MECS Technology Research Innovation for International Development (TRIID) Project Reviews – Grid and Infrastructure Stability

Photo Credit: PEEDA

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 constitutes one of four reports which review the learnings from all four themes of the TRIID call.

These two projects undertook a 6-month study into the Grid Integration of their cooking system, one was based in the lab in Bangladesh (United International University, UIU) and addressed the energy consumption of appliances and matched them to the available PV solar power, the other was based in communities in Nepal with access to micro hydro power on microgrids.

This report draws on the main points of the research, considering the key findings and barriers to the grid integration of electric cooking appliances utilising a renewable source.

Both projects highlighted similar issues and factors associated. The accessibility of technology, in the form of appliances, was considered high enough to allow the shift to eCooking, however both noted the option to enable these appliances to run on a lower voltage. For UIU this was to reduce the power required for cooking and thereby make it cheaper to cook. Clearly, having access to these appliances is key to uptake along with the development of a robust supply chain to enable repairs and support of this shift. Both noted the impact of cost and affordability of electricity use for cooking as a key factor to uptake. The misconception that electric cooking is more expensive was noted and the importance of sharing power usage data with participants, particularly in real time, helps to dispel this myth. In line with this data is also the issue of insulation will allow all appliances to run more efficiently. An honest overview and inclusion of the true costs associated with stacking, in particular the collection of biomass, further go to prove that electricity for cooking is cheaper than commonly perceived. There is much work required to inform people of the true monetary costs of cooking with electricity.

The importance of gender and culture are clearly highlighted with training, support and, where possible, minimum change to cooking habits being a factor in uptake. This needs to be supported by more complete data sets and having the ability to disaggregate data for gender.

There is much to celebrate with a shift to eCook which both projects felt would be a viable alternative to current practices. However, there is a need to consider the impact of energy reliability and low voltage for off-grid supply. This clearly highlights the need for storage or grid access to ensure supply is available when it is required.

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 (mecs) 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 were 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 - 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.

Grid and Infrastructure Adaptability Theme

Whilst the original concept of eCook was based on Solar Home systems, it has become clear that eCook has potential within grid architectures of varying sizes. Moreover, there are clear opportunities for the introduction of cooking to enhance the financial returns and cash flows of grid operators within these different contexts.

The two supported applications under this theme fit both categories with localised and national grids being considered. We had hoped for a larger number of projects within this theme but realise that whilst only two projects were funded their research findings offer insight into the issues associated with both on- and off-grid use for electric cooking.

The reasons for the lack of applications (and therefore the funding of only two projects) are unknown but it is thought that the low levels of funding and short time frame may have been a factor in this complicated sector.

These two studies reviewed different renewable sources of energy (micro hydro and PV solar) yet both noted that the lack of time available for their research impacted on the acquisition of seasonal data to inform the generating capacity of the systems through an annual cycle.

The projects also took two different approaches; one lab-based and the other community based. PEEDA, an organisation based in Nepal, undertook considerable work at the household level to record cooking diaries and behaviour change as well as lab testing for different appliances. They paid their households 100NRP/day to record their cooking into a diary and received a high feedback. They also assess the hydropower output using a data logger to understand 3-phase voltage generation from the MHP unit and interference of use of e-cooking to the power station.

United International University (UIU) focused on developing and testing a solar PV system in the lab in Bangladesh that would address the issue of low-cost electric cooking that would require minimal change to cooking practices. An outline of these projects is noted in table 1 below.

Company	**Project Title**	**Project Area/Country**	**Main Focus**
PEEDA	Assessing electric cooking potential in micro hydropower microgrids in Nepal	Solukhhumbu district, Eastern Nepal	Over 3,300 rural Nepalese communities using micro hydropower (MHP) systems to provide them with electricity with an average power supply of only 100 Watts per consumer. During the wet season, MHP plants offer relatively constant power output throughout the day and night (unlike variable solar photovoltaics or wind) making it an ideal candidate to explore electric cooking. A small-scale e-cooking pilot study in 2018 identified that this highly constrained supply struggled to support the increased load during peak times. This project will address the challenge of enabling widespread adoption of electric cooking in Nepali MHP microgrids by gathering qualitative and quantitative data to inform understanding. These project outcomes will be applicable to the wider Nepali national power grid and other grids and microgrids in countries with similar cooking practices and grid infrastructure.
United International University (UIU)	A solar PV based low cost inverterless grid integrated cooking solution	Bangladesh	This project will identify the cost of clean energy and its accessories as the main hurdle towards adopting clean cooking technologies. With falling price of the solar PV, solar PV based cooking can be an attractive solution in the grid connected areas, where grid will be supplementing any shortfall in the solar PV power. In this project we propose a low-cost grid connected solar PV based cooking solution with minimum changes to cooking practices so users do not find it difficult to adopt in different cultural or geographical locations.

Table 1. Outline data for the projects

In Bangladesh, the expansion of the national grid means that more than 90% of the population should have grid access by 2021. A significant surplus is envisioned so utilising this for cooking would address both the surplus issue and address access to energy for all, as highlighted by the UN's Sustainable Development Goal 7 (SDG7).

In Nepal, 3,300 rural communities have access to micro hydropower. This project wanted to understand the extent to which micro hydropower could support the energy needs of these communities during the dry season (the wet season provide more consistent power supply and hence is better understood) and how battery storage could assist with supporting the demand. With much of the rural population practicing fuel stacking, predominantly with wood and LPG, this would represent a significant behaviour change for many.

Technology and Promoting Uptake

Both projects addressed the use of renewable energy sources, that vary with the seasons, to provide enough electricity to enable cooking. The issue of surplus power within their systems was also reviewed and storage options applied. For PEEDA in Nepal, this was via the use of a lithium ion battery where they reviewed both a central battery to supply the needs of the community as well as one at household (HH) level. They found that batteries can enable more HHs to cook but for both a central and HH system the battery supports 500 HHs compared to a mere 38 HH in the normal scenario.. Inverter efficiency is the biggest issue and relies on the spare energy in a mini-grid being used to its full potential. A centralised system would need upgrading and a HH system would require an intelligent charging system increasing the costs for both options.

For UIU, the excess energy was used to heat water thereby offsetting the amount of electricity required for cooking. This pre-heating reduced the energy used by cooking by 25% and was noted particularly when cooking heavy foods such as chick peas. Clearly the impact on cost reduction is considerable by using pre-heated water. It may be pertinent to note that other research projects have noted the importance of soaking of beans over-night before cooking, which also results in a reduced energy consumption.

Running the UIU system both on- and off-grid was a key element of their work and they did this by ensuring appliances could run on low power. All of their appliances needed to '….work well under DC voltage environments without any necessary modifications'. They managed this by making some low-cost modifications to their system.

To keep the costs of the system low, UIU also wanted to exclude the need for an inverter into their system. *'The main innovation lies in the design of a control circuit that eliminates the need of an inverter and uses grid as an energy backup to ….*account for *the shortfall due to variable weather conditions.'* This modification, along with low power consumption appliances, provided their low-cost system for electric cooking.

PEEDA also needed to modify the appliances to reduce the potential for overloading their systems and reduced the appliance consumption to 1200W to match the power generated. Most induction hobs come with 2kW capacity and would need modification. UIU found that limiting the power supply to below 500W was key. They ensured the 'Power consumption for hotplate, induction cooker and EPC were 480W, 510W and 390W respectively'. This reduced power requirement enabled the power sharing of grid and PV to be close to 75% on a clear sunny day if usual cooking times, of between 10 and 2, were maintained. On average, a 500W system is expected to draw close to 65% of energy from PV (this accounts for cloudy days)'.

UIU noted the need to be able to allow other household appliances to be linked to the DC power output, in particular lighting, TV, computer, and mobile charging. For consumers this makes the appliance inherently more attractive (and is supported by work undertaken in our Business Models theme). It also opens an alternative opportunity for solar use when cooking is not done and will ensure that solar is still used (and not discarded) when grid access is more widely available. UIU note that the impact of grid expansion is seen as a threat to current solar based PV systems.

Learning: Technology is available to support the shift to clean cooking but modifications to allow low-voltage appliances is the key. Adaptations within the factory would enable the greater uptake and use of eCook.

Costs and Affordability

Cost and affordability are cited as one of the main factors for the uptake of clean cooking. Indeed, the perception of this is often changed when cooking demonstrations are undertaken (Kisambara and iDE). Cost was a clear driver for UIU when they set out to realise their system. The report notes a cost of £285 for their installed PV system. They note '*the average cost of cooking energy is estimated as £3-£4/month for a family of 5. This is much lower than the cost for firewood (£5/month), gas (£7/month) and conventional electric cooking (£10/month). This cost includes the estimated energy cost supplied by the PV solar system (£285)*'. UIU also highlight that the actual energy costs will be 40% lower than noted since only 40% of energy will be used off the grid.

PEEDA list the total system costs of their battery electric system at the household level to be $20.30/month for 5 years. For a centralised system to enable 200 HH to cook in two shifts, they estimate a cost of $46,300 (this equates to $19,29 per month). The costs associated with cooking with LPG and wood were compared to electricity, noting electric cooking is cheaper (especially if a labour cost is applied to wood collection). However, battery electric cooking requires significant investment.

PEEDA note the cost comparisons for LPG and electric cooking showed a median cost for two weeks of $1.69 for HH (range from $0.79 to $4.15) for electric and $1.60 for LPG (range of $0.72 to $5.34). the monthly expenses for 100% e-cooking for a family of 5 was $3.68 per HH versus $4.55 per HH on LPG. The lab testing showed that the energy consumption for the two appliances was not that different for food that was cooked for shorter durations however, EPCs consumed much less fuel to cook heavy foods compared to Induction hobs and the conventional pressure cooker.

Learning: Cost and affordability will always be a factor but the perception that using electricity is more expensive is shown to be incorrect in many studies. As the use of biomass becomes more costly and unreliable, electricity use should grow. Ensuring the sharing of data to inform this change is essential to allow this shift.

Insulation

UIU felt that whilst an EPC is more highly insulated than a conventional pressure cooker, the cost of this appliance may hinder its uptake. They therefore decided to compare the cooking energy efficiency of both EPC against conventional pressure cookers adding an insulating cover to the latter to replicate the high efficiency of an EPC. They also chose to insulate the hot plate by '*….put[ting] insulating wools in the empty space inside the hot plate & [used] insulating sheet to reduce heat loss through the walls…..*' They '*designed an insulating cover for the cooking pan. It is lightweight, very simple in design and easy to use..*' much like a jiko. They found the conventional pressure cooker could be a '*formidable competitor*' to the EPC and the lack of behavioural change could contribute to the successful uptake of its use. However, they highlight that the pressure cooker must be used on a hotplate, not an induction hobs, as the aluminium base does not trigger heating.

Since PEEDA used EPC's insulation was already inherent in the appliance design and this was not addressed separately.

Learning: This work supports that of others in highlighting the importance of insulation (SOWTech, Smart Villages, CalPoly)

Fuel Stacking

Fuel stacking is an issue that is raised by many of the other research projects under TRIID and varies depending on country, location, and policy issues. As part of their study, PEEDA did review fuel stacking use. They questioned 15 households and found *'10 used predominantly wood stoves, the other 5 used Induction Cook Stoves (ICS). LPG was used by 8 HH, mainly as backup'.*

'*Stacking was largely used where original stoves (three stone stoves) were the preference. However, where a meal needed to be completed due to time constraints (i.e. leaving for school or work) and when low voltage issues arose, two stoves were used (feeding the need to stack)*'.

PEEDA also note the use of stacking *'for space heating'* particularly in the winter months, an issue which is supported by some of the other TRIID projects. Clearly having a better understanding of this cultural use of cooking materials will inform the uptake of electricity for cooking and should be addressed more specifically in future work.

Learning: Fuel stacking will not be replaced overnight by electricity but highlighting the costs of using biomass, both from a health and expenditure viewpoint, will raise awareness and highlight the benefits of using electricity. In turn, biomass use will decrease.

Seasonality for Energy Production

The issues of seasonality and energy production were highlighted in both projects. For UIU, designing a system that could provide 75% of the energy requirements on a clear sunny day was important resulting in the development of a 500W system using approx. 65% of the average generated power. The impact of cloudy days was considered as much as possible but being able to draw from the grid as a back up was always the aim for UIU. For PEEDA, the impact of the dry season saw typical generating capacity drop by 20kW to 80kW. They found that '*this drop resulted in a struggle to support the 15 HHs cooking with 1kW induction hobs & up to 5 rice cookers at a time*'. Mini-grid stability and power variability across the seasons represents a challenge to electric cooking and encourages stacking. The importance of varied supplies and storage options offers some security, albeit this increases the costs.

Learning: A greater understanding of the seasonality of energy supply is required, along with an ability to factor in the impact of more common events associated with climate change.

Supply chain

Finding reliable and efficient cooking appliances was a key factor for PEEDA and whilst electric cookware came from Kathmandu, induction hobs and batteries had to be sourced from India. As noted in other research projects, the lack of a local supply chain and support mechanisms is a key factor in developing confidence in new product use (Kisambara, iDE and Bidhaa Sasa). PEEDA noted that during the research, two induction hobs broke. *'One showed voltage variation and may have been faulty at the start. The other issue was not identified'.* With supplies coming from India, the implication for service and repair was significant and these two items currently remain in the workshop at PEEDA awaiting repairs.

Equally, there were similar issues with the batteries. The project chose to use 24V lithium ion batteries which, although expensive and not available in Nepal, would offer greater power discharge capability and a longer life span. These too were sourced from India. Tests proved that dishes can be cooked in a comparable time to mains when using the battery and for a similar energy consumption.

PEEDA note that two interchangeable pots for EPC were recommended. This is a request supported by Bidhaa and Kisambara but again relies on an effective supply chain.

For UIU, the lack of low voltage appliances required modifications to be made to currently available ones. Whilst this proved beneficial for the users, allowing a slow-cook facility which used less power, it may not be an economically attractive option for the manufacturers.

Learning: A local and robust supply chain is required to meet the needs of the shift to eCook.

Modelling

PEEDA were one of the few projects who modelled energy use. The data showed that 42 HHs should be able to cook on the mini-grid each day. However, it was noted that 15 HH can destabilise the grid at times. The model assumes 100kW is available when in fact 80kW was the norm. The modelling works well up to 300 HH and then breaks down, this is due to the fact that the required capacity of the central battery was so high and there was insufficient spare power to charge to its nominal power, therefore it could not reach full charge between meals. This high load for cooking depleted the battery and there was insufficient time to re-charge.

Inverter efficiency was found to have an impact on capacity for energy storage (batteries) and therefore uptake of electric cooking. An intelligent charging control system would be required for HH systems, but this in turn, will increase the system costs.

Learning: Whilst modelling is a useful tool, having some 'real' data will allow these assumptions to be tested. A larger study would be required to deliver this research.

Gender

PEEDA's project allowed a gender-based view of the impact of clean cooking as they were working with communities. They note that with 75% of HH's still using biomass and women being the main collectors and cooks, cooking places a huge burden on women. This includes the impact of smoke when cooking, physical impacts of carrying heavy loads, and the threat of attacks (both physical and sexual) whilst collecting fuel. (p.22). This work supports that of other projects which highlight the uneven burden of cooking on women and girls.

Learning: Work here supports the impact of cooking on women and girls. Collecting biomass, the carrying of heavy loads, the impacts on respiratory health and the threat of attacks would all be addressed with a shift to eCook. This understanding is highlighted in a number of other studies including Pesitho and iDE.

Culture

The projects focused little on the impact of culture as part of the research but UIU took care to ensure 'minimum change in habit' with their system. They wanted to ensure that different cultures and geographical regions would not find it difficult to use, thereby increasing the usability and acceptance of a new system.

PEEDA noted that the use of new cooking appliances resulted in a more restricted diet and the cooking of different foods, particularly at the start of the research when households need to learn a new skill. However, due to the duration of the project, they were unable to determine if this was due to the seasonality of produce and is a further reason to suggest support for a longer research project would have helped to ascertain this, and other seasonally-related, facts.

During their exit interviews with households, they gained feedback on the electric cooking devices which highlighted the following benefits:

- quick and easy cooking
- smoke free kitchens
- saving time not lighting a fire
- being able to do other things while cooking
- being able to clean stoves quickly

It is clear people appreciated the benefits of the systems but again the implementation of longer project would enable clarification of whether these benefits and continued use of the appliances persisted beyond the end of the project.

PEEDA did note the cultural practice of 'Perma' where HHs share the burden of collecting wood in bulk once or twice a year. This has an associated value of 500NPR/day which would place electric cooking for LPG/wood fuel users at a lower cost.

Learning: We know that culture is a key factor in the transition to eCook but highlighting the benefits and providing demonstrations will assist in this shift. Over time, the HHs adapted their cooking and became more confident with their EPC.

Limitations and Barriers:

Both projects looked at some of the barriers associated with the uptake of clean cooking which revolved around costs, voltage drops and energy demand.

With the use of induction cookers, both projects highlighted the need for specialist pans to enable cooking. Clearly, this leads to a higher cost, with PEEDA noting that induction hobs and cookware costs an average of $107.00 (from India) whilst the electric pressure cooker costs $59.64 (from Kathmandu). These higher costs would make the first system less accessible for many consumers and would also raise issues associated with the supply chain. However, some further research to highlight the costs associated with the use of induction cookers would be useful to establish the long-term costs of this technology.

Both projects addressed the issue of voltage drops, due to limited spare capacity, and power consumption of their systems. The lack of reliability and low voltage are cited as one of the main problems when cooking and is one of the main reasons that families fuel stack. Whilst adding a battery to the system would solve this issue, it also leads to cost implications. For UIU, the ability to control the energy demand for the appliance allowed the lack of an inverter but this also meant that excess power was unable to be delivered back to the grid when required. There is no indication of the costs associated with the adaption of the appliances.

UIU also discuss the fact that the reduction in the voltage capacity of the appliance means that high energy demand dishes, such as dip frying, can not be cooked. This would be a definite cultural shift for the users of the system, something they set out to not change. However, their lack of field testing may dispute this fact and is something they aim to review during their next stage of development.

Learning: Both studies noted the need for further study to develop their data sets and UIU noted the limitations due to being a lab study. Both suggest that their systems would work well for 500 HHs in Nepal and 100 in Bangladesh.

Conclusion

In conclusion, these two studies clearly support (with some modification and expenditure) two very different systems for the generation of electricity for eCook. Whilst we would benefit from a larger study to review various assumptions and support the modelling data for numbers of households that could benefit from eCook, this is a good first view of the impact of off-grid power supplies (in this case, micro hydro and PV solar) can have in rural areas.

There are several clear needs to support this transition, as highlighted by some of the other TRIID themes. This includes the availability of affordable, low voltage appliances with a robust supply chain to ensure maintenance and longevity of use.

The misconception that electric cooking is more expensive also needs to be addressed. The use of training and demonstrations to encourage the increased use of eCook technology needs to go hand in hand with the provision of data, in real time if possible to help to dispel this myth. In line with this data, the need to highlight the impact of insulation to allow all appliances to run more efficiently and therefore reduce the energy cost.

To support this shift and dispel the cost implications of eCook, an honest overview and inclusion of the true costs associated with stacking, in particular the collection of biomass, would go to prove that electricity for cooking is cheaper than commonly perceived. There is much work required to inform people of the true monetary costs of cooking with electricity.

The cultural impact of cooking are clearly highlighted in both studies. PEEDA note that training for appliances use and the production of local dishes, support to enable greater use of the appliance and, where possible, minimum change to cooking habits are a factor in uptake. This needs to be supported by more complete data sets which highlight the ease of use, design features and costs implications of eCook. Ideally this data would provide the ability to disaggregate data for gender.

There is much to celebrate with a shift to eCook which both projects felt would be a viable alternative to current practices in off-grid areas. With an eye on energy reliability, slow cooking appliances that enable lower power consumption and therefore, lower costs, and a focus on energy storage, either in the traditional manner of battery storage or via water heating to off-set energy use, many of the current barriers to use can be overcome.