

MECS Technology Research Innovation for International Development (TRIID) Project Reviews – Alternative Fuels



Photo Credit: CREATIVenergie

Modern Energy Cooking Services (MECS) Programme

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Executive Summary

This report sets out to review the learning from the first Modern Energy Cooking Services (MECS) Challenge Fund programme which looked at the wider picture of modern energy cooking services (mecs) across sub-Saharan Africa and Asia. This report focuses on the availability, use and barriers to the uptake of alternative fuels for cooking and is one of four reports which consider the learning from each of the TRIID themes.

It is encouraging to note that the learnings supported as part of this themes replicates much of the work done within the other themes, highlighting many similar issues as well as suggesting further work that still needs to be undertaken.

The importance of fuel stacking and the prominence of biomass is a familiar theme, pointing to a complex reasoning behind the use of traditional fuels, which includes cost, culture, health, and an understanding of alternatives.

Education is a strong theme for this research strand. Addressing the communities understanding of the health impacts of traditional fuels is a key message that is currently missing. In addition, transparency on initial costs as well as fuel costs for the different cooking options, the use and buy-in of respected champions and additional information, such as cookbooks, recipe costing information and support networks, to support the uptake of mecs and generate a new confidence in cleaner cooking solutions is highlighted.

Enabling an increase in demand via effective marketing approaches that speak to the decision maker, the user and the wider community will enable confidence in the establishment of supply, maintenance, and support as part of the after-sales service leading to greater availability for last mile and rural users. The importance of a good relationship was highlighted as being key to doing business, *'you can't do business without good relationships'* noted one of CREATIVEnergie's participants.

Addressing cost and affordability will always be a factor but finding the solution that fits the locale is key. Credit facilities (where requested) are highlighted as being important, but transparency of information is a greater need, and benefit, to enable uptake of mecs.

Finally, technological solutions currently offer varying benefits but also have drawbacks. However, the fact that they are all at different stages of readiness will ensure that they can all help enable this shift. It was felt these benefits and drawbacks can be largely overcome by providing information and support.

Tailoring the cooking solution to the locale, incorporating policy (and enforcing it) that enables the market and providing information to allow informed decisions by consumers may well push this need forward but it is a difficult balance.

Challenge Fund Overview

MECS-TRIID Challenge Fund was run to support innovative cooking projects with a four-fold approach:

- Reduce barriers to innovation and advance technology in modern energy cooking;
- Enable a more sustainable, economical, and easily accessible cooking system in countries supported by Foreign and Commonwealth Development Office (FCDO);
- Develop smart ideas that have the potential to advance further;
- Fund early-stage innovations to take to the next stage of development.

The call focused on four themes that would address some of these issues:

Energy storage for cooking - Stimulate ideas generation and test initial concepts around how energy storage could be used in transitions towards the use of modern energy cooking services in one or more countries supported by FCDO.

Grid and infrastructure adaptability - Ideas for new solutions and approaches which help to improve the transition to mecs by improving grid (both national and localised grids) infrastructure was sought. This also includes work to assess challenges of getting the grid to reach all households and enabling consumers to connect to the grid.

Alternative fuels (the topic of this review) - Research into developing new solutions and approaches that improve the implementation and adoption of modern energy cooking services based on fuels other than electricity and provide tangible benefits.

Delivery models, Gender, Accessibility (vulnerable groups such as people with disabilities) and inclusion in MECS - research into developing new services, solutions, and approaches which can demonstrate how modern energy cooking services can be made equitable for men and women, people of different social groups and people with different physical, sensory or cognitive impairments or mental health issues and which will provide tangible benefits and impact.

Applications were varied across the themes but generated a large number for delivery models and alternative fuels.

Alternative Fuels Theme

As the fourth and final theme within TRIID, MECS is trying something other than 'business as usual' in the cooking sector. To address the issue of energy access (currently 3 billion people still cook on biomass which leads 4 million deaths a year), we were keen to review a number of existing cooking technologies.

- LPG, as a petroleum-based fuel solves localised air pollution by offering a tier 5 stove. However, for both the carbon balance and climate change, LPG is not necessarily the best option but it (and derivatives such as natural gas) are likely to remain important sources of 'relatively' clean cooking for some years to come. Consideration of how to make LPG supplies reliable, affordable, and sustainable, and to ensure efficient use of LPG are therefore important.
- Biogas, as an alternative to petroleum-based gas, has had a long history within the development sector. At scale and attached to supplies such as municipal waste, it has shown itself to be reliable, affordable,

and sustainable. However, actions to apply it at the domestic level have achieved mixed results. In this call we considered innovative approaches to biogas that can be used for cooking. Solutions must show how it will be affordable, reliable, and sustainable as well as offering an alternative to what has been tried before.

- Ethanol production as a fuel has prompted debates about food substitutions and use of land. However, at the household level it does present a clean cooking solution. Recent research suggests existing stoves cook food quite slowly and consumer acceptance is low. Innovations at the household level for the use of ethanol for cooking would be considered.
- Solar thermal cookers have had a long history in development and have generally been slow to gain widespread acceptance and go to scale. This call will entertain innovative approaches to the use of solar thermal cooking equipment if it is accompanied with a socio-economic proposition as to why it will have greater acceptability than previous attempts to use solar thermal.

Company	Project Title	Project Area/Country	Public Description
Centre for Climate and Development, Alex Ekwueme Federal University, Nigeria	Enhancing LPG Access for Semi-Urban Populations in Nigeria	Nigeria	Working in two sub-urban towns in South-East Nigeria, the project seeks to establish the extent to which a fee-for-service delivery model can enhance adoption of Liquefied Petroleum Gas (LPG). The project seeks to tackle low awareness, lack of affordability, unacceptability, and unreliability of access to LPG. They will assess the impact of their business model on uptake and interest. This will involve enabling access to low-volume 6kg cylinder gas stoves and a 'Pay-as-You-Use' LPG facility while the energy service provider maintains ownership of the equipment. The project will additionally offer targeted awareness and maintenance services.
CREATIVenergie	Portable Biogas: Assessing the socio-economic viability of packaging and distributing ready to use biogas	Tanzania	Biogas digesters produce a clean and modern alternative cooking fuel but use in sub-Saharan Africa remains low. This project will explore models of distributing surplus biogas, to enable an affordable, reliable, and sustainable supply of household cooking fuel in rural and peri-urban areas, as well as creating a scalable and sustainable income for households and communities with digesters. The project will utilise existing technologies and explore innovative methods of distributing biogas to rural or peri-urban communities. We will explore the feasibility of a pay-as-you-go approach to purchasing biogas fuel, assessing the market potential and viability of the distribution and trading models for different socio-economic groups, and how such approaches can make biogas fuel more accessible, affordable, and accepted.
iDE	Exploring futures of alternative cooking in Cambodia	Cambodia	The core of this project involves researching people's energy needs to understand knowledge, perceptions and behaviours driving their choices behind energy for cooking. The project will explore and test strategies/pathways that transition customers away from biomass towards modern clean cooking energy forms. The intent behind this body of work is to ensure that future adoption strategies for using modern clean cooking energy in Cambodia promote inclusive, equitable access to energy for cooking among households.

PayGo Energy	IoT LPG Cylinder Tag and Trace	Kenya	Tag and tracing of LPG cylinders using IoT tags to improve LPG cylinder logistics and distribution.
Pesitho	Cleaning the Air through cooking: providing alternative energy solutions for cooking practices in the Bidibidi Refugee Settlement in Yumbe district, Uganda	Uganda	As Africa’s population continues to grow and more people migrate to cities and towns, the demand for wood fuel is expected to rise. Pesitho is challenging this with the ECOCA, a compact, self-contained, multi-purpose home cooking unit consisting of a battery pack, solar panel, and a highly insulated pot. Research will be undertaken in the Bidibidi Settlement in Uganda and will consider user behaviour, attitudes and perceptions around clean cooking, renewable energy, pro-environmentalism, and climate change across three types of household.
SunBuckets	Solar Thermal Storage for Cooking	Kenya	<p>Sun Buckets currently has a stored energy solar cooker that is currently used by the energy impoverished in Haiti, Kenya, and Somaliland. The system allows users to cook with solar thermal energy, even at night, using their own pots and pans and without batteries, fuels, fires, or emissions.</p> <p>Sun Buckets will develop two new capabilities:</p> <ol style="list-style-type: none"> 1. Design, build, and test a proof-of-concept electrical heating system for Sun Buckets thermal storage cook stoves. 2. Design, build, and test a proof-of-concept large-scale thermal storage reservoir heated with electricity. The reservoir will provide energy for users through rainy seasons that span several weeks. <p>All the innovations can be fabricated regionally, providing jobs, and reducing shipping.</p>

Table 1. Outline data for the projects

Research options in these themes covered all our suggested technologies. Both Pesitho and SunBuckets looked at the use of solar for the cooking energy source; Pesitho via a fully solar powered electric cooking stove called ECOCA consisting of a battery pack, solar panel, and highly insulated pot whereas SunBuckets reviewed a solar thermal cooking option using phase change material but with no change to cooking practices and pots.

We supported research applications from three gas projects; two LPG projects, one looking at uptake in Nigeria (The Climate and Development Centre) and the other in Kenya with PayGo who reviewed the supply and demand of the market to find ways to address the ‘sachet economy’. The third project (by CREATIVenergie) looked at the issues of packaging and distributing biogas in the Arusha region of Tanzania. Three very different countries with very different scenarios (Nigeria currently export 70% of its LPG and only 2% of Tanzania have access to clean cooking facilities) yet they would appear to have very similar issues (information, supply chain and accessibility).

The final study, in Cambodia, undertook a qualitative assessment (conducted across three Cambodian provinces in rural, peri-urban, and urban locations) of the adoption of modern energy cooking services. Understanding why most people still use biomass for cooking when 92.7% of households (HH’s) have access to electricity was the key driver for this project.

Fuel Stacking

In all countries (Cambodia, Kenya, Nigeria, Tanzania, and Uganda) stacking is the standard. Firewood and charcoal were the most common types of fuel with the typical mix dependent on a range of factors, including cost, availability, seasonality, family size and the food being cooked.

In Uganda, the working group was based in a refugee camp, an area with little access to alternative fuels and many families chose to supplement the stove with traditional cooking fuels. Firewood collection occurred between one and six times a week with most people using only firewood. The time taken per trip varied between 2-6 hours

In Nigeria, fuels included firewood, kerosene, charcoal & LPG; it was noted that LPG was used the least. Even biogas producers in Tanzania used a variety of fuel for everyday needs. Typically, this was a mix of firewood, charcoal, and LPG.

In Cambodia, 67% of HH's use biomass, 35% of which use improved cook stoves. 27% of the population use a traditional stove and 5% three-stone stoves. Collecting wood takes rural HH's 20 hours/week. Biomass, specifically charcoal, is most frequently stacked as a secondary fuel source. iDE did however note a sharp increase in the adoption of electric rice cookers as a common trend as well as a rise in small LPG stoves which use refilled butane canisters. Whilst prone to leakages and safety issues, the team noted that informal supply chains ensured distribution of LPG canisters to last mile locations.

In Turkana, Kenya where PayGo undertook their research, 5% of HH's have access to electricity and most rely on firewood & charcoal for cooking needs.

Learning: As noted in previous reviews, this work highlights the predominance of biomass fuels. It points to a complex reasoning behind the use of traditional fuels, which includes cost, culture, health, and an understanding of alternatives.

Seasonality for energy production

Few of the projects picked up on the impact of seasonality, however the production and bagging of biogas was found to be affected by high wind speeds and cold days. This reduced production (by as much as two days) and issues associated with filling bags was felt to impact on the reliability and sustainability of supply. Outside of this theme, seasonality was also raised as an issue by PEEDA and UIU, the former who noted the impact of the dry season on the production of energy for their micro hydro scheme and the latter the impact of cloudy (monsoon) days on solar PV.

Learning: Largely this was not a factor for these projects but is a consideration when looking at sustainable production of biogas, an issue that is particularly important for rural HH's where this may be their main energy source.

Culture

Culture was a theme that was addressed by most projects relating to the methods of cooking that most people use.

In the ECOCA project, the location of cooking was noted where typically HH's were mud-brick houses with a thatch roof and low ventilation. Most families had a separate cooking room not attached to the house and cooking inside was preferable (this was also noted in the SunBuckets research). Cooking indoors offers safety and allows food production to take place regardless of the weather.

Equally, understanding perceptions around cooking is key to changing attitudes; in Cambodia iDE noted that traditional cooking methods such as grilling over firewood are perceived as being 'healthier and germ free'. Traditional methods were associated with health because they use less oil for grilling as compared to frying or

deep frying but the reference to it being ‘germ free’ related to the boiling of water for medicinal purposes would appear to be anecdotal.

In Tanzania, women noted the importance of biomass fuel for cooking traditional foods, for example Loshoro (a banana, maize, and milk meal) which is cooked in a clay pot using firewood. However, for others time was a factor and it was felt the use of firewood would be better for foods that take longer, but this was contradicted by others who felt that using biogas was better as it helped speed the process up. The use of firewood for slow cooking was felt most appropriate. If nothing else, this work points to the need for a greater understanding of the cultural aspect of cooking and an unpicking of the different reasons for the use of different energy sources.

In Cambodia, an increase of income and a subsequent move from traditional to modern housing was highlighted as impacting positively on the uptake of mecs. iDE note that a move to urban areas and an increase in income often results in less cooking and more pre-cook options. This move to a modern home and the importance of maintaining status within the community is leading to the adoption of new technology such as clean cooking appliances. These assist with the reduction in firewood and therefore reduce the amount of soot, enabling walls to remain cleaner for longer. This aspirational aspect of mecs was a key understanding of the work here. In addition, rural areas want ‘...fast and easy [methods] to cook food’ which would favour cleaner cooking methods. This reflects the clear need of a targeted marketing approach to different users’ needs to address these complex messages.

Deference to the decisions of elders tends to be a common socio-cultural norm and iDE noted comments such as, ‘I live with my parents and cook with firewood because they are old and prefer food to be cooked in a traditional way...’. This also supports some of the thinking about healthier cooking styles, such as grilling, which are a traditionally method done over charcoal.

Learning: Understanding the cultural background to cooking methods are important if we are to address the concerns about a shift to clean cooking. Taste, length of time to cook and tradition are key concerns. Addressing them effectively would enable a smoother transition.

Gender

The impact of gender for cooking was considered by many of the projects. This included the preferred place to cook (indoors to provide a greater level of security, Pesitho & SunBuckets) and standing up is preferable from a safety perspective. Participants within the CREATIVenergie study noted this helps as ‘you don’t get burnt easily in case of an accident’. This statement and action have repercussions for both children and those with disabilities too.

iDE reflected on the main users of cooking appliances (women) and the budget holder (men) and the disparity between the messages businesses and sales teams deliver. They note these ‘fail to acknowledge the true cooking needs of women. The language and format of sales pitches do not speak to women’. In Cambodian society, as in many African countries, hierarchy and elders’ decisions are key to choices. Taking family dynamics into account for sales pitches would be useful and could impact on ‘the voice and agency of women to purchase mecs’.

For CREATIVenergie the gender divide focused on the role of the decision maker and the household. Without this joint approach, effective biogas production would not occur. Whilst the head of household (men) will take ‘responsibility and ownership of the biogas digester’, they rely on the family to feed and mix it and women ‘are responsible for using the fuel and technologies for cooking’. This system not only allows for an opportunity for paid work to family members, it also speaks to the need to build these factors into a sales pitch enabling producers to speak to the right people across the chain. These services are importance for the value chain and to gain a greater understanding for the ‘unofficial’ workforce.

Learning: MECS' research has shown that involving women in the production of systems and processes is a positive outcome of change providing greater responsibility and agency for women. However, addressing the market message to fit family dynamics is a key factor in speaking to individual needs.

Technology and Promoting Uptake

Each of the research projects offered a different solution to cooking. In Uganda, Pesitho's ECOCA is a fully off-grid solution that comes with a 265-watt solar panel to provide power to a 20Ah battery which sits inside a cooking module. It has a highly insulated pot which enables food to be cooked after boiling point is reached, in theory, without any additional energy input. The unit can be used to charge light bulbs, phones, and small appliances.

SunBuckets offer a thermal storage system which discharges heat over a long period and allows cooking to be undertaken without the use of electricity. The system allows cooks to use their own pots and pans thereby preserving cooking traditions and methods. The issue with PCM is that for a system to be effective over a long period, it needs to be much larger which makes it immobile. Charging must take place outside or via a solar panel which increases costs and raises issues of security. This is an issue which is also faced by the ECOCA which requires levels of peak power delivered only when linked to a solar panel. HH's were therefore only able to cook twice a day (breakfast and lunch), reverting to firewood in the evening.

Both the Climate and Development Centre in Nigeria and PayGo in Kenya were looking at issues associated with a proven technology, LPG. In Nigeria, participants were enthusiastic about LPG but perceptions surrounding its safety were an issue. Many noted that one needed to *'show care [when using] and often people were careless'*. CREATIVnergie also recorded similar concerns in stakeholder workshops. These safety concerns could be addressed by offering support and training through local enumerators, the use of local people of influence who act as champions for LPG use and support from women's community groups.

For PayGo, addressing the payment plan was their driving factor. They utilised existing technology to enable a payment plan to suit the consumer. They argue that the lack of a linear supply chain leads to invisibility of the required elements which *'is a missed opportunity for both suppliers and consumers. For suppliers, the data is not captured so decision making is made more difficult. For consumers, there is no means of validating their purchase – the cylinder may be filled illegally; it may be underfilled, or it may not be in a safe condition'*. By utilising an IoT cylinder tag and trace technology they can not only link to all parts of the supply chain (retailers, distributors, and wholesalers) but it enables end to end visibility to energy use and supply along with payment to suit consumers. *'It enables the amount of gas purchased to be measured accurately thereby allowing small purchases to be made which fit current customer spending. This monitoring leads to lower losses in the system, can feed into forecasting and enable cost savings to be made in purchasing LPG at source'*.

This increased supply chain visibility led to several improvements:

- a 91% customer retention rate
- a 98%-cylinder retention rate
- Annual gas revenue per customer of \$48 (they claim this is over 50% higher than the industry benchmark. They attribute their ability to predict usage and provide reliable distribution and supply as a key factor to their success).

Meanwhile, in Tanzania work to address the production and storage of biogas was explored. The research noted that a minimum digester size should be 16m³ to enable the producer to maintain an effective supply of gas for themselves as well as supporting selling of surplus. Once they addressed the issue of no commercially available devices to capture the surplus (CREATIVnergie adapted one themselves to ensure the existing supply from the

digester was not affected by taking off this surplus off), the use of storage bags that were light and already available were considered the best way forward. However, this solution was not without its issues. Whilst bags were light, they were bulky to transport and were easily damaged. Once distributed, they also needed to be pressurised to enable full use. The issue of the perfect storage and transportation medium had still not been rectified by the end of the project, but many users suggested using a cylinder, much like LPG, would be the best approach. However, the cost associated with this may preclude greater uptake.

To promote the biogas system, a 'Cook Off' took place where several people cooked the same meal with different fuels or appliances. Current biogas users were 'overwhelming in favour of using it as it is considered simple, easy and fast' however, users were not in favour of the 'rice cooker'. This was thought to be because the rice cooker had a slow cook functionality and the perception that a strong flame is required to enable faster cooking was noted supported with this appliance. The single hob burner had a stronger user preference.

In comparison in Cambodia, iDE explored the increasing preference for electric cookstoves, largely driven by the cost and convenience of appliances. They noted that information, in the form of smart meters, only add to the appliances' desirability and could be 'a powerful nudge' to uptake.

iDE noted several initiatives that could promote the uptake of electric cooking:

- Community cooking clubs and mobile master chef competitions
- Hands on testing at MECS restaurants
- Build rapport with village chiefs – using champions
- After sales support
- Facebook testimonials from purchasing customers
- Smart meters to show electricity use
- Complimentary recipe books
- Female sales agents trained as chefs
- Targeting workplaces in urban areas

Learning: Time-shifted cooking options hold the key for clean cooking adoption, but technological solutions are at different stages of readiness to enable this shift. All the researched options have benefits and drawbacks many of which can be largely overcome by providing information and support. Finding the right solution for both a regional and cultural context are important as well as pitching to the right price point.

Costs and Affordability

The impact of cost was an issue many of our researchers considered and ranged from the impact of an under-developed supply chain and lack of transparency, to credit facilities and upfront costs.

For LPG consumers, the cost of the cylinder was cited as a barrier to uptake. The Climate and Development Centre offered various options including 'a borrow and use option where women paid for additional gas and the cylinder was maintained as part of the service, as well as 'mortgage-type' system where they used the LPG whilst paying for ownership in instalments'. 6kg cylinders were used for their affordability compared to the 10kg but the lack of 'financial capacity' of users was cited as the main reason for a lack of continued use.

For PayGo, a review of the supply chain noted that fragmentation and lack of technology resulted in increased staffing and distribution costs which were passed onto the customer. Using their 'IoT sensors to monitor LPG tanks to improve distribution efficiency has resulted in a 20% decrease in costs over a 3-month period'. This monitoring enables the prediction of demand which in turn allows consumption and distribution data to optimise distribution'. This greater efficiency and better distribution leads to lower costs and a reduced price

for the consumer. Utilising the PAYG option, this enables most consumers who live in the ‘sachet economy’ (purchasing small amounts to suit income) access to goods and services they would otherwise not be able to afford. Monitoring for LPG would offer one of the keys to successful technology uptake.

CREATIVenergie reviewed the payback period for biogas producers. Whilst consumers noted they would be willing to spend 1000TSH per bag of biogas (a costs similar, or just below, what they would pay for LPG or charcoal), producers managed to sell for TSH 3000. Production and distribution of (surplus) biogas equate to TSH 422,000 (with maintenance at an additional TSH 500 per month). With a revenue of TSH 3000 per bag, pay back would be 13 months making this a viable option for investment. For consumers, biogas was deemed a desirable fuel comparable to LPG.

In Cambodia, iDE note that rural Cambodians have a preference of paying for appliances upfront. They do not trust finance options and dislike ‘people from MFI’s coming to their house to ask for money’ which can lead to a loss of status within their communities. They would prefer to purchase their products from a shop which instils confidence in the product and seller. However, the perception that only rich people cook with electricity (because they can afford to do so) increases the perceptions that this type of cooking is unaffordable. They found that awareness raising, coupled with the data from an energy meter, would highlight the real costs of cooking with electricity and help dispel myths.

Learning: Cost and affordability will always be a factor for the uptake of mecs but finding the solution that fits the locale is key. The provision of credit facilities (where requested) and transparency in information are highlighted as key enablers.

Supply chain

As noted in previous sections and across the projects, the issue of a fully functioning supply chain has been a limiting factor. For Pesitho and CREATIVenergie, the lack of spare parts, maintenance and repairs were not in evidence. This lack of a robust supply chain needs to be addressed to ensure longevity of the appliance and engender confidence in consumers.

In Nigeria and Tanzania, limited distribution capacities and poor infrastructure impacted on the location of filling stations. The need for the development of cylinder exchange stations in communities were noted as being a key element to uptake. Others note that whilst wood is taking longer to collect, distance from fuel markets, poor infrastructure and access prevent further uptake of mecs.

For PayGo, the ‘fragmented and broken supply chain leads to higher costs’. This is highlighted by the need to source a QR Tag supplier for their cylinders. Since this was not available locally, QR tags had to be imported. The impact on lead times and the rapport that needed to be built with the supplier, lead to delays in the receipt of goods which impacts on the ability to process orders and deliveries. These additional costs were then passed down to the consumer.

Where access to appliances and services is possible, the omission of after sales support and difficulty of sourcing spare parts leads to a lack of take up. This lack of reliability reduces confidence in both the appliance and fuel source, undermining the uptake of new technology. Further the lack of contact and information is a limiting factor, as indicates the importance of local champions and information about how to cook local recipes on new appliances.

Finally, the ability to view and compare products is a key factor as people are distrustful of door-to-door salespeople ‘... I would never buy something from an unknown person, no matter what they tell me’. The perception is that if someone has invested money into a shop, they are trustworthy.

Learning: Supply, maintenance and support are all highlighted as being stumbling blocks to the uptake of cleaner cooking solutions. With respected champions and information, confidence in new products can be assisted but addressing the three key barriers is essential to enable this shift and is supported by projects in other themes (TaTEDO, SOWTech, Kisambara, Bidhaa Sasa etc)

Health and Wellbeing

Health and wellbeing were universally noted for users however, CREATIVenergie noted the impact of biogas for users with mobility issues. Considering the accessibility and weight of the bags of biogas they noted that people with mobility issues can *'cook comfortably and efficiently with bagged biogas'*. This insight is something overlooked by many projects but is a considerable factor for many households, especially where elderly residents are living.

Mental health and physical well-being were addressed by the other projects. For Pesitho, this activity took a slightly different path as they aspired to review lung-function as a result of using cleaner fuels. Unfortunately, the tests were inconclusive, in part, due to the small sample size of testers and the fact that the study was for a short period of time. The proximity of other HH's may also have been a factor and they suggest that, in future, cluster study groups would give a clearer idea of the impact of clean technology on lung function.

However, Pesitho did note that reduced fuel collection had a significant impact on health, in particular mental well-being associated with the lack of sleep due to worrying. This worry centred around the collection of wood (whether the travel distance is too far, or it is arduous and whether women will have their wood stolen from them) which would impact on the women's ability to provide a meal for their family. With regards to physical well-being, they were informed that the use of ECOCA was associated with a reduction in headaches, eye pain (from smoke) and less coughing.

In Nigeria and Cambodia, the link between physical health and open-fire cooking was little understood by cooks. The universal understanding in Nigeria was related to the environmental impact of cooking with biomass with few people understanding the link between cooking and smoke inhalation. On providing this information, the project team noted the *'women were 'grabbed' by this information the most'*. In Cambodia, the perception is that cooking meat with charcoal (via grilling) is a healthier option as it requires less oil. This traditional practice reduced the interest in clean cooking.

PayGo note that LPG has a negative perception from many funders and investors, as it is a fossil fuel. However, they argue that as it is the cleanest fuel available for many, the benefits of LPG over kerosene and wood fuel need to be highlighted to investors. Equally, the importance of LPG as a steppingstone to electric cooking, enabling those with weak grids to access cleaner cooking methods, should not be understated.

Learning: Whilst the importance of climate and environmental impact of using traditional fuels is widely understood, communities need much more support in understanding the health impacts and numbers of death associated with the use of these fuels.

Limitations and Barriers

Many of the projects noted a range of limitations and barriers to the uptake of mecs that have been supported across the other themes.

In Uganda, the fact that the ECOCA could not be used continuously resulted in a less than optimum uptake. An issue with the peak power and charging performance of the battery meant that the system required connection

to the solar panel to enable cooking. It was often difficult to cook after dusk, so users reverted to biomass. This, therefore, led only to a proportional reduction in fuel wood collection which meant that the system was not as effective as it could have been in reducing wood fuel use and collecting times. In addition, the desire for two pots for the stoves was highlighted (echoing the wishes of other projects across other themes). It would allow for different foodstuffs in each pot and different pot sizes would enable different foodstuffs to be cooked more efficiently.

In Nigeria, the lack of understanding of the health implications of wood fuel use and the perception that LPG is hazardous hindered initial interest. However, with support and training by the end of the research 98% of participants highlighted they would encourage others to use the system. Addressing the initial high costs of the cylinder, the lack of finance mechanisms and the availability of refilling stations, would enable greater uptake.

In Cambodia, low-income HHS noted firewood is the only affordable choice. The key challenges are a lack of understanding of modern technology and established perceptions/preferences which direct people to the use of traditional methods and fuels. Infrastructure is a barrier for uptake in rural areas with only 8-10% of Cambodia having paved roads, this becomes a real barrier for distributors who are unable to get their supplies to location which require them. This leads to a lack of choice and access to new technology.

Where consumers have moved to LPG, safety concerns meant that many users choose small LPG (6kg) cookstoves. This was considered a safer option than the large LPG canister. *'My neighbours told me to be careful with the LPG tanks, so after my child was born, I decided to give it away....to keep my family safe'*. Government policy and accountability in the supply chain, along with education could go a long way to overcoming this barrier.

CREATIVenergie found that seasonality and the size of the bags were the largest barriers when it came to distribution. Seasonality affected the security of supply and the size made it difficult to distribute multiple biogas bags simultaneously, meaning that for a distribution model, multiple trips need to be made to the supplier.

Finally, SunBuckets highlights the supply chain limitations in enabling their system to be produced in-country. This included availability of raw materials, identifying a reliable foundry to manufacture the sun barrel, and sourcing the relevant manufacturer to produce their system. This was a key factor in their project and would not only enable a more affordable option to be made but would also provide employment for local communities. The lack of a supply chain meant that local production was not possible.

Learning: The impact of supply, along with information and support is the key limitation highlighted by all these projects. With greater information, consumer demand may well push this need forward but it is a difficult balance. Many generic and specific barriers to uptake exist which need to be systematically addressed.

Conclusion

These research projects have given a clear overview of the issues at play in the transition to clean cooking. Whilst technology has a part to play, and many of the energy sources detailed here are well established, some still offer stumbling blocks. Some of these blocks are larger than others but the indication is that they will all be overcome at some point in the future and many offer steppingstones to the greater adoption of mecs.

The issues closer at hand are those of education, understanding and supply chain. Consumers need to understand the impact of traditional fuels on health and well-being and we need to address incorrect perceptions related to cost and use. For electricity, the low awareness of the potential to cook with this fuel are

compounded by the perception that doing this would be expensive. *'A gap in the unit cost for cooking enforces this perception'*. Providing transparent usage information via an energy meter is the way to address users concerns.

Policy is highlighted as being a current stumbling block that could be turned to an advantage. For example, greater emphasis and enforcement of regulations for the LPG industry would enable the development of a competitive market, allow suppliers to address user's safety concerns, enable the tracing of cylinders and to improve distribution efficiency. This in turn will bring costs down and develop a policy of inclusiveness, so no-one is left behind.

