RENEWABLE ENERGY FOR EFFICIENT FOOD PROCESSING TO IMPROVE RURAL LIVELIHOODS (R4FOOD): REPORT IN CONTRIBUTION TO WORK PACKAGE 2 – TASKS 2.2 AND 3

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Summary:

The report presents progress by Stellenbosch University in contribution towards work package 2 of the R4Food project. The information presented has been compiled from secondary sources in literature. The focus of the report is on the extent to which food processing is done in Africa, the existing efforts to improve food processing in Africa's rural areas, specifically in terms of energy efficiency and technology development and the potential to apply renewable energy resources to improve the efficiency of food processing as a means of improving rural livelihoods. According to literature, food insecurity in Africa is in part a result of poor yields in food production and to a greater extent due to postharvest losses, mainly as a result of lack of modern technologies for processing of the food. Although mechanization of these rural food processes could be a key solution to addressing food insecurity, the high energy demand coupled with escalating cost of fossil fuel is a major setback to rural food processors. Proper postharvest food processing is critical in ensuring even food distribution in time and space and has potential to improve rural livelihood by providing income generation options. The processing entails producing new products, separate components of the food crop, size reduction, drying and mixing. The food processing is also done at three levels: Primary processing that is done immediately after harvesting; secondary level, which involves improving quality before subsequent use and tertiary processing that, involves transformation of the food for consumption. Rural based food processing often involve activities such as milling, fermenting, drying and other value addition processes to increase economic value such as beer brewing (maize or sorghum e.t.c.), baking, fish smoking, palm oil processing and cassava processing. These processes are either executed by individuals or groups of people usually women, in most rural areas of Africa. Fish smoking, cereal, cassava and palm oil processing are examples of food processing for which can benefit from application of renewable energy such as biogas, solar, biomass and hydro.

Background

According to the project document for R4Food project, Stellenbosch university (SU) is in the second quarter contributing towards work package 2 (WP2): Existing rural food processing and renewable energy use being led by NJALA. In this WP, SU is specifically contributing to the following tasks:

- T2.2 Assess the extent of rural food processing, the technologies utilised, the energy mix and level of inputs currently required (SU 0.5)
- T2.3 identifies the potential for various forms of renewable energy and assesses existing deployments in rural regions (SU 0.5).

These tasks are scheduled for the period 4-8 months from the start of the project. It is in this context that this report is presented. The information was gathered from secondary sources through literature search. The report has been divided according to the following sections:

- Extent of rural food processing in Africa
- Energy technologies being deployed in food processing
- The current energy mix and level of inputs required

Table of Contents

List of Tables

1.1 Introduction

Currently, though the world has a potential of producing enough food to supply an adequate diet for all, hundreds of millions of people still go hungry. Food deficiency related diseases are rife especially in rural parts of poor developing countries, most of which depend heavily on agriculture for their livelihood. It is suggested that addressing this pandemic food crisis require concerted efforts to speed up agricultural and rural development, including agro-industry (APO, 2001). Most of the 800 million people who are chronically undernourished live in the Low Income Food Deficit Countries (LIFDCs) made up of over 80 countries that do not produce enough food to feed their population and cannot afford to bridge the gap with imports. Estimates indicates over half of these countries are located in Africa (APO, 2001).

Farming systems in most developing countries are characterized with low yields and increased food loss, which result in food insecurity. Food security, which is ensuring adequate food for everyone at all times, can be achieved not only by increased productivity but also accessibility to food. Among other factors, accessibility to food depends on the distribution network, availability, affordability and acceptability. Proper postharvest food processing is critical in ensuring food distribution in time and space and has potential to improve rural livelihood by providing income generation options (Hicks, 1995) thus contributing considerable proportion of the economic output of developing nations (FAO, 1995).

In most rural areas, the small-scale or subsistence farm produce are often processed increase the shelf life for consumption or for sales (FAO, 2002). Most of the food processing is performed by women (Lado, 1992; Sefa-Dedeh, 1993) employing inefficient traditional techniques. Products that are commonly processed by traditional technologies include groundnut oil, Cassava flour, gari, palm oil, grain flour and traditional beverages from cereals (Obilana, 2001; FAO, 2002; Bergert, 2000). Rural food processing can play a vital role in rural poverty alleviation and sustainable development in many African countries. It can increase farmers' wages by offering a ready market for farm products, generate off-farm employment, and reduce rural–urban migration.

Traditional food processing technologies have similar operating principles and unit operations as those found in modern food technologies; however their mode of application may be different (Sefa-Dedeh, 1993). The inefficiency of traditional technologies is due the rudimentary equipment and techniques employed. Several identified setbacks with these indigenous technologies are labor intensive, uneconomical operations, low efficiency, time consuming nature of the processes, and lack of quality assurance (Ajao et al., 2009; Lartey, 1975, Zu et al, 2012).

It has been suggested that mechanization of these rural food processes is the key solution to addressing the aforementioned setbacks. However, the high energy demand in food processing coupled with escalating cost of fossil fuel is a major setback in establishing modern food processing facilities in developing and underdeveloped countries in Africa. This has limited adoption of these technologies by rural processors (Adjei-Nsiah et al., 2012; Zu et al., 2012; Quaye et al., 2009; Kleih et al., 2013).

This report is a compilation of the extent to which food processing is done in rural areas and the existing efforts made in improving African rural food processing specifically in terms of energy requirements, technology initiatives and the potential to apply renewable energy resources to improve rural livelihood.

2.1 Extent of rural food processing in Africa

Food processing is a vital activity which enhances digestibility, appeal and shelf life of food of food products. It also to a large extent ensures availability of foods during lean seasons and to areas beyond the source of production, consequently stabilizing supplies and enhancing food security. Another important aspect of food processing is its yield of great diet diversity resulting in wider consumer choice. The fundamental food processing commences with food preservation.

Rural based food processing entails fundamental transformation activities such as milling, fermenting, drying as well as further processing of products into finish products with marketing potentials such as gari. These processes are either executed by individuals or group of people usually women in most rural areas in Africa as a means of income generation. Some of these foods with high product demand such as palm oil often employ mechanized processes with small scale capacities. Table 1 below highlights some small scale rural food enterprises and their energy demands.

Table 1: Sample Energy-Intensive, Small-Scale Enterprises Operated by women (modified from Reddy, Williams and Johansson, 1997)

Enterprise	Comment
Beer Brewing (maize or sorghum)	25 % of fuelwood used in Ouagadougou; main source of income for 54 % of women surveyed in Tanzanian village; 1 kg wood/1 litre of beer
Bakeries	Wood is 25 % of bread production costs in Kenya; 0.8-1.5 kg wood/1 kg of bread

Fish smoking	40, 000 tons of wood/year in Mopti, Mali; 1.5-12KG wood/kg smoked fish; fuel is 40 % of processing costs.
Palm oil processing	Extremely arduous, requires lifting and moving heavy containers of liquids; 0.43 kg wood/ 1 litre oil; 55 % of income of female households in Cameroon
Cassava processing	Women in 2 Nigerian districts earned $171/year each; 1 kg wood/ 4kg cassava
Food preparation and processing	48 % of mothers in Dangbe district in Ghana engaged; 49 % of women in one village in Burkina Faso

2.1.1 Levels of rural food processing

Depending on the required product and degree of processing techniques, three classes of food processing can be identified in the rural areas namely: primary, secondary and tertiary.

Table 2 below highlights some basic traditional food processing techniques employed in rural food processing.

- Primary processing encompasses the immediate post-harvest handling tasks such as drying, shelling and threshing of cereal and legumes which is usually carried out to reduce the fiber content and extend the storage life of the foodstuff.
- Secondary transformation usually entails prior alterations of the food before subsequent use. Cereal and legume grains may be cleaned, graded, parboiled, dehulled and polished or split into halves. Most grains are usually pounded or milled and sieved into various grades of flour. Tubers may be peeled and sliced and then sun dried.
- Tertiary processing involves the conversion of uncooked materials into products and food combinations for human consumption. The processing may take place at a commercial level, as in the extrusion cooking of cereal-legume mixes or the production of commercial weaning foods, or at the domestic level in the preparation of family meals.

Table 2: Objectives and main features of traditional African food processing techniques

Technique/Operation	Objectives	Main feature/limitations
Milling (e.g. corn): Dry milling	To separate the bran and germ from endosperm	Carried out by pounding the grain in mortar with pestle or grinding with stones. Laborious, inefficient, limited capacity
Wet milling	To recover mainly starch in the production of fermented foods	Carried out by pounding or grinding after steeping. Laborious, limited capacity, high protein losses, poor quality product.
Heat processing: Roasting	To impart desirable qualities, enhance palatability, reduce anti-nutritional factors.	Peanuts are roasted by stirring in hot sand in flat-bottom frying pot over a hot flame. Laborious, limited capacity
Parboiling (eg. rice)	To facilitate milling and enrich milled rice with B-vitamins and minerals	Done by steeping paddy rice in cold or warm water followed by steaming in bags in drums. Limited capacity, poor quality product.
Drying: Shallow layer sun drying	To reduce moisture content and extend shelf life.	Product is spread in a thin layer in the open (roadside, rooftop, packed earth etc). Labor intensive, requires considerable space, moisture too high for long-term stability, poor quality
Smoke drying (e.g. meat)	To impart desirable sensory qualities, reduce moisture content and extend shelf-life	Meat chunks after boiling are exposed to smoke in earthen kiln or drums. Limited capacity, poor quality product.

Fermentation	To extend shelf-life, inhibit spoilage and pathogenic micro-organisms, impart desirable sensory qualities, improve nutritional value and digestibility.	Natural fermentation with microbial flora selection by means of substrate composition and back-slopping. Limited capacity, variable quality

Source: modified from Awor, 1993

2.1.2 Overview of some rural food processes

Several foods are processed employing combinations of some of the basic traditional techniques aforementioned. However, with recent technological improvements, some laborious stages of most of these food processes have been mechanized in an attempt to improve the process. Below are descriptions of some of these rural food processes.

2.1.2.1 Traditional cassava flour production

In some rural areas in Nigeria and Zambia, the production of the fermented flour entails peeling of the root tubers, washing and splitting the tubers into chunks, soaking of the chunks in pots of water or edges of streams for about 3 to 4 days to ferment and soften. The fermented chunks are then sun dried for about two days and finally ground and sieved to obtain the flour (Uzogara et al, 1990; Nyirenda et al, 2011). Alternative approach identified in Nigeria involves soaking of the whole root tuber in water to ferment, peeling the fermented tuber, dewatering, sun-drying, milling and sieving to obtain the flour (Kuboye, 1985). In some Southern Africa cassava belt countries such as Malawi and Zambia, the production of the unfermented flour simply requires peeling of the tuber, washing, splitting and drying to make the ‘makaka’ chips, which can be pounded or milled to make the ‘makaka flour’ (Nyirenda et al, 2011). In Ghana, the flour is prepared for consumption by pouring it slowly into a pot of boiling water over a fire and continuing to cook until the mixture forms a glutinous, translucent paste (FAO, 1989).

Several identified detriments associated with mostly the traditional fermented cassava flour processing are lack of standardized processing approaches and process controls leaving room for processors own judgment and consequently resulting in inconsistencies in quality (Iwuoha and Eke, 1996). Other detriments are the dangers and reported cases of food poisoning by ingestion of some cassava products or associated products due to high hydrogen cyanide contents in traditionally processed cassava products due to improper processing (Iwuoha and Eke, 1996, Nyirenda et al, 2011). All these challenges encountered in traditional cassava flour processing curtails its application in potential industrial processes such as bread and biscuit baking among others hence limiting cassava flour production to household level for subsistence needs.

High Quality Cassava flour (HQCF) production

In recent years, the prospects of producing High quality cassava flour that meets industrial quality standards in some advanced cassava processing belts in West Africa such as Ghana and Nigeria has yielded positive feedback of potential and achievable High quality cassava flour (HQCF) production (Quaye et al, 2009). HQCF production in Ghana in 2011 was estimated to be approximately 4000 Metric tons.

It has been established that the High quality cassava flour can be used as an alternative for starch and other imported materials like wheat flour. Some of its potential non-food applications are in production of adhesives for paperboard manufacture, as an extender for plywood glues and as a source of starch in textiles industries. It's identified food applications are raw material for glucose production, industrial alcohol production, the formulation of composite flours in the bakery industry, and for the production of cassava glucose syrup for use in the confectionery industry (Quaye et al, 2009; Dziedzoave et al, 2003).

Process description

High Quality Cassava Flour (HQCF) processing differs from that of the traditional flour process mostly in areas of good and thorough processing as it requires a conscious effort of adherence to Good Manufacturing Practice (GMP) in order to attain the desirable high quality. The production of HQCF commences with the selection of well matured and healthy cassava tubers (10-14 months). These are then peeled, washed, grating (alternate approach is slicing and chipping), pressing, disintegration, sifting, drying, milling, screening, packaging and storage (Dziedzoave et al, 2003).

In the traditional flour production, the only mechanized stage in some rural areas is the milling of the dried cassava chips into flour. However, this is often manually pounded using wooden mortar and pestle in most rural areas.

With the high quality requirement of the product, the HQCF processing demands sophisticated and mechanized equipment or process units namely: mechanized cassava grater, cassava slicer/chipper, Cassava press (Hydraulic and screw press), cassava dough sieving machine, electric or fuel operated dryers, milling machines (plate and hammer mills) and Flour sifter.

2.1.2.2 Gari production

'Gari' is a roasted fermented cassava meal produced in some rural household in some African countries such as Nigeria and Ghana (Kreamer, 1986). The most common procedure is to harvest a few roots at a time so that they may be processed before they spoil. In this process, the cassava is firstly peeled by hand using simple knifes. This process is sometimes preceded by washing of the tuber but this is rarely the case. The peeled tubers are then sliced into manageable sizes. These are then washed in basins as dirt from the peels are transferred to the cassava during peeling. The sliced cassava chunks are then pulped using graters fashioned fom flat metal plates and wood.

Manual grating is a tedious and slow process as enough effort is required to press the cassava unto the grater for it to be pulped. The grated tubers (dough) are then transferred into fermenting baskets created by weaving split raffia fronds or a clean jute bag (Kreamer, 1986). The filled basket is covered with plastic or cloth and left overnight to aid in the anaerobic fermentation. Heavy stones or a squeezing mechanism facbricated from bamboo and nylon ropes are employed to extract the starchy fluid from the dough. This arrangement is then left for about two days in the open for complete fermentation and souring of the dough. After drainage is complete, the meal is removed from the bag and sieved on a flat sitter made from palm fibre. The sieved material is placed, a little at a time, in wide, shallow metal pots over a wood fire.

Roasting is mainly done in batches of about 2-3 kg in cast-iron pans sitting on clay tripod ovens or low hearths which are fueled by firewood. The frying requires constant stirring with wooden paddles or calabash pieces to impede agglomeration of the fines into larger lumps which are undesirable making the roasting stage labor intensive. Completion of roasting is identified by the swooshing sound made by the gari in the pan usually after 30 to 35 minutes and a temperature of 80 °C to 85 °C with the moisture content of the final product reduced to about 18 % (Quaye et al, 2009).

Improved "*Gari*" processing technologies

This process is similar in principles to that of the traditional process. However the tedious grating and starch extraction stages have been mechanized. These are carried out by locally fabricated mechanized cassava grater and presses. Diesel-engine-powered mechanical graters and hydraulic dewatering presses have replaced hand grating methods and reduced the time needed for pressing. The mechanized graters have been widely adopted in most production areas but the same cannot be said about the mechanized press (Kreamer, 1986).

Full adoption of the two technologies is usually seen in small scale processing plants in Ghana and Nigeria but these are rare (Kreamer, 1986; Williams, 1982).

2.1.2.3 Traditional Palm oil Processing

Producing this variety of palm oil begins with harvesting the fruit bunches from the small scale farms and conveying them by carrying in baskets on the head to the processing sites. They are then threshed manually using objects such as cutlass to release the fruitlets. The fruitlets are then washed and boiled until cooked. This is followed by pounding the boiled fruits in large mortars using pestles to ease the mesocarp from the nuts. After this, the nuts are separated from the fibrous mash by hand and the mash kneaded to express the oil. Cold water is poured into the mash and left to stand for 8-18 hours (Ata, 1974). This allows the lighter oil to settle on the surface which is skimmed off. Small quantities of salt may be added to the oil followed by boiling until effervescence ceases. The oil is then cooled and packaged.

Semi-mechanized technology in palm oil processing

The semi-mechanized technology is characterized by two major innovations in the processing equipment; the manual or mechanized screw press and the diesel-powered digester. Both are locally manufactured or assembled by artisans in the oil palm producing regions such as Ghana, Cameroon and Nigeria (FAO, 2002).

2.1.2.4 Preservation of leafy vegetables by sun drying

Sun drying is the common means of processing leafy vegetables for storage in most rural areas. Slippery mucilaginous vegetables, such as okra, are never blanched or boiled. The leaves are simply dried directly after stripping from the stems. Other leaves may be blanched or parboiled; tree leaves may also be pounded to soften them before drying. This dried leaves are usually added directly to soups and stews during preparation. Dried cowpea leaves may be fried, as well as boiled. During drying, nutrients such as vitamin A and ascorbic acid are often greatly reduced. The extent of the vitamin loss depends on the pre-treatment and the temperature and duration of the drying process (FAO, 1990a).

2.1.2.5 Preservation of fish and meat

Typical traditional means of processing fish and meat primarily for preservation are smoking, drying and salting.

- In some cases, some types of fishes are fermented. A typical example is “guedj”, a fermented fish produced in Senegal. It is prepared by stacking unsold fresh fish in heaps in the open air for about 24 hours to ferment. This is followed by disemboweling and filleting the fish. The filleted fish is then soaked in sea water in wooden containers. The water is usually changed weekly when it develops foul odor. Finally, the partially fermented fish is spread on straw for two to four days to dry in the sun and wind (FAO, 1990b).

- Although fresh meat is preferred when available, dried meat is prepared to ensure a supply to distant markets and to preserve meat that is not required for immediate consumption. A combination of sun and air drying is the most common technique for the preservation of meat from domesticated animals. Game, and the meat of small rodents, is often dried and smoked in situ over a log fire (FAO, 1990b).

2.1.2.6 Germination and fermentation of cereals

Most African countries employ germination and fermentation practices in processing of cereals for beverages and porridges. These techniques improve the flavor and digestibility of the product.

In the preparation of "obushera", a popular porridge in Uganda, sorghum or millet is mixed with water and wood ash and left to germinate and ferment for some few days. During the fermentation, enzymes partially break down the grain starch. The grain is subsequently washed, dried and ground to a fine flour which may be cooked with sugar into the porridge (FAO, 1989c).

3.1 Energy technologies being deployed in food processing

Presently, technologies being introduced to address energy needs are directed at improving efficient utilisation of existing predominant energy sources such as biomass and solar. Below are some highlights of these technologies deployment in Africa.

3.1.1 Improved Stoves

- Dissemination of improved cookstoves has been undertaken in most Southern and Eastern African countries. These stoves are designed to utilize wood fuel efficiently, thereby reducing the drudgery and expenditure of acquiring wood fuels for cooking needs (Karekezi and Ranja, 1997).

Table 3: Estimated Number of Improved Cook stoves in selected Sub Saharan African Countries

Country	Number Distributed
Kenya	1,450,000
Burkina Faso	200,000
Niger	200,000
Tanzania	54,000
Ethiopia	45,000
Sudan	28,000
Uganda	52,000
Zimbabwe	20,800

Sources: Karekezi and Ranja, 1997; Karekezi and Tuyareeba, 1994; AFREPREN Data Base, 2000; Karekezi, 2002

3.1.2 Biogas Technologies

Several considerations of small-scale biogas technologies for rural applications particularly in household cooking have been explored in the last three decades. The convincing factors of biogas implementation in these rural areas are its readily available feedstock, which is abundant animal dung in most rural areas of sub-Saharan Africa, and it's relatively less complicated technology. Its technical viability in rural areas has further been proven in several demonstrations and field tests (Karekezi and Kithyoma, 2003).

However, mass deployments have not been successful due to some unforeseen challenges. The small scale animal farmers had challenges of securing sufficient feedstock to ensure steady generation of the biogas. Also, the investment cost of even the smallest biogas units proved to be a challenge for most poor rural households. However, some suggestions indicate that larger combined septic tank/biogas units run by some institutions such as hospitals and schools seem to be highly viable than the small-scale biogas digesters (Karekezi and Kithyoma, 2003).

Table 4: Small and Medium scale biogas units in selected sub-Saharan African Countries

Country	Number Distributed
Tanzania	>1,000
Kenya	500
Botswana	215
Burundi	279
Zimbabwe	200
Lesotho	40
Burkina Faso	20

Sources: Karekezi and Ranja, 1997; Karekezi, 2002

3.1.3 Solar PV

There have been widespread supports of solar photovoltics as a potential energy technology for rural areas. This has led to several PV projects in almost all countries in sub-Saharan Africa (Karekazi and Kithyoma, 2003). However, limiting the success of adopting solar PV to only the affluent in mostly urban areas of these countries is the high costs of installation of the solar PV. It was established that its average cost of about US$21/Wp was unattainable for most rural poor (McNelis et al, 1992).

Table 5: PV dissemination in selected sub-Saharan African countries

Country	Estimated Number of systems	Estimated kWp
Uganda	538	152
Botswana	5,724	286
Zambia	5,000	400
Zimbabwe	84,468	1,689
Kenya	150,000	3,600
South Africa	150,000	11,000

Sources: Nieuwenhout, 1991; Bachou and Otiti, 1994; Diphaha and Burton, 1993; Karekezi and Ranja, 1997; AFREPREN, 2001; Hankins, 2001; DBSA, 1999

3.1.4 Solar thermal technologies

Solar thermal technologies that are being employed in African rural food processing are solar cookers and solar dryers (Kammen 1991; 1992).

4.1 The current energy mix and level of inputs required

The current energy mix employed in most rural food processing is mainly biomass and solar oriented. However, with the emerging mechanised technologies, electricity and diesel are gradually taking roots in some improved and advanced rural food processing facilities.

Biomass

- Traditional biomass remains the most exploited form of energy on the continent. They are mainly wood waste, Animal waste, agricultural residues (field and process residues) and charcoal which are primarily combusted for cooking and heating needs. As Traditional woodstoves are highly inefficient, these energy resources tend to be over exploited for relatively lesser gains.
- Estimates shows that in Sub-Saharan Africa, with the exception of South Africa, biomass energy contributed an average share of 57.6% of total energy needs in 2008 (IEA, 2011). In 2011, its contribution to the total energy demand increased to 80% with charcoal contributing about 95 % of urban demand (Belward et al, 2011).
- Charcoal and firewood is currently being used beyond household level as it is gaining utilization in agriculture and rural industries such as brick processing, food processing, and tobacco curing among others (Karekezi and Ranja, 1997).

Solar

Solar energy is usually harnessed in direct drying of food products such as meat, crops and evaporating seawater. Recent technology developments have resulted in some minimal utilization of solar in some small scale applications such as household cooking and lighting. Its extensive application at the community level includes vaccine refrigeration, water pumping and purification as well as electrification (Karekezi and Ranja, 1997).

Diesel and electricity

Most of the mechanized units such as hammer mills, presses, and mechanized graters among others are usually designed to be powered by a diesel engine or an electric motor which consequently subjects the improved or mechanized processes to electricity, crude fuel oils and gas as their major energy sources (Jekayinfa and Bamgboye, 2008).

Table 6: Fuels used for cooking in rural households for selected African countries (% of fuels used) (reproduced from World Bank, 2000)

Country	Firewood	Gas, Kerosene	Charcoal	Electricity	Other
Central African Republic	100	0	0	0	0
Guinea	99	0	1	0	0
Gambia	97	1	1	0	1
Mali	97	0	0	0	2
Tanzania	96	0	3	0	0
Madagascar	94	0	5	0	0
Uganda	94	2	4	0	0
Kenya	93	2	4	0	0
Ghana	92	1	7	0.1	0.2
Burkina Faso	91	1	1	0	7
Niger	90	1	0	0	9
Cote d'Ivoire	89	1	2	0	8
Zambia	89	0	9	1	1
Botswana	85.73	14.1	0	0.03	0
Senegal	84	2	12	0	2
South Africa	49	23	5	21	2
Djibouti	44	48	5	1	2

4.1.1 Level of inputs required

Biomass application challenges

- Though readily available, traditional biomass usage has several detrimental effects particularly on women and children who often work directly with it. The indoor air pollution from poorly ventilated biofuel cooking stoves and kitchens is a significant contributor to respiratory illnesses in most of sub-Saharan Africa (Ezzati and Kammen 2002).
- Overdependence on biomass, especially wood for charcoal production, also encourages land degradation. This concern is currently rife in some areas such as Lusaka in Zambia, Dar-es-Salaam of Tanzania and Nairobi in Kenya where high

charcoal demand appears to contribute to degradation of the surrounding woodlands and forests (Kantai, 2002).

Solar cost

- There is growing evidence that solar PV projects in the region have mainly benefited high-income segments of the population, due to the high cost of solar PV. Solar PV is unaffordable to majority of the population in sub-Saharan Africa, given the high levels of poverty (Karekezi and Kithyoma, 2002).

Challenges of Adopting Mechanized units

- Several researchers agree to a large extent that mechanization of traditional rural food processes is the key to improving the total conditions of rural food processing in areas of health and safety concerns, quality of products and improving production capacity (Klein et al, 2013; Quaye et al, 2009; Dziedzoave et al, 2003; Nang'ayo et al, 2005).
- Though several efforts have been made to mechanize most of the stages of some of these food processes, complete adoption of the mechanized technologies by rural processors is very minimal as a result of perceived high risk factors and implications on profit margins (Adjei-Nsiah et al, 2012; Zu et al, 2012; Quaye et al, 2009; Kleih et al, 2013).
- Furthermore, the shying away from complete mechanization is also to an extent due to unavailability or expensive nature of modern energy such as electricity and fuel oils which are the major energy sources for powering most of these mechanized units as compared to readily available manual labor in the rural areas (Kleih et al, 2013; Quaye et al, 2009).

5.1 Potential of other forms of renewable energy

Small Scale Hydro Systems

Improving mechanization in most rural food processing, such as HQCF processing, are energy intensive and relies on high electricity demand which cannot be met in an economical manner by solar PV alone (Karekezi and Ranja, 1997). A promising technology is small scale hydro systems. Small-scale hydropower plants for electricity generation are available in mini, micro and pico (descending order) sizes.

Also unlike other technologies, these systems have advantages of diverse uses such as irrigation, energy generation amongst others. In addition, it is a very reliable technology that has a solid track record. Their modularity (small scales of kW ranges) also makes them ideal in meeting local needs and possibility of situating them close to end users thereby eliminating high costs associated with transmission and distribution grids (Nguyen, 2007).

Biogas potential from food processing waste

Biogas Potential in Palm oil mills

Palm Oil Mill Effluents (POME) is a waste stream or by-product of the palm oil mills comprising of all liquids waste with characteristics brownish colloidal suspension (Chong and Zaharuddin, 1988), high BOD (about 100 mg/l), suspended solids and oil and grease rendering it environmentally unsafe for direct disposal into waterways or water bodies (Er et al., 2011). Estimations indicates for every 1 ton of crude palm oil extracted from milling, a corresponding 2.5 tons of POME is generated (Sulaiman et al., 2009). Other studies report an average of 0.1 ton of POME is generated for every ton of fresh fruit bunch (FFB) processed (Lim, 2010).

It has been realized that the emission rate of methane from the POME treatment ponds is 1043.1 kg/day/pond (Yacob et al., 2005). Research data also indicate that biomethanation of POME at process conditions of 35 °C to 55 °C results in methane yields between 0.47 - 0.92 m^3/kg BOD_{added} (Yeoh, 2004). Thus, there is a great potential for POME to be utilized to generate biogas, which can be used for the energy needs in the palm oil industry. In the case of the traditional palm oil processing which is undertaken in households or backyards, household biogas digester could be employed to convert the POME into biogas which can be used to replace firewood and charcoal in cooking to minimize deforestation and indoor smoke related diseases from biomass combustion. In the small cooperatives mills, small or medium-scale biogas digesters will be an ideal choice for digestion of POME to produce biogas.

Biogas from cassava processing

Recent studies indicates that mixing the cassava peels, which is a residue from cassava processing, with a much lower C/N material such as farm animal dungs could stabilize the mixtures C/N ratio to appreciable values between 22 and 30 making it suitable for biogas generation (Adelekan and Bamgboye, 2009).

Demonstrations revealed that highest biogas yields of 21.3 l/kg TS, 35.0 l/kg TS and 13.7 l/kg TS were obtained for mixtures of cassava peel with cattle, piggery and poultry waste respectively in the ratios of 1:1 for a retention period of 30 days (Adelekan and Bamgboye, 2009). Considering several households in most rural areas rear farm animals, obtaining the farm animal wastes and mixing them with the cassava processing waste in household digesters is a realistic and achievable means of producing biogas for household needs in these rural areas.

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