A REVIEW OF FUEL SAVING TECHNOLOGIES AND ALTERNATIVE ENERGY SOURCES IN LAKE CHILWA BASIN

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1 Summary

This paper provides a review of fuel saving technologies and alternative energy sources that could be adopted by communities in the basin, identifies critical success factors for each technology and finally recommends the best course of action for LCBCCAP to take in order to increase adoption of efficient technologies and achieve impact at scale. The review concludes that energy efficient cook stoves, fish solar driers and fish smoking kilns offer scope for wide-scale promotion and adoption among individual households without need for heavy subsidies. For biomass briquettes to be promoted and adopted o a basin wide scale, there is need to address cost of the equipment and the end product and to reduce labour involved in the processing of biomass into briquettes. Biogas offers potential but this is limited to institutions such as schools where construction costs are offset by the high volume of organic wastes produced, the wide variety of uses that the gas is subjected to and the immediate changes it brings to the institutions. It is therefore recommended that the LCBCCAP prioritizes the promotion, sale and distribution of energy efficient cook stoves in the basin as this is likely to achieve high impact within a relatively short time frame. Due to the fact that there are other organizations such as Total Land Care and Emmanuel International that have a good track record with these technologies, LCBCCAP must work through these organizations to achieve impact at scale. Further, promotion of improved fish smoking kilns and solar driers must be scaled out to other areas of Lake Chilwa beyond the current hotspots of Mposa, Kachulu and Phalombe. Participatory approaches must be used at all levels of development, promotion and adoption to ensure that the communities own the technologies and continue to use them beyond the lifetime of the project.

2 Introduction and Background

The energy sector in Malawi comprises five main subsectors, namely: petroleum products, electricity, coal, other renewable energy sources and biomass i.e. fuel wood (GoM, 2009). Biomass energy however is the most important source of energy in Malawi with the country's 14 million people relying heavily on it. Biomass energy accounts for 88% of the total energy and 98% of household use (Openshaw, 2010). This is the case because of high poverty levels as well as low coverage of electricity and other alternative sources of energy (Yaron et al., 2010). Biomass energy is obtained from firewood, charcoal and crop/industrial residues. About 67 percent of fuel wood is used in rural households for cooking and heating, 15 percent in urban households, 7 percent is used in tobacco and tea industries and the remainder (11 percent) is used for other purposes, including small scale and urban industries (Annual Economic Report, 2010).

Chiwaula and Chaweza (2011) in study on charcoal and firewood value chain analysis observed that households in the Lake Chilwa basin use different energy sources but charcoal and firewood were the most important ones. 75.54% and 69.97% of the respondents in the study reported to be using firewood and charcoal respectively for cooking. This finding agrees with Kambewa and Chiwaula (2010) who using the second integrated household survey (IHS2) data illustrated that 91% of households in Malawi use firewood for cooking while 7% use charcoal. Additionally, a reasonably high proportion (41%) of the households reported that they used electricity as a source of energy. These should be the households that reside in the urban centres within the basin. In an urban energy consumption survey, Kambewa et al. (2007) showed that overall, 38% of the urban households in Malawi use electricity as their main source of energy for cooking while 42% indicated that charcoal is the main source of energy for cooking. Chiwaula and Chaweza (2011) also noted that maize cobs, which are available after maize harvest contribute a noticeable percentage (7.75%) and that firewood is used by both households and fish processors. On average, fish processors used 2129 kg of firewood in a year which is equivalent to 3.19 m^3 solid wood. On the other hand, households used 1551 kg of firewood per year which is equivalent to 2.33 m^3 of solid wood. This means that on per capita basis, fish processors are using more firewood than households. In terms of total volume of firewood consumed, households may be consuming more than processors because of their higher numbers. On average a household uses 11 bags of standard charcoal bags, translating to 437 kg of charcoal per household per year.

Despite the heavy reliance on biomass energy, biomass is increasingly getting scarce in some areas in Malawi due to high population density and uneven distribution of population. The Northern Region has 44% of forest but 13% of the population. About 26% of the forests lie in the Central Region, which has 42% of the population, while 30% of the forests lie in the Southern Region, where 45% of the population lives (Zulu 2010).

This paper attempts to review energy sources in the country with special focus on the Lake Chilwa basin. It is envisaged that the insights from this paper will inform the development of a policy brief that could be shared with the Government and other Non-Governmental Organisations (NGOs) that might wish to promote some of these fuel efficient technologies.

The paper is organised as follows: Section 3 presents the energy sector in Malawi, which describes the various sources of energy used in the country. Section 4 is the review of energy sources used and promoted in the Lake Chilwa basin. The report is concluded in Section 5.

3. Energy Saving Technologies in Malawi

The current energy sources available in Malawi can be divided into non-renewable and renewable. Non-renewable energy sources include petroleum products and coal; whereas renewable energy sources comprise electricity, solar, wind, biogas, briquettes and biomass (E.A.D., 2000).

Malawi is heavily dependent on imported petroleum products which were mainly used by the transport sector; accounting for 89.99% of the total hydrocarbons. The rest is shared by industry and domestic use, with industry ranging from 2.87% and agriculture consumption around 1.90%. Domestic use of paraffin (estimated at 5.25%) is generally declining due to poor supply (The State of the Environment and Outlook Report, 2010). The other non-renewable energy source available in the country is coal. Coal is used exclusively as an energy source for industrial production mainly for tobacco processing, textile, sugar production and beer brewing (GoM, 2009).

Electricity is one of the renewable sources of energy and it provides 2.8% of Malawi's energy needs (GoM, 2009). Hydroelectricity contributes 95% of the total electricity used (SADC Energy Sector, 1998). Electricity is mainly used in the urban areas, where only 15% of the total population reside, in the industries and households. Of the total urban population, less than 20% have access to electricity and the percentage falls to 1% in the rural areas (Chiwaya, 1999).

GoM (2009) listed solar, wind, solar-wind hybrid systems, natural gas, biogas and briquette as the most important renewable and alternative energy sources in Malawi. However, their contribution towards total energy still remained very low being less than 1% in 2009. Despite the existence of government plans to harness and develop renewable energy sources, solar, wind and biogas remain the least developed energy sources in the country. The harnessing of solar, wind and biogas are constrained by inadequate local knowledge and high cost of the end use technologies commensurate with the sources of energy. These factors have led to very low investment, research and development of these energy sources compared with other energy subsectors like mini-hydro systems (Ministry of Energy and Mining, 1997). For the case of biogas technology in Malawi, over 50% of the biogas plants in Malawi are non-operational due to poor dissemination approach, lack of commitment by owners, breaking up of biogas plant groups, lack of technical support and back up services and poor institutional framework (SADC Energy Sector, 1998). Biogas technologies were introduced in the country in the 1970's but their diffusion rate has been very slow and limited. The technology faces a number of barriers and constraints among which poor animal husbandry practices, poor project planning, cultural beliefs, inadequate skills etc. However, the country has high potential for biogas technologies especially in rural areas where power for lighting and cooking is in high demand (GoM, 2003).

GoM (2003) observed that wind technologies were mostly imported and that they were mostly for water pumping. They have been in the country from the early 1940's. These imported wind technologies are still expensive including operational costs. However, local wind technology manufacturing has sprouted designed for Malawi conditions for water pumping. The other important source of renewable energy is solar: Malawi has great solar output in most areas amounting on average to 3,000 hours of sunshine per year. Solar photo voltaic systems have so far been used for off-grid solar home systems, public/street lighting, vaccine refrigeration and also irrigation water pumping.

Biomass energy which mainly comprises firewood and charcoal is the energy source that is heavily used by most Malawians. Openshaw (2010) observed that fuelwood and charcoal industries were also important employers, accounting for an estimated 133,000 jobs and 2% of the labour force in the country. Forests contribute to nearly 75 percent of the total biomass supply in Malawi. With 9 percent of the country's population having access to electricity (Legros, Harvet, Bruce & Bonjour, 2009), fuel wood remains the primary source of energy for heating and cooking. Thus, the remaining 91 percent of households – 2.3 million in the rural areas and 410,000 in the urban areas – are highly vulnerable to consistent indoor air pollution exposure, as their dependencies on biomass-based fuel sources is

expected to persist over the short and long term. The exposure is highest for women and children who frequently occupy cooking spaces throughout the day.

The Malawi Government (2010) reported fuel wood extraction as one of the leading causes of deforestation and environmental degradation in Malawi. There are three main sources of fuel wood, namely; customary forests[1], forest reserves and plantation forests. Customary forests are the most important source of fuel wood contributing 37 percent of the total fuel wood supply. Jumbe and Anglesen (2006) reported that 35 percent of households in Malawi collected fuel wood exclusively from customary forests. Forest reserves are the second most important source of fuel wood contributing 26 percent of the final energy consumption. However, forest reserves are generally not accessible to the local community as these are protected areas. Plantation forests are the third important source of fuel wood contributing 11 percent of the final fuel wood supply.

Between 1990 and 2010, forest cover has declined from 41 percent to 34 percent (FAO, 2010). Thus with the heavy reliance on forests for energy, there has been a growing increase to protect the forests from further degradation. This has been achieved partially through attempted shift from absolute use of the three-stone fire method of cooking and heating or traditional fish smoking methods to sole wood-burning efficient and clean technologies or combination of the traditional and improved methods of cooking and heating or fish smoking but with less of the traditional methods. This shift in cooking/heating and fish smoking technologies has achieved a reduction in indoor air pollution. More than 97 percent of rural households and more than 85 percent of urban households are exposed to hazardous indoor air conditions as a result of inefficient combustion of biomass fuels (National Statistical Office of Malawi, 2008).

The Malawi Cookstove Market Assessment Report (2013) grouped fuel energy technologies existent in Malawi for cooking and heating into baseline/traditional and improved clean & fuel efficient technologies. Similarly, in the fish smoking industries, there are traditional methods of fish smoking and improved (fuel efficient) fish smoking kilns (Luhanga, 2012). Baseline technologies for cooking and heating mainly constitute of the three-stone fire and the traditional charcoal burner. According to the Malawi Cookstove Market Assessment Report (2013), three-stone fire is the most basic method of cooking used by most households in the country. The gadget features a pot that rests on three stones or bricks suspending the pot above an open fire built in open air or within kitchen settings. This is an inefficient fuel wood

[1] Customary forests are those located on unallocated common access land, and Village Forest Areas (VFAs) under the jurisdiction of Traditional Authorities (TAs).

use and an important source of air pollution production. The other baseline technology for cooking is the traditional charcoal burner. This is the only charcoal-focussed technology available in Malawi for the charcoal fuelled households. Charcoal burners are produced in a variety of settings from metal sheets that are moulded in a stove body by local tinsmiths. These burners often have a ceramic interior liner. There is high dependency on charcoal burners in the urban areas and due to the inefficient fuel use, there are high levels of indoor carbon monoxide (World Health Organisation, 2009).

Chilora (2013) observed that in the fish smoking industry, the most common method of fish smoking in Malawi is the use the traditional smoking kilns i.e. open pits/fires with improved wire gauze on top to smoke the fish. This method uses a lot of firewood relative to improved fish smoking kiln. The fish smoking structures do not retain most of the heat and smoke produced by firewood and a lot of escapes to the atmosphere hence large amounts of firewood are needed to successfully smoke fish products. Luhanga (2012) in a study on performance of fish smoking kilns in the Lake Chilwa basin found that each fish smoker if used improved fish smoking kilns consistently for one year avoided deforestation worth 0.5ha of forestland.

There are also improved efficient and clean technologies for cooking and heating. Such technologies use less wood and with less air indoor pollution as compared to the baseline three-stone fire. These include the mud stoves, Chitetezo Mbaula, fixed Esperanza stove, Total Land Care stove, portable rocket stove, imported rocket stove (ICCM) and institutional cookstove.

Mud stove is a basic structure made of mud, clay with a pot-rest above the combustion chamber that supports the pot. Such a stove is made in a local context at household level and has a short lifespan for its use. These stoves are typically assembled in a household's kitchen, often by residents, as an attempt to improve the transfer of heat to a pot for higher rates of efficient fuel use. Then there is Chitetezo Mbaula which was designed domestically by Programme for Basic Energy and Conservation in Southern Africa (ProBEC), GiZ-supported technical program. The cookstove reduces fuel consumption by 30 percent from the baseline. The Chitetezo Mbaula is locally made and its lifespan is up to 3 years depending on handling of the user. Chitetezo Mbaula is the most widely dispersed of the improved cookstoves in Malawi. The other efficient technology is the fixed Esperanza stove which is the most prominent fixed-in-place improved cookstove design available in Malawi and offers fuel use reduction of approximately 48 percent compared to the baseline three-stone fire. The stove consists of ceramic interior column that forms a combustion chamber surrounded by a body constructed of locally sourced bricks. The Esperanza offers a lifespan of approximately five years.

The Total Land Care stove is basically a modified mud stove design that comprises approximately 40 bricks and was constructed through capacity building efforts of Total Land Care's extension officers. The design shared structural similarities with mud stoves and had an interior made of locally sourced burnt cricks. The other types of improved stoves are rocket stoves; the first one is the portable rocket stove which is the most widely available metal improved cookstove in Malawi. The style of the cookstove has been constructed and promoted by diverse actors. The stove offers approximately fuel reduction of 50 percent from baseline three-stone fire condition. The other rocket stove available in Malawi is the imported rocket stoves (ICCM). Although the ICCM rocket stoves offer the largest fuel savings, they are largely cost prohibitive to most Malawi consumers. Generally, these stoves have experienced only marginal uptake in Malawi among wealthy consumers or institutions, rather than receiving interest from the broader cookstove consumer market. The last type of improved stove is the institutional cookstove which offers high capacity, clean cooking with fuel reductions upward of 70 percent compared to baseline cooking technologies. These are generally applicable to schools, prisons other institutions conducting high volumes cooking. Institutional stoves offer high lifetime savings due to their major reductions in fuel use compared to baseline cooking practices.

4. Energy Saving Technologies in Malawi

Although fuelwood shortages in the rural Lake Chilwa basin have not affected the pattern of living yet, many Lake Chilwa residents walk distances of up to 8km to fetch an adequate supply of fuelwood. Others are cutting the once treasured mango tree which is a source of nutrition and income while many more are increasingly depending on inferior less energy dense biomass fuels like grass, maize stalks, pigeon pea stems etc. for cooking and heating. Yet others supplement their fuelwood through buying (FRIM 2012). This is evidence enough of fuelwood shortages within the basin. Realising the fuel wood shortage situation in the basin, the Lake Chilwa Basin Climate Change Adaptation Project (LCBCCAP) promoted the use of Chitetezo cookstoves as a fuel saving cooking/heating technology. A total of 1963 cook stoves were distributed, one per household to interested households in the Lake Chilwa Basin villages in Zomba and Machinga Districts. 214 women have been trained in cook stove making. These cookstoves have a high potential of being used as a main cooking stove as they proved to save fuel wood. Bachelors were specifically mentioned to have liked them.

The LCBCCAP also promoted fuel energy saving fish smoking kilns in the Lake Chilwa basin. These proved to be more efficient in in usage of firewood, labour and time for smoking a given quantity of fish

(Luhanga, 2012). Chilora (2013) observed that the average wood usage per kg of fish was higher in traditional smoking than in the improved efficient (fuel energy saving) fish smoking kilns. On average, improved fish smoking kilns used 30 percent less wood to smoke a given unit of fish as compared to traditional fish smoking methods. Chilora also observed that smoked fish products from improved smoking had considerably lower levels of polycyclic aromatic hydro carbons compounds (toxic compound in the smoke deposits on the smoked fish products) by about 12 percent than the traditional oven.

Fuel energy saving fish smoking kilns were not necessarily a new innovation on the fish processing platform; GiZ through the Malawi-German Fisheries and Aquaculture Development Project first introduced them to fish processors in the basin in 1987. However, fish processors did not fully adopt them due to the high input costs, in particular the chicken wire. Following the re-introduction of the improved fish smoking kilns in 2010, the technology has since been widely adopted owing to the following:

- Participatory approaches

The implementation process heavily borrowed from the concepts of participatory research in development. The communities were involved from the development stages all through. A series of rapid progressive meetings were conducted with the beach village committees and women fish processors in order to build rapport, elicit support, share information and entice participation of the fish processors in using the new technology.

- Monitoring and Evaluation

Implementation sites for the new technology were being visited regularly by the government officers and at least monthly by project technical staff to ensure that reports on the performance of the technology were consistently captured so as to inform the modification of the technology.

- Involvement of the District Assembly Structures

For the innovation to remain sustainable, the implementation process has used the existing local district assembly structures in the development process of the innovation. District forestry officers were at the hub of the implementation and rolling out of the technology. After the project phases out, there will still be need for continuity of the programmes.

The programme has also promoted the use of solar fish dryers in the basin and technical studies have showed that these solar dryers reduce fish drying period by 50%. In addition, the fish processed in the

solar driers is of higher quality as it is free from contaminants like insect and dust. Consequently, the fish product fetches a higher market value.

Alternative Energy Sources

Briquettes

Briquettes made from waste paper and other plant wastes from households and biogas are the two major alternatives to biomass energy that can be promoted in the basin. Biomass briquettes are energy dense and therefore have been promoted as a potential replacement for charcoal. Briquettes are made through mechanical compression of organic wastes. Biomass briquette making was introduced in Malawi in the 1980's but adoption has been slow due to a variety of technical and economic constraints including the high cost and variable performance of briquette machines, laborious and tedious pre treatment processes for biomass before it can be compresses, high cost and ready availability of charcoal. According to Renewable Energy briquettes have potential to become a cost-efficient and sustainable source of energy which can empower local entrepreneurship while contributing to waste management problem as well, biomass briquettes are hardly known and spread in Malawi.

Because of the potential described above, LCBCCAP piloted a briquette production at the Chancellor College but the project was not able to upscale in the basin. Due to the various challenges encountered by the communities implementing the programme, in November 2011, Renew'N'Able Malawi coordinated an exchange visit for a group of 35 farmers from Zomba who had undergone training on briquette making as an alternative to woodfuels to Bvumbwe and Thyolo. These participants formed the core group that started to work with Chancellor College to manufacture briquettes. However, biomass briquette making has not been expanded in the programme beyond the pilot area around Chancellor College. The main reason for lack of outscaling is that the technology has so far not been adjusted to local circumstances nor been developed to the full potential. In addition, biomass briquettes are more expensive than firewood and the amounts required to cook a meal are higher than the firewood commonly used by households. The technology however has room for success in the basin since the waste materials are readily available. However, wide use would only occur if the technology was made less expensive and the process of making the briquettes made less laborious and labor demands are reduced to become more comparable to using non processed biomass in improved chitetezo stoves.

Biogas

Biogas is produced through the digestion of organic matter by anaerobic bacteria in a process called methanogenesis where methane gas is as a by-product of their digestion process. The gas is captured in a chamber and used for heating and lighting. Biogas can be produced from any type of organic matter provided the conditions under which the biomass is degraded are anaerobic. The common organic wastes used to produce biogas are animal manure and human wastes. The former elicits negative perceptions especially when used for cooking since the gas is associated with human wastes. However, biogas production from human wastes has been piloted successfully in South Africa where biogas is produced from school toilets and is used for heating, lighting and refrigeration.

In Malawi, a number of biogas digesters have been installed in Malawi since the 1970s. Outscaling of the technology has also been low. However, there have been few but notable successes. For example, Mzuzu University have been operating bio-gas plants since 2011. The eleven biogas plants are said to save 26 tons of firewood and reduce carbon emissions by 31 tons.

Realizing the potential of biogas as a renewable energy that could mitigate climate change impacts and reduce deforestation, LCBCCAP supported the installation of a pilot biogas plant at the Tiyanjane Women's Centre in Kachitsa Village in Salima District. Biogas was being produced from pigs that were also provided to the centre. The initiative was designed to provide an alternative and clean energy source for cooking while addressing low income among the women. Biogas is known for its reduced indoor pollution and lung infections. The biogas plant also produces bio-slurry, a powerful fertilizer which is better than the expensive chemical fertilisers. The project was however not fully implemented due to lack of funds. The initiative has thus not been up scaled in the basin. For biogas adoption to be enhanced there is need for subsidies to be introduced to support the initial construction of bio-digesters. Such an approach has been used in South Africa. There is also need to consider livestock populations (concentration and numbers). From the literature, it is evident that successful initiatives are localized around dairy farms or where households rear pigs in contained spaces. Considering the number of livestock being raised in the basin, the success of such technologies is questionable besides the technologies being expensive for ordinary households. However, wide impact of biogas technologies could be achieved if the technology was introduced in institutions such as primary and secondary schools where the gas could be used for cooking, lighting and refrigeration.

5. Conclusion and Next Steps

Based on the review, the energy efficient cook stoves, fish solar driers and fish smoking kilns offer scope for wide-scale promotion and adoption among individual households without need for heavy subsidies. For biomass briquettes to be promoted and adopted o a basin wide scale, there is need to address cost of the equipment and the end product and to reduce labour involved in the processing of biomass into briquettes. Biogas offers potential but this is limited to institutions such as schools where construction costs are offset by the high volume of organic wastes produced, the wide variety of uses that the gas is subjected to and the immediate changes it brings to the institutions. It is therefore recommended that the LCBCCAP prioritizes the promotion, sale and distribution of energy efficient cook stoves in the basin as this is likely to achieve high impact within a relatively short time frame. Due to the fact that there are other organizations such as Total Land Care and Emmanuel International that have a good track record with these technologies, LCBCCAP must work through these organizations to achieve impact at scale. Further, promotion of improved fish smoking kilns and solar driers must be scaled out to other areas of Lake Chilwa beyond the current hotspots of Mposa, Kachulu and Phalombe. Participatory approaches must be used at all levels of development, promotion and adoption to ensure that the communities own the technologies and continue to use them beyond the lifetime of the project.

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