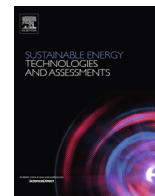


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Original article

eCook: What behavioural challenges await this potentially transformative concept?

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ABSTRACT

This paper aims to identify and understand the challenges that may confront the scaling up of a proposed battery electric cooking concept (Batchelor 2013), eCook, which offers the potential for emission free cooking, with time/money savings and broader environmental benefits from reduced fuelwood/charcoal consumption. By drawing on the literature on the transition to electric cooking in South Africa and more broadly, literature from across the Global South analysing the uptake of ICS (improved cookstoves), LPG (liquid petroleum gas) and solar home systems, this study identifies the factors (e.g. successful delivery models and marketing strategies) that have enabled these innovations to reach scale. This knowledge is then related to the eCook concept, by identifying the potential users of this promising technology and outlining potential marketing strategies, as well as a user-focused iterative design process, that will enable social enterprises to reach them. Uptake is predicted to be most rapid in hot climates where fuelwood/charcoal is purchased and low energy diets and low power cooking devices are the standard. Mobile enabled fee-for-service (utility) business models, the establishment of a service network, awareness raising campaigns on the benefits of clean cooking, female-focussed training programmes and bundling eCook systems with locally appropriate appliances to enable productive activities are seen as key to reaching scale.

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Introduction and research objectives

This paper is situated at the intersection between two major global challenges; the continued use of biomass for cooking amongst large swathes of the global population which is harmful to health and to the environment, and the challenge to extend modern energy access to all (encapsulated within the seventh Sustainable Development Goal). A burgeoning literature (reviewed by [67,68]) details the significant human costs that high levels of dependence upon traditional cooking methods bring for households across the continent. These include the enormous health toll of exposure to black carbon and other particulates present in the smoke from cooking fires [28,57], burns and the impact of firewood collection itself, the economic costs of high fuel expenditure and the time lost in gathering fuel, as well as the environmental implications of GreenHouse Gas (GHG) emissions, forest degradation

and deforestation from unsustainable practices. The international community has not been inactive in the face of these challenges and over the past decades there have been a succession of initiatives which have sought to promote the uptake of improved cookstoves and modern cooking fuels. Nevertheless, by 2015 the uptake of clean cooking solutions (transition to LPG, renewable fuels or improved efficiency biomass cookstoves) remains as low as 10% in Sub-Saharan Africa (compared with 27% in South Asia, 41% in Southeast Asia, 51% in East Asia and 80% in Latin America: World Bank [67,68]).

The electric cooking concept put forward in this paper is based upon the premise that by 2020 the cost of using solar photovoltaic (PV) panels (or potentially any other off-grid, mini-grid or unreliable grid power source) to charge a battery, and then using the battery for cooking as and when required, is likely to be comparable to the monthly cost of cooking with charcoal and wood in most parts of the Global South [4]. The use of electric cooking systems could meet the twin goals of both increasing access to modern energy services, and providing a means of truly clean cooking to households across the Global South. In fact, some [66] suggest that highly insulated, very low power stoves (100 W, \$100 purchase price) are

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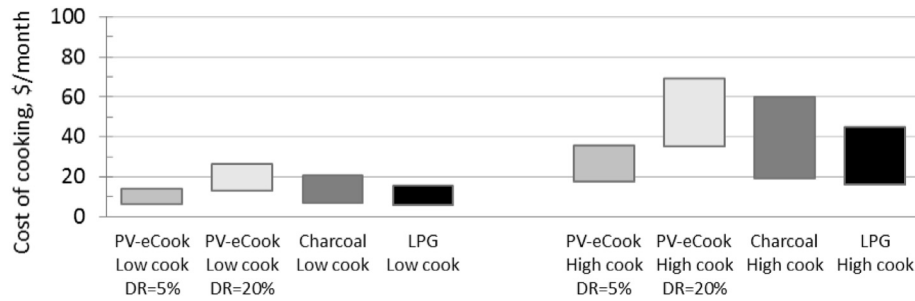


Fig. 1. Predicted comparative cooking costs in 2020 [35]. DR = Discount Rate.

already cost effective in the Ugandan context. However, the behavioural change challenges of cooking with insulated utensils are clearly much greater than on a conventional electric hob.

In what follows, we explore the potential contribution of a basic electric cooking concept, eCook, which consists of a simple battery and 500 W electric hob [3], towards meeting these twin goals. Whilst induction hobs may offer higher efficiencies [39], a cold hob magnetically heating specialist pots/pans (with a high ferrous content) requires greater behavioural change to transition from fuelwood/charcoal. However, although we are initially focussing on the simple hotplate, induction hobs are expected to play an important role in the future evolution of the eCook concept.

The battery storage is the key eCook system component, as it enables households with unreliable electricity supplies to cook at a time that is convenient to them. The concept is not a specific product, more a potential future configuration of existing components and has initially been proposed in two forms:

- packaged with solar PV panels¹ in a similar format to the popular Solar Home Systems (SHS) and referred to here as PV-eCook; and
- packaged with a battery charger² for grid or mini-/micro-/nano-grid connections, referred to as B-eCook.

Our particular focus concerns the social/behavioural implications that will need to be addressed in the development of this concept. This work was commissioned by the UK Department for International Development (DfID) alongside two other studies, which were undertaken in parallel, addressing specific aspects of the economic and technical feasibility of the eCook concept.

The first study [35] modelled the economics of the PV-eCook concept. Whilst a bigger battery and a more powerful hotplate would certainly enhance the usability of the product, their model showed that the majority of the upfront costs would be invested in the battery for the system, which therefore means that optimising the size of this component is critical. They take the necessary useful energy for cooking and work 'back' to what size the battery would need to be, before finally taking two scenarios of insolation and working out what size a photovoltaic array would be required to keep the battery charged. In order to benchmark the cost of PV-eCook, Leach and Oduru [35] compare the outputs with equivalent energy consumption (and cost) data for cooking with charcoal or LPG. They created eight generalised scenarios: a 'low cook' scenario with Discount Rates (DRs) of 5% and 20%, and a 'high cook' scenario with the same DRs, modelled at 2015 and 2020 prices. 'Low/high cook' accounts for the cultural differences in cooking practices that result in lower or higher energy and power requirements. Their calculations illustrate that, while today in 2015 the range of monthly costs for the PV-eCook system is certainly higher

than for most charcoal and LPG markets, if current price trends continue, by 2020, the monthly cost of PV-eCook is likely to be comparable to that of charcoal and LPG (see Fig. 1). The initial purchase cost of the optimistic (5% DR) 'low cook' scenario is predicted to be US \$718, implying that innovative financing mechanisms will be required to enable poor households to access the technology. As well as concerns over the cost of the battery, there were also questions about the durability and lifetime of currently available batteries. Accordingly, a second study was specifically commissioned on the technical capabilities of current and emerging battery chemistries relevant to the eCook proposition. This second study [56] concluded that currently available LiFePO₄ batteries should be viable for the proposition, although it also drew attention to the absence of independent data on battery performance in high temperature and high discharge conditions.

Although the technical, social and economic dimensions are clearly intertwined, the rest of this paper is conducted on the assumption that the eCook concept will be both technically and economically feasible³ and instead focuses on the social/behavioural implications that will need to be considered in its development by specifically addressing the following two research questions posed by DfID in the remit for their original study:

- "What are the possible intra and inter household dynamics among African households (including the very poor) that may affect the uptake of [the proposed eCook concept]?"
- "What are the behavioural change challenges that should be understood and investigated through longer term research that may affect the [further development] of the concept?"

Our specific focus in the paper concerns the potential uptake of the eCook concept within the Sub-Saharan African (SSA) context although, where appropriate, we draw upon relevant examples from other parts of the Global South (and beyond). In what follows we draw upon both the original report presented to DfID on behavioural change by Brown and Sumanik-Leary [11]⁴ and the synthesis of all three of the studies written by Batchelor [5].

The first part of the paper comprises a literature review focusing on four related energy transitions, with the aim of drawing out the key lessons learned and highlighting their relevance to the proposed eCook concept. These comprise:

- Electric cooking in South Africa, the only SSA country which has had considerable uptake of electric cooking to date.
- Improved cookstoves, which have been adopted to varying degrees across the Global South.

³ Readers interested in more detailed discussion of the technical and economic dimensions should consult [35] and [56]. For further information on the genesis of the eCook concept see [4].

⁴ The report for DfID goes into the issues raised in what follows in far more detail than we are able to do in this relatively concise paper.

¹ i.e. battery, charge controller, PV panels and electric hob.

² i.e. battery, AC battery charger and electric hob.

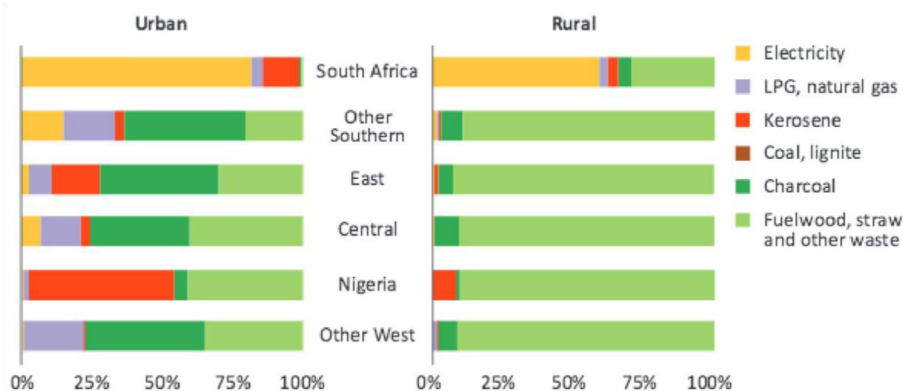


Fig. 2. Main fuel used by African households for cooking [27].

- c. LPG, which is comparable to electric cooking from an end-user perspective.
- d. Solar Home Systems (SHS), as the PV-eCook concept is fundamentally akin to a higher capacity SHS designed to replace solid fuel burning for cooking instead of kerosene/candles for lighting.

The second section draws on the first to make recommendations for how the eCook transition could be facilitated and contains two sub-sections:

- a. A very high-level market analysis using the findings from the literature review to identify the market segments most likely to embrace the proposed eCook concept. It begins by comparing eCook to other clean cooking technologies, before exploring how it might relate to existing energy access dynamics and socio-economic status, climatic conditions, national policy contexts, local cooking practices and other key factors.
- b. A discussion of alternative marketing strategies for eCook, which explores issues such as intrahousehold dynamics, community engagement, participation, household decision-making processes and a user-focussed, locally-framed design approach.

Finally, in the conclusion we draw together our thoughts on the potential developmental impact of eCook and outline some of the knowledge gaps that could be addressed by further programmes of detailed empirical research.

Related energy transitions

Electric cooking in South Africa

South Africa is one of the few places in Africa where a significant number of people already cook using electricity Fig. 2; [10,15,26,51]. A review of the literature on the use of electricity for cooking in South Africa reveals a number of drivers behind its growth, as well as a number of barriers to its further adoption. Positive drivers (Table 1) supporting the transition to electric cooking in South Africa identified included: lower purchase prices for electric stoves than LPG stoves; the high fire risk of paraffin stoves in informal urban settlements (which led to the government favouring safer electric cooking in national policy) and the low unit cost (which several studies demonstrate have made electricity significantly cheaper per meal than LPG, paraffin or ethanol gel). It should

Table 1

The key drivers for the transition to electric cooking in South Africa.

Driver	Sources
Electric stove purchase price < LPG stove.	[14,9]
High fire risk of paraffin stoves.	[14,9]
Low unit cost (kWh) of electricity	[14]

be noted also that even where electric cooking is prevalent fuel stacking⁵ is common and that reliability of supply issues often translate into the strategic use of alternative fuels.

Regarding barriers (Table 2), it is interesting to note that despite the evidence on the relative cost of electric cooking indicated above, electricity has often been perceived as too expensive for cooking, even where it has been in fact competitive with alternative fuels. Consumers also frequently thought that the stoves were 'more expensive' than alternatives. The government's Free Basic Electricity programme, under which the first 50 kWh/month is free for poor households, whilst not changing the situation overnight, appears to have helped change the perception of electricity costs to some degree amongst the poorer sectors.

Clearly, not everyone in South Africa uses electricity for cooking. Of those who have not taken up electricity, there is a context specific barrier – particularly relevant where collecting firewood is possible. Low income homes connected to the grid would still prefer to use firewood for cooking as it has no cash cost to the household. There are also areas of South Africa that remain unconnected to the grid – both rural and informal urban areas. However this situation is changing with the government increasing the number of relatively reliable grid connections, as national policy is focused on grid expansion. Many sources reported that multiple fuel use is already common and therefore, due to the limited amount of energy storage available in a battery sized for daily use, fuel stacking is likely to be almost universal amongst future eCook users in order to cater for times of exceptionally high demand (e.g. when entertaining guests). Complimentary evidence from Ethiopia [1] shows that the relative prices of electricity and fuelwood were also key determinants to adoption and sustained use of electric stoves in this context, as was access to credit to make the initial purchase.

Finally there appear to have been two further factors identify that have mitigated against further transitions towards electric cooking in South Africa – the presence of poor quality equipment (hob) and the additional peak demand that electric cooking

⁵ The use of multiple fuels, each usually with a different cooking appliance ([10,52]).

Table 2
Key barriers preventing the transition to electric cooking in South Africa and (where applicable) the enablers that overcame them.

Barrier	Enabler	Sources
Cooking with electricity perceived as expensive	FBE (Free Basic Electricity) – 50 kWh/month for poor households	[14,9]
Collected firewood still attractive to low income households	Fuel stacking common	[14,58,51] [9,1]
Lack of grid connection in rural and informal urban areas	Increasing number of relatively reliable grid connections, due to national policy focus on grid expansion	[9,51]
Poor quality equipment (hob)		[14]
Initial purchase costs	Access to credit	[1]
Additional peak demand on already overloaded national generating capacity		[26,31]

places on South Africa's already strained electricity infrastructure (leading to mixed messages from state agencies over the desirability of electric cooking). Interestingly, recent literature suggests that the South African government intends to promote LPG as a cooking fuel, primarily to reduce demand on the nation's already overstretched national generating infrastructure [31]. Clearly this presents an opportunity for eCook, as using battery storage offers the potential for significant numbers of people to transition to cooking with electricity, whilst spreading this demand out throughout the day.

Improved Cookstoves

Considerable international effort has been exerted over recent decades in designing and distributing Improved CookStoves (ICS), with the aims of encouraging more efficient use of fuelwood/charcoal (reducing the pressure on local forestry resources and reducing the time spent collecting it) and reducing the damaging health impacts of high levels of indoor air pollution. The literature states three clear drivers behind this transition:

1. The first is the potential for local manufacture of stoves with its associate benefits: giving communities the opportunity to participate in the design and delivery of locally appropriate stoves; boosting the local economy; building capacity for after-sales service and creating local jobs [43]. It is worth noting, however, that there is also a counter narrative in the literature that suggests that even Improved Charcoal Cookstoves should be manufactured in factories where the quality of the stoves can be controlled since it is argued that locally produced stoves often are poor quality and do not actually perform as promoted (in terms of reducing carbon emissions and reducing air pollution).
2. The second driver is the growing international concern over the serious health and ecological problems caused by traditional cooking practices, particularly for women and children [49,37,50]. ICS have been promoted as a solution to these challenges at a variety of scales (from international agencies such as the WHO to grass roots NGOs), using a variety of mechanisms (e.g. policy support for market systems, subsidies, awareness raising campaigns), due to their ability to improve indoor air quality, reduce the risk of burns within the household and reduce carbon emissions and slow the pace of deforestation.
3. The third driver is the time taken to collect fuelwood (primarily in rural areas) and the cost of purchased fuelwood/charcoal which in many contexts is becoming increasingly significant [49,16,19,50].

While the second and third of these drivers are directly relevant to eCook, the first is only partially applicable. However since the ICS sector has been operating globally for more than three decades, there are also considerable insights into the barriers experienced, along with enablers of uptake that can overcome those barriers. Table 3 presents the key insights that we have drawn from this literature.

Liquid Petroleum Gas (LPG)

LPG is comparable to electric cooking in terms of the end-user experience and is widely used as an equivalent to natural gas in Northern regions without a mains gas supply [31,46]. As a result, this section presents the results of a review of the literature surrounding the transition to LPG in the Global South in order to offer a greater understanding of the factors that influence consumer choice when switching to a modern cooking fuel. Based on studies from low and middle income countries, it appears that a key driver for LPG programmes is the desire and aspiration for modernisation [24,46]. LPG is indeed a highly versatile fuel, compatible with a wide range of utensils and able to meet highly variable demand patterns (as long as additional fuel is available of course). Several studies suggest a strong link between electrification and uptake of LPG. As with ICS, key drivers include the increasing price of charcoal, and a desire for improvements in health from lower kitchen emissions [24,61,42]. Interestingly, some local manufacture of LPG equipment is possible [61].

In terms of barriers to LPG uptake, the literature highlights the high relative cost levels of LPG (compared to biomass). Subsidies are often poorly targeted, tending to benefit the rich, well-educated urban elite or in some cases, motor vehicle owners [42,24,61,46]). The supply of LPG is dependent on imports in countries without indigenous resources or the expertise to exploit them. In these contexts, supply chain vulnerabilities can frequently create price volatility and even cut off supply [61,67,68,46]. Governments have mitigated these barriers with clear marketing of health and other benefits; well-targeted subsidies, e.g. initial purchase costs (stove, cylinder, accessories) for low income rural households; and exploitation of national fossil fuel reserves where they exist or opening up markets to international suppliers and introducing effective price controls. In Indonesia, resistance to change amongst existing market actors was carefully addressed by the national LPG conversion campaign, which offered policy support to existing kerosene dealers in order to upgrade to LPG [46].

Table 4 and Table 5 list the key drivers, barriers and enablers we have identified from the literature exploring the transition to LPG in the Global South.

Solar Home Systems

Understanding the factors underlying the substantial growth in the use of Solar Home Systems (SHS) and pico-solar products across the Global South is of particular relevance to the PV-eCook concept, which is essentially a higher capacity SHS designed to replace solid fuel burning for cooking rather than replacing kerosene/candles for lighting. The key drivers and barriers to the growth of use in solar systems are presented in Tables 6 and 7 below.

Recommendations for eCook

Over the preceding pages we have presented a review of experiences from a variety of transitions to cleaner cooking

Table 3

Key barriers preventing the transition to ICS in the Global South and (where applicable) the enablers that overcame them.

Barrier	Enabler	Sources
Poor quality imitation ICS	Development and enforcement of international/national standards	[43,49,50]
Financing: <ul style="list-style-type: none"> • Upfront cost of the stove • Poorly designed subsidies undermining end-user ownership • Lack of capital for business growth • Firewood in rural areas usually collected for free 	Innovative financing mechanisms: <ul style="list-style-type: none"> • Micro-credit • International carbon funding • Financing support for key • Sector actors and development of entrepreneurialism 	[40,2,37,67,43,50,38]
In many cultures, ICS benefits are mainly for women, whilst men make purchasing decisions		[49,40,23,48]
User practices often different to laboratory test conditions used by stove designers & still only a partial solution: <ul style="list-style-type: none"> • Even the best ICS still produce harmful emissions, particularly when not used as designed • Can be incompatible with local cooking practices due to lack of adaptability • Efficiencies can be lower than traditional three stone fire if not utilised appropriately • Ongoing need for firewood/charcoal • Small reductions in fuelwood use don't always translate into fuelwood collection time savings. 		[21,49,30,49,37,12,40]
Policy focus on electrification, not biomass means lack of high-level political buy-in.	Strong global and national promotional framework (GACC)	[49]
Lack of awareness of locally available ICS products and their benefits.	Well-regulated market based approaches with effective social marketing strategies: <ul style="list-style-type: none"> • Knowing the market • Matching message to context specific purchasing triggers & barriers • Getting the mix right • Surge of social marketing activities is required initially • Early adopters who may not be the poorest facilitate word of mouth dissemination in new places • Targeted awareness raising campaigns on benefits of ICS • Village leaders facilitating consensus in community decision making and promotion of the technology 	[65,55,44,20,43,23,49,21,37,50]
Each context different: <ul style="list-style-type: none"> • Local availability of skills and construction materials • Effectiveness of particular marketing messages 	<ul style="list-style-type: none"> • Evolution of designs and marketing strategies to match local cooking practices and locally available skills and materials • Development of effective after-sales service • Greater participation of women throughout the value chain, from product design to after-sales service • Locally appropriate marketing campaigns (see above). 	[49,43,48]

technologies and other energy services (SHS). In this next section we draw upon these experiences to reflect upon the possible intra and inter household dynamics among African households that may affect the uptake of the proposed eCook concept in order to identify key potential market segments and make recommendations for how the eCook concept might be taken forward in a way that makes transition more likely for a greater number of households.

Market analysis

The affordability of an eCook system will be only one factor – the distribution network, maintenance requirements, awareness of consumers, and the changing prices of alternative fuels all play a part (among others) on influencing the potential uptake of the PV-eCook proposition. Both the economic modelling conducted by Leach and Odoro [35] and the data presented in this study have addressed alternative cooking fuels, and pointed out that households are likely to undertake different ‘fuel stacking’ strategies in different market segments depending on a wide range of factors.

Accordingly, here we attempt to build on the systematic review commissioned by DFID on the Factors influencing the large-scale uptake by households of cleaner and more efficient household energy technologies [47], later summarised in [46] and [50]) by situating the eCook concept alongside existing clean cooking technologies. Our analysis (summarised in Table 8. and outlined in

Table 4

The key drivers for the transition to LPG in the Global South.

Driver	Sources
Desire for modernisation – aspirational fuel	[24,46]
Deforestation from excessive fuelwood collection/charcoal production leading to rising consumer prices of fuelwood/charcoal	[24,61,42]
Health/safety: <ul style="list-style-type: none"> • Less dangerous than paraffin/kerosene • Reduces indoor air pollution 	[14,42]
Potential for local manufacture of stoves, cylinders and even LPG itself if local gas reserves exist	[61]
Highly flexible – faster cooking and able to adapt to a range of utensils and meet highly variable demand patterns	[31,46]

more detail in Brown and Sumanik-Leary [11]) suggests that PV-eCook is likely to sit alongside LPG as an aspirational cooking technology. Although we expect the cost to fall considerably over time, strong accompanying financing schemes will be needed to allow the user to repay the value of the system over time⁶. PV-eCook is likely to have broad geographical reach, arguably even broader than

⁶ Of course, the cost of offering these financing schemes will need to be taken into account when making economic comparisons between eCook and traditional cooking practices.

Table 5
Key barriers preventing the transition to LPG in the Global South and (where applicable) the enablers that overcame them.

Barrier	Enabler	Sources
Taste – smoky flavour preferred by some rural households		[46]
Safety risk, or perceived safety risk	User training, stove/cylinder manufacturer/distributor regulation	[33,46,54,8]
Resistance to change within supply chain for existing fuels	Policy support to allow existing dealers to upgrade their business to LPG	[46]
High capital costs and variable fuel costs. Subsidies often poorly targeted, so benefit can fall primarily on: <ul style="list-style-type: none"> the rich, well-educated urban elite motor vehicle owners, especially if cross-subsidised from petrol 	Clear marketing of health and other benefits, paired with well targeted subsidies, e.g. initial purchase costs (stove, cylinder, accessories) for low income rural households	[42,24,61,46]
Supply issues: <ul style="list-style-type: none"> Dependent on imports in countries without indigenous resources or the expertise to exploit them Supply chain vulnerabilities can create price volatility and even cut off supply 	Exploitation of national fossil fuel reserves where they exist, opening up to international suppliers and introducing effective price controls to ensure diversity of supply	[61,67,68,46]

Table 6
The key drivers for the transition to SHS in the Global South.

Driver	Sources
Replacement of other purchased fuels, e.g. kerosene, candles	[32,41,53]
Micro-benefits highly valued by users: <ul style="list-style-type: none"> § Lighting for indoor air quality, safety, studying, social space, evening work § Mobile phone charging, TV and other 'connective' applications 	[59,41,29,8,53,45]
Inter-household power generation differences minimal as solar resource geographically well correlated with people living without access to electricity, spatial variation of resource generally low on a national scale and power production linearly proportional to the solar resource.	[62]

LPG, as it does not depend on the local availability of specific fuels or feedstocks.

Like solar cookers, it clearly requires a good solar resource, however in most parts of the Global South is high. Although well suited to boiling stew-like dishes during the day, the major barrier for solar cookers has been their lack of flexibility to cater to a range of cooking patterns and utensils [7]. However, in common with LPG, biogas and traditional fires, eCook is highly adaptable to a range of cooking utensils, as pots and pans of varying shapes and sizes can easily be accommodated by the standard electric and the concept can undoubtedly be adapted to include alternative appliances such as rice cookers and toasters. However, a major limitation is expected to be its ability to accommodate variable cooking patterns, as in order to be cost effective, the battery must

be sized for every day use. As a result, fuel stacking should be expected, as users are likely to resort to more flexible supplementary technologies (e.g. LPG, ICS or traditional fires) in order to meet exceptionally high demand on special occasions such as religious holidays.

As one might expect, each of the technologies has specific advantages that might attract specific users and disadvantages that might turn them away. The conclusion is that there is no universal solution, and that therefore fuel-stacking is to be expected in almost all circumstances.

Market segments: Where is this transition likely to take place first?

We now move on to provide a commentary on which potential market segments might be the most likely to adopt eCook in different settings. Firstly, the key criteria were drawn from the various literature reviews discussed above. This explored the interplay of existing energy access dynamics and socio-economic status in determining the most likely markets for eCook in some detail, as well as consideration of the potential influence of variation in climatic conditions, national policy frameworks and local cooking practices. The full analysis is presented by Brown and Sumanik-Leary [11], however, due to space restrictions, in this paper we limit ourselves to presenting just the key elements of our analysis, focusing most closely on the interplay between current cooking practices and current levels of electricity access (Table 9).

We predict that uptake of the eCook concept will be most rapid in hot climates, where there is no need for heating from a traditional stove; contexts where fuelwood/charcoal is purchased and prices are increasing most rapidly; cultures where low energy diets (fewer meals that require lower thermal input during the cooking

Table 7
Key barriers preventing the transition to SHS in the Global South and (where applicable) the enablers that overcame them.

Barrier	Enabler	Sources
Limited range of energy services (and therefore productive uses), so potential for poverty alleviation limited. Potential for negative perception of SHS if grid extension also available	Growing capacity of SHS systems	[29,36]
Theft of high value components		[36]
Awareness low in older, poorer and less well educated households	Awareness raising campaigns targeted at specific groups of users	[64,53,60]
Maintenance and after sales service: success of SHS programmes frequently affected by poor maintenance, low quality products and lack of after sales service	Development of effective service networks Local capacity building for small businesses and technicians Independent product testing and standards	[13,59,34,62,6,63]
Cost issues: <ul style="list-style-type: none"> § High initial purchase costs and even monthly payments make SHS difficult for poor households to afford § Productive uses and hence income enhancement potential limited § Savings on low kerosene, disposable batteries etc. expenditure by poor households often not enough to cover SHS costs 	<ul style="list-style-type: none"> Decrease in price of LEDs and PV panels Extensive donor support for PV Enabling national policies (e.g. VAT & import tax exemption) New business models Fee-for-service with mobile payments and/or micro-credit 	[17,22,36,34,29]
Every local context unique, so significant time and effort required to find a delivery model that works in each new place	Market analyses for each new context to determine who to target and how	[13]

Table 8

Comparison of the key factors affecting the initial adoption of the eCook concept with the most common clean cooking interventions.

	Three stone fire	Solar cookers	ICS	Biogas	LPG	eCook
Perception	Traditional	Intermediary	Intermediary	Intermediary/ aspirational	Aspirational	Aspirational
Upfront cost	None	Med	Low-Med	High	High	High (falling)
Awareness	Universal	Low	Med	Low	Med	None
Land/Livestock requirement	Forest/livestock/ ag. residues for solid fuel	None	Forest/livestock/ ag. residues for solid fuel	Livestock/ag. residues for digestate	None	None
Environmental restrictions	None	Sunny location	None	Warm location	None	Sunny location (PV-eCook)
Flexibility in range of utensils	High	Low	Med	High	High	High
Ability to accommodate variable cooking patterns	High	Low	Med	Med	High	Low
Training requirements	Low	Med	Med	High	Med	High (PVeCook) Med (BeCook)

Table 9

Categorisation of potential eCook adopters according to existing levels of energy access and assessment of each sectors' likelihood to transition.

Likelihood of transition		Key barriers to transition			
Transition to eCook very unlikely		Locally appropriate delivery model	DM		
Transition to eCook challenging as many barriers to address		Awareness raising showing health benefits**	AR		
Transition to eCook possible if several barriers are addressed		Innovative financing*	IF		
Transition to eCook likely if several barriers are addressed		Technical training on PV systems	TT		
Transition to eCook likely if key barrier addressed		Battery subsidy	BS		

CURRENT ACCESS TO ELECTRICITY					
CURRENT COOKING APPLIANCE	None		Off-grid/isolated systems, e.g. Solar Home Systems (SHS)	Unreliable national grid or mini-/micro-/nano-grid	Reliable national grid supply
	3 stone fire or traditional stove Solid fuel collectors	Least likely to transition, as technical, financial and cultural barriers greatest.	Transition to PV-eCook possible with DM, AR & IF. No obvious financial substitution.	Transition to B-eCook possible with B-eCook, DM, AR & IF. No obvious financial substitution.	Battery not required from end-user perspective***. Transition very unlikely - households have currently chosen time based collection rather than cash expenditure on energy.
3 stone fire or traditional stove Solid fuel purchasers	Transition to PV-eCook possible if TT, IF, AR & DM offered.	Likely transition to PV-eCook with DM, AR & IF as fuel payments can offset cost.	Likely transition to B-eCook with DM, AR & IF as fuel payments can offset cost.	Battery not required from end-user perspective***. Possible transition to eCook with IF, BS, DM & AR.	
Improved Cookstove** Solid fuel collectors	Transition to PV-eCook challenging as TT, DM & IF. No obvious financial substitution possible.	Transition to PV-eCook possible : DM, AR & IF required. No obvious financial substitution.	Transition to B-eCook possible : DM, AR & IF required. No obvious financial substitution.	Battery not required from end-user perspective***. Transition very unlikely - households have currently chosen time based collection rather than cash expenditure on energy.	
Improved Cookstove** Solid fuel purchasers	Transition to PV-eCook possible if TT, DM, AR & IF offered.	Most likely to transition to PV-eCook as fuel payments can offset cost. Requires DM & IF.	Most likely to transition to B-eCook as fuel payments can offset cost. Requires DM & IF.	Battery not required from end-user perspective***. Possible transition to B-eCook with DM, IF, BS & AR.	
LPG/Biogas**	Already have access to other forms of modern energy, but relative monetary/time costs of fuel may drive transition to eCook. Requires TT, DM & IF.	Already have access to other forms of modern energy, but relative monetary/time costs of fuel may drive transition to eCook. Requires DM & IF.	Already have access to other forms of modern energy, but relative monetary/time costs of fuel may drive transition to eCook. Requires DM & IF*.	Battery not required from end-user perspective***. Already have access to other forms of modern energy, but relative monetary/time costs of fuel may drive transition to eCook if DM, IF & BS.	
Electricity	N/a	Already using a form of PV-eCook. If these people exist, they warrant further study.	Likely to transition to B-eCook, which offers superior reliability. Requires DM & IF.	Battery not required from end-user perspective***. Uptake of eCook only possible with BS.	

Assumptions – *For some market segments eCook equal or less than current expenditure. **User may be aware of health benefits having made transition to ICS/LPG/biogas. ***Battery only needed for national grid level system optimisation – load balancing and peak load reduction.

process per meal) and low power cooking devices are the standard; and in higher income, better educated, younger households.

The transition to PV-eCook is most likely to take place first in rural areas without potential for grid connection in the short- or medium-term, where SHS programmes have already reached scale in a sustainable manner, developing locally appropriate delivery models and paving the way for PV-eCook. Naturally, places with high solar resource throughout the year would be most favourable.

B-eCook is expected to spread most rapidly in urban settlements with unreliable grid or mini-grid connections in countries with a low unit cost for electricity. B-eCook is potentially a synergistic precursor to PV-eCook, as the urban market could be used to set up local service networks and create awareness before reaching out to the less accessible rural markets. Of course, the relative price

points of other cooking fuels are also a critical factor, which vary both geographically and temporally.

Countries with strong policy support for electrification (and/or SHS for PV-eCook) are likely to provide more favourable enabling environments for eCook initiatives and the value that load balancing (and if appropriate, also peak load reduction) can offer to the national electricity generation network is expected to be crucial for obtaining high level support for B-eCook.

Marketing strategies

To ensure that appropriate after-sales service is available and feedback is collected from end users and delivered to relevant stakeholders, a suitable service network should already be in place when eCook is launched. Ideally this should be achieved by

adapting existing networks, e.g. by strengthening the existing SHS infrastructure in rural areas to accommodate PV-eCook. Potentially, firewood/charcoal producers/vendors could be trained up as local technicians, as they stand to lose business in areas where uptake is rapid. However, in many contexts, training programmes may be most effective if focussed on women, as they are likely to be the primary beneficiaries and will therefore have the greatest motivation to see the technology succeed [23,20,63,25,18]. Bundling eCook with locally appropriate appliances can maximise the value of the embedded electrical infrastructure offered to households. This is particularly important in cultural contexts where men make major household decisions, as it can offer an incentive both to purchase and to keep up with repayments. Productive appliances that match with the availability of the solar resource, such as irrigation pumps, are particularly appropriate for PV-eCook in rural areas, where few opportunities for paid work that could take advantage of the time saved on food preparation and/or fuel collection exist.

Awareness raising campaigns on the benefits of clean cooking that are tailored to the local market (matching messages to context-specific purchasing triggers/barriers, brand awareness of locally available high quality and affordable products, credible partners and cost-effective campaign delivery mechanisms) should pave the way for eCook in new places by beginning with a surge of social marketing activities. However, in order to ensure maximum impact throughout society, longer term awareness raising campaigns should be targeted at older, less well educated and poorer households who are less likely to be amongst early adopters [48,25]. Finally, in order to overcome the potential perception of PV as an inferior technology that communities can be 'locked-in' to, PV-eCook should be designed to enable quick and easy conversion to B-eCook if/when the grid arrives.

It is perhaps interesting to note that many of these recommendations also apply to other technologies and in particular to ICS. The peer reviewer of our original report for DFID noted that "I have seen this recommended so many times (and even have recommended it myself!) for stoves that are of very poor quality. Once the consumer tries the stove, all this effort is for naught, because it does not perform. However, before these issues are addressed, you have to have a product to sell that provides a clear benefit vis a vis the cost to a consumer that is willing to pay for it." The performance of any eCook product will be absolutely fundamental, and will need to be closely matched the cooking (and other) needs of that particular household before any potential customer would make a decision to purchase, no matter how successful a marketing campaign has been conducted.

User-focussed design

This final sub-section of the recommendations starts from the premise that whilst a generic eCook prototype may serve as a starting point in each new place, each context will present its own challenges and opportunities and the value of ensuring that eCook continues to evolve in tune with these cannot be overstated. The continual evolution of eCook into a locally appropriate solution for meeting cooking energy demand in any potential location could be achieved using participatory design and extensive iterative field testing.

What is more, ensuring that the design of all eCook products remains focussed on the real needs of its users could universally improve its uptake. For example, incorporating a simple battery charge indicator into the eCook concept would enable the user to prioritise when they wanted to carry out these energy saving measures, i.e. putting a lid on the pan when there's a long simmer ahead and the battery is already low. Pairing PV-eCook with locally productive applications that exploit the additional energy available

during the sunniest seasons, such as irrigation pumps, also offers particular promise. However, further research is needed to determine whether these alternative applications will actually take away from the energy required for cooking as opposed to utilising the excess power.

Conclusion

This paper has considered the socio-cultural barriers and drivers to the proposed eCook concept. It draws on lessons learned from comparable technologies to illustrate the potential drivers, barriers, and challenges that await future attempts to scale up. It concludes that with a strategic market based approach focusing on the supporting infrastructure, there is a strong likelihood of uptake by specific market segments. In such a short paper we have not attempted to locate the market segments geographically, but have described their characteristics. Further description of this typology can be found in Brown and Sumanik-Leary [11].

Potential development impact

The eCook concept offers significant potential for a transition towards emission free cooking, with time/money savings for adopters and broader environmental benefits from reductions in fuelwood collection/purchase of charcoal/wood. In contrast to other technologies such as solar cookers, where the adaptation of cooking practices has been a substantial barrier, the behaviour change required to use an electric hob is relatively minimal.

The high upfront cost (and therefore longer investment horizon for poor households) is predicted to be the most significant barrier that will affect household uptake. As a result, a utility business model is seen as the most attractive for poor households, particularly if combined with mobile enabled payment mechanisms. Leach and Oduro [35] illustrate that the total upfront costs are indeed of a similar order to those of existing grid and rural electrification programmes.

Adapting cooking practices to a limited amount of energy is also predicted to be a significant barrier, as although the system could be sized to cater for all variations in cooking patterns, at least initially, systems will need to be sized for everyday use in order to be cost effective. Cultural preferences for food with a smoky taste may also mean that fuelwood/charcoal are still preferred for certain meals. As a result, fuel stacking is to be expected in virtually all contexts, in order for households to cater for days with significantly higher demand.

Recommendation for future research and application in practice

In brief, the three papers commissioned by DFID confirm that the eCook concept is worth further investigation. The proposition could be used to alleviate the impact of kitchen emissions on household health, and to contribute to Sustainable Development Goal 7 (ensure access to affordable, reliable, sustainable, modern energy for all). The papers recommend further research to be conducted now that will enable action once the price point is reached in or around 2020. Specifically, with respect to the behavioural change aspect, the following paragraphs describe the next steps required to develop this initiative during this period.

A global market assessment to identify actual places that most closely resemble the ideal context described above should be undertaken. In each high potential location, a more detailed local market assessment can determine how eCook should be carried out in order to achieve maximum impact for the poorest members of society. If the results of the local market assessment are favourable, a participatory process should ensue, whereby local people can determine how eCook can best evolve to meet their needs, engaging local

leaders, particularly women, as champions. The potential for local manufacture should be given thorough consideration in each place, as supply chains, manufacturing capacities and enabling policies vary greatly.

There is no substitute for empirical data and as a result, field trials in locations identified above are the logical next step. eCook should be trialled in a significant number of households, collecting valuable data on actual energy consumption, consumer satisfaction and suggestions for further design modifications to both the generic and local variant of the concept. The dynamics of fuel stacking should be given particular attention, as understanding the degree to which any eCook device is able to replace pre-existing stoves will determine to what degree the benefits can be obtained.

Thinking more broadly, like all innovations, it will be important to disseminate the concept as widely as possible and network with relevant international organisations. Agencies with a mandate of cleaner cooking, such as the Global Alliance for Clean Cookstoves (GACC), and those that call for clean cooking solutions that make significant health improvements, such as the World Health Organization, should include eCook in their research alongside the existing clean cooking solutions. However, new alliances will also need to be made between those focused on cooking with those concerned with the wider agenda of SDG7 and the focus on modern energy provision, such as the SE4All alliance and USAID's Power Africa initiative.

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