Appendix 1

Review of eCooking

in Sub-Saharan Africa

Contents

Version control		
Version Number	**Date issued**	**Update information**
V1.0	29/09/2019	First published version
V2.0	8/11/19	Version control table added. SunFire Solution stoves added

Introduction

This review will look at the current methods of cooking in Sub-Saharan Africa with emphasis on the situation in Malawi. The types of eCook stoves that are available at present including those in development as well as those that have been trailing in the field and are in production.

It is envisaged that this document will be an ongoing work as details of new eCook stoves are found.

Current cooking situation

Types of food cooked

Cooking practises in rural and peri-urban Sub-Saharan Africa have changed little in generations. The type of food cooked and the ways of preparation and cooking the food has been passed down from mother to daughter orally with few recipes written down.[1] Over much of Sub-Saharan Africa the staple starch component in the diet is a maize-based porridge called various names including nsima, ugali, pap, obusuma, kimnyet, nshima, Mieliepap, phutu, sadza, kwon etc.[2] It can also be made from sorgham and millett. The cereal grains are boiled in water or milk and stirred to form a thick paste or porridge which is eaten with a meat or vegetable stew. This is an oversimplification as each culture has its own variation.

Cooking the maize porridge requires long slow cooking to break open the cereal grains. According to our research in Malawi the main meal is eaten in the early afternoon. This consists of nsima served with a tomato and onion relish, a meat/fish dish and/or vegetables such as pumpkin leaves, amaranthus or rape/spinach, dry beans that have been slow cooked. The women of the family start to cook this meal in the mid to late morning. The meal is cooked in an aluminium pot (with a capacity of about 5 litres for a family of 8) with a smaller pot for the relish, vegetables and stews.

Current stoves used

The most common and the traditional means of cooking in the poorer areas of Sub-Saharan Africa is on a three stone cook stove. This comprises three level bricks or stones onto which the cooking pot is placed. A fire is lit in the central area of the stones and firewood is continually fed into the fire between the stones. Charcoal is also often used instead of or as well as wood. The wood has to be collected or bought as does the charcoal. This method of cooking is highly inefficient with 85 to 90% of the energy content in the wood lost as heat to the environment outside the cooking pot.[3]

There have been advances in wood stove design. These stoves are designed to be more fuel efficient. One design is a brick/stone built stove covered in local clay. The wood is put in an opening at the front and the pans are put on the top of the stove. The heat from the fire is directed upwards to the pot reducing the heat

1 Stirring the Pot: A History of African Cuisine (Africa in World History), James C. McCann, 2009
2 https://en.wikipedia.org/wiki/Ugali
3 https://www.permaculture.co.uk/articles/cooking-efficiently-3-stone-fires-biomass-hobs

dissipating around the outside of the pot and being lost. The fire is also protected from the weather, especially wind which can blow the heat away from the cooking pot.

Rocket stoves are also proving popular. These stoves are available in a variety of shapes and sizes but they all have an L-shaped combustion chamber that is insulated. This chamber improves the combustion of the wood and channels the hot gases up to the cooking pot.[4] These means that they are more efficient in cooking the food and use significantly less fuel. Tests have shown that it uses 60% less wood fuel to boil 1L of water and simmer it for 30min.[5]

Current status of cooking fuels in Sub-Saharan Africa

According to the FAO in their study "The role of wood energy in Africa"[6] wood fuel accounts for 90-98% of the residential energy consumption in most of Sub-Saharan Africa. This includes both fire wood and charcoal. Overall in the years 1980-1994 the growth rate for firewood fell to 1% per annum but this was off set by a growth rate of 2.8% for charcoal. The population growth rate for the same period was 2.8%. However twice as much wood would be needed in terms of charcoal to meet the same useful energy need as firewood (considering 18% combustion efficiency for charcoal and 13% for firewood).

In Malawi between 1998 and 2014, the percentage of the population that relied on biomass energy actually increased from 94% to greater than 97%. Over this same period, reliance on charcoal nationally increased from 2% in 1998 to 11.3% in 2014, and charcoal surpassed firewood as the largest source of urban household cooking fuel (54.4% in 2014). Charcoal in Malawi is largely an urban fuel used by 11.3% of all households nationally and 54% of urban households in 2015.[7]

Progress of e-cookers in Sub-Saharan Africa

Over the last few years there have been a number of initiatives to reduce the use of wood and charcoal as the primary cooking fuel. The drivers for this change are primarily climate change, deforestation and health concerns. These will not be discussed in detail in this review as they are well documented in both the

4 https://www.cleancookingalliance.org/technology-and-fuels/stoves/
5 https://www.permaculture.co.uk/articles/cooking-efficiently-3-stone-fires-biomass-hobs
6 http://www.fao.org/3/x2740E/x2740e01.htm#TopOfPage
7 Malawi National Charcoal Strategy 2017-2027, Republic of Malawi, The Ministry of Natural Resources, Energy And Mining

scientific and general literature. The use of kerosene and LPG is one area of alternative fuels that is used, with biogas and briquettes also being advocated.[8]

Drivers for change

The three main drivers for change are climate change, deforestation and health issues.

1 Climate change

The primary source of heat for the earth's climate is the sun. This heat is absorbed by the atmosphere which then re-radiates it. Some of this is lost to space whilst the rest is absorbed and re-emitted by the greenhouse gases in the atmosphere. As the level of greenhouse gases increases more heat is trapped causing a rise in the earths temperatures.[9] The burning of wood and charcoal releases carbon dioxide which contributes to the increase in greenhouse gases.

2 Deforestation

There is much talk recently about the burning of woo being carbon neutral.[10] However this is for managed forests where felled trees are replaced with the planting of new trees. These trees will absorb the carbon dioxide released by the burning of the felled wood. However in much of the world, including Sub-Saharan Africa, this is no the case. Trees are being removed and they are not being replaced causing wide-scale deforestation. The Malawi government in their National Charcoal Strategy predict that by 2030 the demand for charcoal and wood will have exceeded the supply of trees.[11] Not only is the source of carbon dioxide absorption being removed but the lack of tree cover is exposing soils to the elements which resulting in soil erosion.

3 Health issues

There are a number of health issues associated with the traditional wood & charcoal stoves. The burning of the wood and charcoal in enclosed spaces put particulates into the air causing respiratory problems. In Malawi, household air pollution is the number one risk factor for burden of disease, and the World Health Organisation reports that more than 50% of premature deaths among children aged under five worldwide are due to pneumonia. The open fires also give rise to increased risk of burns and scalds. The vast majority of hospitalised burn victims in Malawi are under the age of six years old with hot liquid scalds and open flame burns are the most common type of injury.[12]

Energy sources for eCook stoves

There are a number of energy sources suitable for eCook stoves. These include mains electricity, batteries, solar panels and a combination of energy sources. These will be discussed in this section.

8 Guide to cookstove technologies and fuels, Global Alliance for Clean Cookstoves
9 https://royalsociety.org/topics-policy/projects/climate-change-evidence-causes/basics-of-climate-change/
10 https://www.epa.gov/newsreleases/administrator-pruitt-promotes-environmental-stewardship-forestry-leaders-and-students
11 National Charcoal Strategy of Malawi 2017-2027, Republic of Malawi, The Ministry of Natural resources, Energy and Mining
12 https://www.goldstandard.org/projects/cleaner-and-safer-stoves-malawi

1 Mains electricity

In the western world electricity is taken as an essential commodity whereas in Sub-Saharan Africa it is at best a luxury and at worst non-existent. The IEA reported in 2014 that electrification rates vary enormously in Sub-Saharan Africa but in the majority of countries less than 50% of the population have access to electricity. In 20 countries less than 75% of the populations have access to electricity.[13] These percentages increase greatly when the difference between rural and urban electrification is analysed.[14] Overall in Sub-Saharan Africa the urban electrification rate is 59% compared to 16% rural electrification. There is less than 10% rural electrification in 25 countries with Chad, Liberia and South Sudan having 0% rural electrification.

Even in those communities that have mains electricity the stability of the supply is a problem. The IEA reports that for those in Sub-Saharan Africa that do have access to mains electricity the supply is often unreliable, necessitating widespread and costly private use of back-up generators running on diesel or gasoline. Electricity tariffs are, in many cases, among the highest in the world and, outside South Africa, losses in poorly maintained transmission and distribution networks are double the world average.[15]

2 Batteries

Although there have been many advancements in battery technology[16] the use of stand alone batteries to power cook stoves is limited[17]. Batteries are mainly used as a backup for electric stoves when there is disruption in power.[18]

The UK organisation Power-Aid have produced an “all-in-one portable power station” based on a lithium battery with a built in inverter with their Malawian partners although the cost of the unit makes it unaffordable for low income household use[19].

3 Solar power

One thing that Africa has plenty of is sun making solar power a realistic proposition as an alternative power source. Although solar panels exist the trend tends to be for large scale or for mini-grids[20]. Until recently the cost of solar panel has been prohibitively expensive and there has been no easy means to pay for the electricity used. This is all changing. The cost of solar panel is decreasing making them more affordable.. Also countries such as Kenya and more recently Malawi have removed VAT from solar panel. Another barrier to buying solar panels was the need to pay for them up front. In places where payment in instalment has been introduced the uptake has been higher. There has also been an upsurge in mobile phone ownership and usage in Sub-Saharan Africa. This has enabled the introduction of pay-as-you-go for electricity used via the phone[21].

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13 Africa Energy Outlook, International Energy Agency, 2014

14 A review of the behavioural change challenges facing a proposed solar and battery electric cooking concept, Ed Brown and Jon Sumanik-Leary, 2015

15 Africa Energy Outlook, International Energy Agency, 2014

16 Batchelor *et al*., *Energy Research & Social Science* 40 (2018) 257–272,

17 https://globalpressjournal.com/africa/democratic-republic-of-congo/fueled-passion-eliminating-deforestation-congolese-entrepreneur-debuts-battery-powered-cook-stoves/

18 eCook Global Market Assessment Where will the transition take place first? Technical Report · July 2018 DOI: 10.13140/RG.2.2.22612.30082

19 https://www.power-aid.org/power-box

20 https://www.pv-magazine.com/region/sub-saharan-africa/

21 https://www.newyorker.com/magazine/2017/06/26/the-race-to-solar-power-africa

eCook stoves available

There is little information on eCook stoves that are available in Sub-Saharan Africa. In affluent areas of cities and towns western style cookers are used but this report is not looking into such areas but is concentrating on rural and peri-urban areas. Most of the cookers that are available are imported from Asia.

1 Rice cookers/slow cookers

These are bought off the shelf and are normally imported from India or China[22]. The cookers work by the rice and water being added to the pot. The electrical heating element then heats the water to boiling point. The rice absorbs the water and cooks, Once the water is all absorbed the temperature rises and a thermostat trips the switch turning the cooker off. The types available range from the simple ones where the cookers switch of when the rice has absorbed the water to those that can be programmed for automatic cooking and warming of rice, porridge, soup etc. The cooker requires a constant electricity supply and can be used with a backup battery.

2 Pressure cookers

Most work on eCooking appears to have been done with pressure cookers. The advantage of pressure cookers is that the food can cook quicker than when using conventional methods which therefore reduces the energy needed. It is estimated that when cooking for one hour a pressure cooker uses around 25% of the electricity compared to an electric hot plate and over a 4 hour period of cooking it is twice as efficient as a slow cooker, 6 times more efficient than an induction stove and 7 times more efficient than a hot plate[23]. However there is much fear of using pressure cookers; a legacy of tales of them blowing up[24]. They also have to be imported into the country.

3 Electric hobs/hot plate

Electric hob/hotplates normally have space for one or two pans. They use a lot of energy and are not suitable for the long slow cooking that foods such as the maize porridge require. They are more suitable for the cooking of the sauce and relish accompaniments to the maize. These items need to be imported in usually from India or China but are available in retail shops[25].

22 https://www.alibaba.com/catalog/rice-cookers_cid606

23 Beyond fire: How to achieve electric cooking. Couture, T D and Jacobs, D, May 2019

24 K. Chepkurui, Leary, J., Minja, A., Sago, S., Batchelor S., Sawe, E., Brown, E., Leach M., Scott, N., Shuma, J. 2019. "eCook and Gender in Tanzania – March 2019 Final Report." TaTEDO, Loughborough University, University of Surrey & Gamos Ltd. supported by Innovate UK, UK Aid & Gamos Ltd. Available from: https://elstove.com/innovate-reports

25 Preliminary design and analysis of a proposed solar and battery electric cooking concept: costs and pricing, Leach and Oduro, 2015

4 Solar cookers

Solar cookers can be divided into two main categories. Those that use the solar power directly via parabolic solar collectors and those that use photovoltaic (PV) panels.

Parabolic solar cookers

Parabolic solar heaters work by concentrating the heat from the sun onto a small area. They produce very high temperatures and are therefore most suitable for quick cooking methods such as grilling or frying rather than long slow cooking[26]. Another limitation of solar cooking is that the sun is not available 24/7 and therefore the cooking time is restricted especially after sunset and on cloudy days[27]. There have been research done into thermal storage of the heat for use when the sunlight is not available. A means of tracking the sun is also advisable to maximise the energy harvested.

Examples

1. Cambridge Development Initiative at Cambridge University developed a solar oven surrounded by a solar dish that was capable of cooking bread, pizzas etc[28].

2. The Blazing Tube Solar Appliance[29] comprises a triple cavity vacuum tube containing vegetable oil, a trough shaped Compound Parabolic Curve high efficiency reflector and a heat retention cook box. The compound parabolic curve surrounds the vacuum tube which is attached to the cook box. The Blazing Tube Solar Appliances were supplied by UNHCR to refugees in the Goudoubo Refugee Camp in Burkina Faso[30]. Unfortunately other there was initial adoption of the technology the use of the stoves were not continued by the women using them for a number of reason which will be discussed later.

3. The Devos Cooker is another type of solar cooker[31]. This comprises a parabolic concentrator and a table where food can be prepared as well as cooked. This was also trialled by the UNHCR at the Goudoubo Refugee camp but was rejected by the refugees[32]. The reason is not given.

26 https://solarcooking.fandom.com/wiki/Category:Parabolic_solar_cooker_designs
27 https://www.crses.sun.ac.za/files/research/completed-research/eppei/OOCraig.pdf
28 Low cost solar oven – Summary, Keno; https://www.fastcompany.com/3033624/a-cheap-solar-powered-oven-that-bakes-bread-without-pollution
29 http://www.blazingtubesolar.com/
30 https://blogs.lse.ac.uk/internationaldevelopment/2018/01/12/the-broken-promise-of-solar-cooking-the-case-of-goudoubo-refugee-camp/
31 https://solarcooking.fandom.com/wiki/Devos_Solar_Cooker
32 https://blogs.lse.ac.uk/internationaldevelopment/2018/01/12/the-broken-promise-of-solar-cooking-the-case-of-goudoubo-refugee-camp/

4. Indirect solar cookers use the energy gathered by the parabolic concentrator to heat up a heat transfer medium such as oil filled pipes. The advantage so these structures is that the cooking can be done at a distance from the heat collection source[33].

5. GoSun Fusion has a parabolic reflector which concentrates the sun's rays onto a vacuum tube. The vacuum tube also works as an insulator. However to cook a full meal there is also the need to use a 12V battery to power a thermal heating element in the base of the cooking tray. This cook-stoves retails at about $500[34].

6. SunFire Solutions Solar Stove is a plastic injection moulded box with a reflective lining and a clear perspex lid. It can cook and bake stews and soups but it only has a small capacity (one 2 litre and one 4 litre pot). It takes 60mins to boil 1 litre water and can cook a chicken stew for 4 people in 3.5 hours[35]. It costs 850 South Africa Rand.

7. SunFire parabolic solar cookers focus the suns rays on a pot stand which is part of the design. The cooking pan it then put onto the stand to cook the food. It is available in 3 sizes and can boil a 1 litre of water in 12-4 mins depending on size. The sizes range from 1.2-1.8m diameter and cost 1,500-2,500 South African Rand. The parabolic dish needs to be adjusted every 30-40 mins[36].

Photovoltaic cookers

As the cost of solar photovoltatic panels has decreased so the feasibility of using them for cooking has increased. The solar panels can be connected directly to the electric stove to provide the energy required. However like other energy collection methods relying on solar power they are not usually used in isolation and need some method of storing the energy for use when the sun is not shining. There are 2 main methods of doing this – using a battery or Thermal Energy Storage (TES).

33 Solar Energy Storage, Bent Sørensen, published by Academic Press
34 https://www.cnet.com/news/gosun-shows-off-new-solar-oven-at-ces-2019/
35 https://www.sunfire.co.za/product/sun-stove/
36 https://www.sunfire.co.za/product/solar-cookers/

Stand alone PV cookstove

Work has been done in USA and Uganda looking at using PV panels alone to power an eCook stove. They concluded that the insulation was the key to the design. With little or no insulation too much heat was lost to the atmosphere and the required temperatures for cooking could not be reached. The solar energy is converted into electricity which is then used as the energy source. They used the boil and simmer technique for cooking as it is a long slow cook[37]

Battery storage

Until recently the cost of the battery has been a barrier to household use for cooking but recent advances in technology and reduction in cost has made the use more of a reality[38]. The battery can be charged during the sunlit hours and then the stored energy used when required.

5 Other eCook stoves

Battery powered eCook stove

A local entrepreneur in Democratic republic of Congo has produced a battery operated brazier stoves that costs as much as one bag of charcoal and runs on two batteries cheap batteries. It still requires some charcoal but the amount is reduced to about one tenth and can use charcoal dust rather than lump charcoal[39].

Cooking using phase-change material

Calfornia Polytechnic State University (Cal Poly) have devised an eCook stove that uses the phase change material erythritol as a form to store heat. The phase change material is in an insulated box. The material is heated by PV during the day which melts. When the material changes phase back to a solid it releases energy and heat which is then used for cooking[40].

Sun Buckets uses a parabolic reflector in conjunction with phase change material. The “Bucket” containing the phase change material is charged using a parabolic reflector. This is them removed and the bucket taken to the place of cooking. It has an aluminium top cooking surface. The business model that they are looking at is to have a central charging point where householders can swap spent units for fully changed ones[41].

37 Watkins et al, Development Engineering, 2 (2017), 47-52
38 Energy Research & Social Science, 40 (2018), 257-272
39 https://globalpressjournal.com/africa/democratic-republic-of-congo/fueled-passion-eliminating-deforestation-congolese-entrepreneur-debuts-battery-powered-cook-stoves/
40 https://solarcooking.fandom.com/wiki/Category:Photovoltaic_cooker_designs
41 https://solarcooking.fandom.com/wiki/Sun_Buckets

Issues that need to be considered

There are a number of problems and issues that need to be addressed before an eCook stove can be implemented.

Uncertain/unreliable power supply

Before the use of eCook stoves will become widespread in Sub-Saharan Africa there has got to be a reliable power supply. If firewood is still needed as a back up the change to eCooking will be very slow although there is evidence that fuel stacking is becoming more widespread[42].

Cost

The upfront cost of buying an eCookstove is cited as one of the biggest barriers to changing to an eCook stoves[43]. It is estimated that in sub-Saharan Africa only 50% of households pay for fuel with the remaining 50% gather firewood locally for free[44]. The ability to spread the cost by having monthly payment terms and/ or microloans will aid the buying of eCook stoves.

Taste

Food taste different when cooked on a wood-fire. Compare the taste of a sausage cooked on a barbecue compared to one cooked on a grill. This will require a change in habit and is not something that can be designed into an eCook stove.

Changing cooking techniques

There may need to be a change in cooking techniques. Rather that cooking as we would a stew on top of a cooker as slow cooker approach may be needed where the food is heated up then left to cook in an insulated box.

Adaptability

Like Western cooking more than one cooking method is often used when preparing a meal. The cook-stove should therefore ideally be able to be used for multiple cooking techniques eg stews, boiling, frying, grilling[33].

Barriers to change in refugee camp

There were also a number of other reasons cited as to why the Blazing Tube Solar Appliances were not adopted by UNHCR to refugees in the Goudoubo Refugee Camp in Burkina Faso[45].

Misleading size

It was assumed that as the solar cook stove was significantly bigger than the rest of the cookstoves in the camp it was able to cook bigger portions. However the pots that fitted it were too small and households with over 5 people had to cook in at least 2 shifts.

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42 https://energypedia.info/wiki/Cooking_Fuels

43 Brown and Sumanik-Leary, A review of the behavioural change challenges facing a proposed solar and battery electric cooking concept, 2015, DOI:http://dx.doi.org/10.12774/eod_cr.browneetal

44 Beyond fire: How to achieve electric cooking. Couture, T D and Jacobs, D, May 2019

45 https://blogs.lse.ac.uk/internationaldevelopment/2018/01/12/the-broken-promise-of-solar-cooking-the-case-of-goudoubo-refugee-camp/

Fuel expenses and reliability

Cloudy weather in the refugee camp meant that the solar cookers were not reliable enough for the refugee women to reduce their biomass fuels consumption, and consequently, their expenses. This contrasted with the women who received Liquified Petroleum Gas (LPG) cookstoves and who reduced their biomass dependency by 50 percent.

Climate Change considerations

Most women's worries about environmental issues only concerned deforestation. They acknowledged their firewood collection practices had negative effects to the environment but the y all shared the same perception that solar cookers were less environment-friendly than LPG stoves.

Food taste and preparation time

Women's constant inability to cook food items, such as beans, meat or maize, was a fundamental barrier. Refugee women reported feeling comfortable with solar cooker when cooking rice or sauce, otherwise they reported spending too much time preparing a meal.

Intra-household conflicts

Refugee women spouses' dislike the taste of food prepared with the solar cook-stove which prompted marriage problems and even divorce threats.

Conclusion

There are many types of eCook stove being developed and tested that may be suitable for rural Sub-Saharan Africa. The pros and cons of these need to be examined in conjunction with user requirements to develop an eCook stove that not only works but is also acceptable to the people who will be using it.