acquainted with the eCook concept and relevant national programmes. On the second day, participants carried out practical experiments with eCook appliances and worked in small groups to design an eCook product/service tailored to the needs of everyday cooks in Myanmar. On the final day, participants summarised the key opportunities and challenges that await for eCook in Myanmar.

5.7.2 Key outcomes

Representatives from key government ministries confirmed that eCook has the potential to address several of Myanmar's interlinked development challenges, however coordinated action is required to overcome the key barriers highlighted during this research.

A PARTICIPATORY DESIGN EXERCISE WITH LIVE COOKING DEMONSTRATIONS SHOWED THAT FOOD COOKED ON ENERGY-EFFICIENT ELECTRIC COOKING APPLIANCES WAS JUST AS DELICIOUS AS FOOD COOKED ON OTHER FUELS.

Live cooking demonstrations showcased the range of energy-efficient electric cooking appliances currently available by cooking popular Myanmar dishes. Some groups used charcoal, some used LPG, but the food was judged to be just as delicious across all fuels, yet much easier to prepare and much cheaper with electricity.

As part of the eCook product/service design small group work on day 2, a modelling exercise was carried out to calculate the relative cost of each group's solution compared to the cost of other popular cooking fuels. Repayment horizons of 3, 5 and 20-years were modelled to represent different private sector and utility business models. Under the private sector 'pay-as-you-go' business model, users would pay a monthly fee for 3 or 5 years. The monthly payments would be set such that after the 3 or 5 years, the supplier would have recovered their

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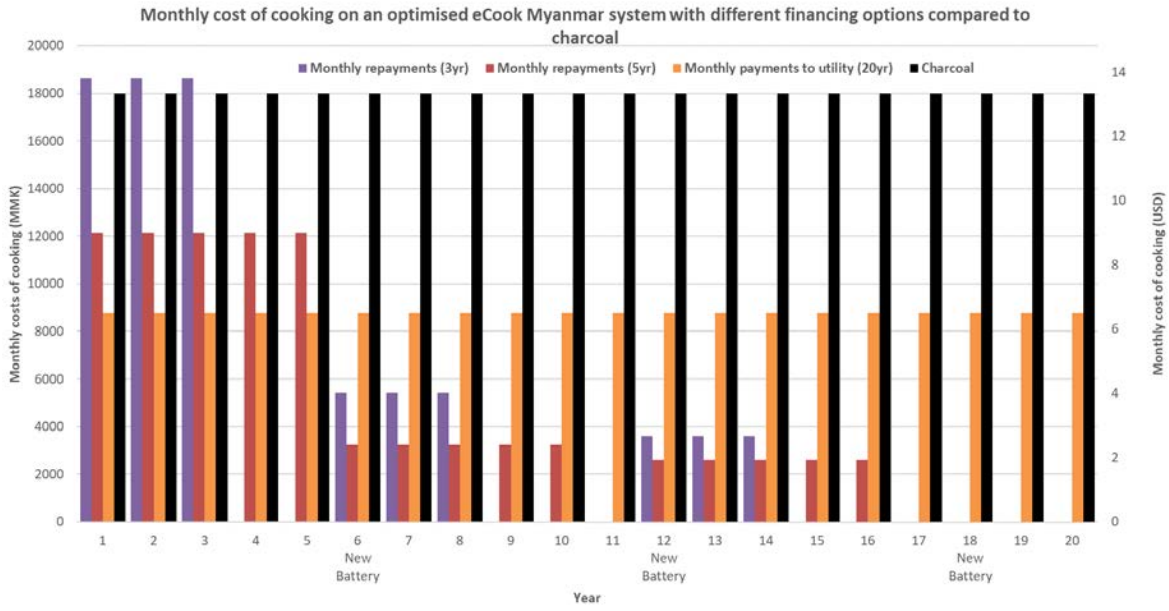
investment. At the end of the period the user would own the equipment. The equipment would still be functioning, and essentially the users would continue to cook for free. However, from this point onwards the users would be responsible for maintenance and replacement. Since batteries are expected to last 6 to 7 years, users would likely need to replace the batteries at that point. Even though energy storage costs are decreasing, so the price of batteries is expected to be cheaper by then, the user is likely to still require financing support for such replacements. Under the utility business model, the utility would set the monthly tariff to recover its investment over 20 years, and the user would never own the equipment. The utility would retain responsibility for replacement and maintenance and replacements for as long as the user pays the monthly fee. These magnitude and duration of these different payment schedules are compared in Figure 5.

AN OPTIMISED SYSTEM DESIGNED TO MEET THE NEEDS OF A HOUSEHOLD OF SIX WAS DESIGNED WITH MONTHLY COSTS OF 6,000-19,000 MMK (4-12.5 USD).

Figure 13: Payment schedules of an optimised PV-Cook system designed to meet the cooking needs of a household of six people.



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During the practical cooking design session participants were split into 3 groups and offered a range of cooking equipment with which to cook a typical Myanmar meal, consisting of rice, curry, soup and green tea. Energy readings were taken by the participants, and the quality of the resulting dishes, the experience of the cooking processes and the energy data were later discussed by the participants. Participants noted that their processes for cooking may not have been the most efficient, and given more experience they are likely to have been able to make significant energy savings. For instance, in one case the wrong pot was used with a pressure cooker, causing steam to escape throughout the cooking process, and resulting in significantly higher energy readings than expected. Extrapolating the data from the workshop and calculating monthly costs of cooking in this way, the results range from 18,000-50,000 MMK (US$13-$36) monthly cost for a system designed to meet a household of six's everyday cooking needs using different blends of electricity, charcoal and firewood.

IF ECOOK CAN BE PARTNERED WITH APPROPRIATE SOCIAL MARKETING & TRAINING DESIGNED TO ENABLE USERS TO COOK EFFICIENTLY WITH ENERGY-EFFICIENT ELECTRIC APPLIANCES, BATTERY BANKS CAN BE MUCH SMALLER & COSTS CAN BE SIGNIFICANTLY REDUCED

There is a need for eCook to be partnered with appropriate social marketing and training designed to enable users to cook efficiently with energy saving electrical appliances. This was highlighted by the fact that some of the energy data obtained during this exercise was higher than one might obtain from a practiced cook familiar with the equipment. The report therefore outlines two optimised systems based upon combining the data obtained during the workshop with comparable tests carried out in the REAM office. Figure 5 shows the payment schedules for the first of these, which was also designed to meet a household's everyday needs, but with an optimised all electric system with monthly costs ranging from 6,000-10,000 MMK (4-6.5 USD) for Grid-eCook and 8,500-19,000 MMK (5.5-12.5 USD) for PV-eCook. The second optimised system was designed to cook just rice two times a day and has monthly costs ranging from 1,500-2,500 MMK (1-1.5 USD) for Grid-eCook and 2,500-6,000 MMK (1.5-4 USD) for PV-eCook. This single appliance based 'rice-eCook' system could be a gradual first step for many towards cooking entirely on battery

A STREAMLINED ECOOK DEVICE WITH A SINGLE DC APPLIANCE WAS FOUND TO COST 1,500-6,000 MMK/MONTH (1-4 USD/MONTH). THIS COULD COOKRICE TWICE A DAY & COULD BE THE FIRST STEP FOR MANY TOWARDS AN ALL ELECTRIC COOKING SOLUTION.

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electric systems, with the user adding more appliances as they gain more confidence in the technology and/or as more money becomes available.

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6 Conclusion

There are clear indications particularly from the diaries and focus group exercises, that households would adopt electricity for cooking – if the price and other conditions were 'right'. Behaviour change is as important as we had originally thought, but our understanding of how people cook and the compatibility with different electrical appliances has improved. We can now see that the motivations to change behaviour to adopt an aspirational product that offers more than what a charcoal stove can (or even LPG) are an alternative and seemingly more viable pathway than creating something that mimics as closely as possible the slow and inefficient nature of charcoal stoves**.**

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

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

The price point may not yet have been reached for battery-supported eCooking, however the evidence from the cooking diaries shows that it is already cost effective to cook with off-the-shelf energy-efficient electric cooking appliances. The cost and challenges involved in building the demonstration prototype highlight the current situation – challenges in sourcing key components locally (higher capacity lithium ion batteries and DC cooking appliances) and a high cost for what is available (batteries at $520/kWh). This comes as no surprise to us. Our premise since 2013 has been that components will become cheaper and more available as learning rates kick in for lithium ion batteries in particular. If adequate supply chains are established, by 2020 eCook systems will be affordable in Tanzania.

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

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

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

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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 14 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.

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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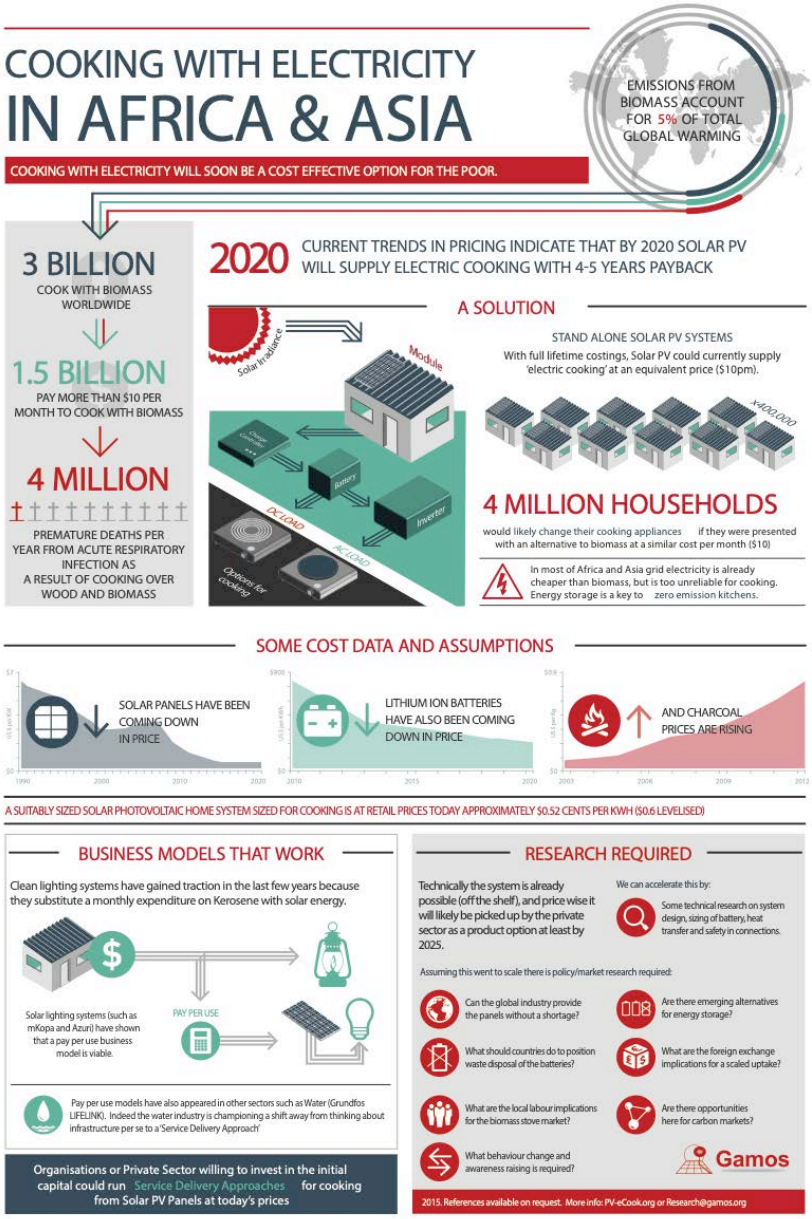

Figure 14 Infographic summarising the concept in order to lobby research and policy actors.

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.

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

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

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

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

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

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

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

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

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

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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 15 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.

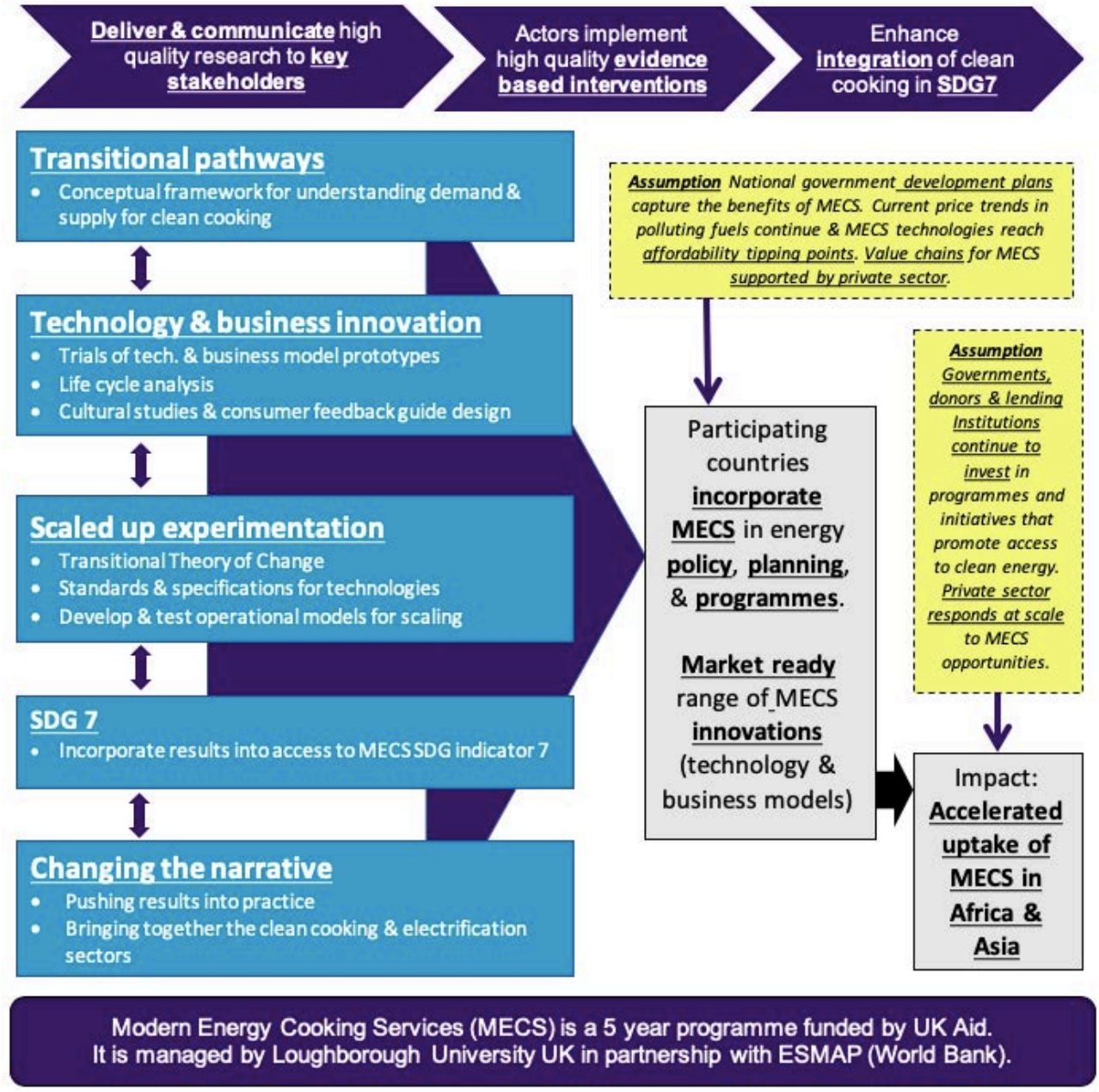

Figure 15: Overview of the MECS programme.

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