Opportunities for Different Agricultural and Forest Wastes as Sources of Energy in Tanzania: An overview

[1]Halidini Sarakikya, [2]Abdulkadir Kirobo
[1]Department of Electrical Engineering, Arusha Technical College, Arusha, Tanzania
[2]Department of Information & Communication Technology, Arusha Technical College, Arusha, Tanzania

Abstract
The importance of Agricultural and forest residue for energy generation cannot be left unexplained as they are easily available and have much potential as renewable energy resources in the form of Biomass. The energy generated from Agricultural and forest residue is clean and therefore environmentally friend. The objective of this paper is to look at uses of these biomasses, how to convert them and finally their utilization systems. The paper has identified various agricultural and forest waste/residues which can be converted into energy as well as the advantages which are gained from using these biomasses as sources of energy in Tanzania. It is recommended in the paper that briquettes as a source of energy can be made from all methods of conversion discussed. In this, biogas is a result of anaerobic digestion which gives energy and fertilizer for soil enrichment. Pyrolysis of these residues produces syngas and other useful chemicals and also various animal foodstuffs. The paper suggests that the use of forest residue and agricultural waste has the opportunity to create jobs and bring bio-economic growth of the Country.

Keywords: *Agricultural, Energy, Conversion techniques, Forest, Residue.*

1. Introduction
Biomasses which are in the form of agriculture and forest residues have much potential for renewable energy resources. Forest residues and other related resources which are classified as waste can be converted into high value products by using Biotechnology and Bioengineering to form the basis for energy production [1]. The estimate land forest area of Tanzania is 38.8 million hectares (41%) and most of this forest area is occupied by woodland which is 90% [2 & 3]. This large forest area produces a large quantity of residues, which most of them are biomass, have enormous of energy and can play an important role in meeting the energy demand required by the country. Regarding biomass residues, there are about 15 million tons/annum of crop residues, 200,000 tones of volatile solid sisal waste and 1.1million tones/annum of forest residues [4].

There is no proper management of these wastes and utilization in Tanzania including other developing countries. These wastes are openly burned and sometimes are left to decompose. The burning and decomposition of these wastes cause environmental degradation and pollution which amounts to hazards for human and ecology. Other effects associated with decomposition of these wastes are insects, rats, fire and odor when left as waste almost everywhere [1 & 4]. The type and quantity of these agricultural wastes in Tanzania are sometimes different from one region to another. They also differ from one season to another, because some crops are cultivated for business purposes. In rural areas around the country, a significant amount of agriculture waste such as those from maize are directly burned and combusted in low efficient

traditional cookers. In most Villages, cooking process is done on three stones arranged triangularly to accommodate the pot as shown on Figure 1, and in some other areas, mud stoves are used and as a result there is inefficient energy use and air pollution.

2. Objective of the Study

This paper aims at identifying various agricultural and forest wastes in the country and recommend their routes of utilizing them as a source of energy resources for entire economic development of the Nation.

Figure 1: Traditional Three stone cooking

2.1 Forest Area and Plantation

Biomass in the form fire wood is a major source of energy in Tanzania. The biomass accounts for 89% of energy consumption in a Country. Petroleum and electricity account for about 9.2% and 1.8% respectively. Coal and other energies contribute to 0.3% and 0.1 respectively [5].The forestry sector has a very important role to play in Tanzania's economy. Although in absolute terms, its contribution to total gross domestic product (GDP) is low, it has increased considerably during the past 10 years by about 35%, from 2.6 to 3.4 % of GDP.

The country's forests contain such a high level of biologically diverse resources [6]. When planted and grown on a large scale, forest crops will have the potential of improving agricultural productivity, conserve and protect land from soil erosion and will uplift the country economy. The day to day operations such as thinning, extracting stem wood for pulp and timber and natural attrition generate the forest residues. In sawmill industries, wood processing generates a significant amount of residues in the form of saw dust and other rejected wood chips. In many areas of the country, saw dusts are used as a source of energy for cooking, using a saw dust cooker shown on Figure 2.

Figure 2: A saw dust cooker used in rural areas of Tanzania

2.2 Residues from agricultural crops

Are mostly obtained during harvesting, and when food and crop processing is being done. However, in Tanzania at present there are no any crops which are planted for the purpose of energy production. Therefore there is a need for a Government to initiate a campaign of encouraging individuals to change their altitude towards planting and growing crops for energy purpose. Sugar cane, maize, sorghum, eucalyptus and oil basing crops such as sunflower and cashew nuts are the agricultural crops which can be cultivated specifically for energy production purposes [1]. There are a lot of these agro wastes in the country, especially in harvesting seasons but they are not considered as energy resources products. According to [7], crop wastes and forest processing waste and residues can be removed and utilized for energy production.

2.3 Resources from Cattle manure

Cattle manure is an organic matter, mostly derived from animal feces except in the case of green manure, which can be used as organic fertilizer in agriculture. Manure contributes to the fertility of the soil by adding organic matter and nutrients, such as nitrogen, that are trapped by bacteria in the soil [8].Tanzania has Animal droppings from 14 million cattle and 11 million goats and sheep, the rest of other waste is produced by human beings. There is potential to generate more than 500 MW, with a sustained yield of 24.3 million m^3 per annum [4]. Manure quality depends on the environment or area from which they are recovered or obtained. In northern parts of the Country, especially those areas occupied by Maasai People (Maasai Land), cow and donkey wastes in the form of dung are used as energy resources for domestic cooking and heating.

2.4 Benefits of Agricultural Residues as Biomass for rural Energy Production

There are a lot of advantages gained from using agricultural residues as biomass for energy production. Among these are;

- Their availability is obvious and they are quite available in a huge quantity in rural areas.
- When used as energy resources, they serve as best way of waste disposal.
- It will reduce the rate of deforestation as the rate of cutting trees in the forest will greatly be reduced
- The use of these deposits will reduce the greenhouse gas effects and there will be things like ground water contaminations caused by decayed residues moving from the ground through liquids to the surface water.
- Their use will create or will be generating income for people living in rural areas. When the market is established, the residues will have value.

2.5 Limitations of Agriculture and Forest residues as Biomass Fuel

Although several kinds of agriculture residues and forest wastes are preferred to be utilized as fuels, to some extent their use has become difficult due to their uneven characteristic. Majority of these residues are not suitable for direct combustion as fuel. This is because they have lower density, higher moisture content and they also have Lower Heating Value (LHV). Also there exists problem on their transportation, handling and storage [9]. Because of this they need to be transformed into other forms that will make them burn easily and efficiently. Biomasses which are converted into biofuels

come from two origins. The first is conventional agricultural products and the second is from lignocellulosic products and residues [1]. Agricultural and forest waste are converted into energy products by thermal chemical or biological conversion process and the process produce solid, liquid, or gaseous fuels, whereby agriculture residues can be converted into heat energy [10].

3.0 Conversion Routes from Agricultural and Forestry Residues to Energy and Products

Figure 3 shows conventional routes or processes used to recover energy from agricultural and forestry residues [1 & 10].

3.1 Thermal Methods

- Direct Combustion: Combustion is a rapid exothermic reaction that liberates substantial energy as heat and flames as a combustion reaction with the ability to propagate through a suitable medium. In this process energy is given in the form of heat. This is the most method of conversion used by most of people in rural areas. Heat energy is obtained after direct combusting the biomass and used for cooking, space heating and sometimes lighting [11]. Three stone fire, wood stoves and charcoal stoves are among the traditional appliances employed in this application. These traditional stoves are inefficiency, and therefore, efforts are made to improve their combustion efficiency [7]. Biomass combustion efficiency can be improved through co-combustion a process which is also known as co-firing, and which has the advantage of reducing costs and minimizing emission [12].
- Gasification: Is the thermal chemical conversion of solid or liquid carbon based materials (feedstock) into combustible gaseous product (combustible gas) by the application of gasification agent. In this process, partial combustion of the materials is carried out in the presence of oxygen, but fewer amounts than that is required for complete combustion. The process produces (CO, CO_2, H_2, CH_4 etc. The main part of the gasification process is the gasifier, where a reaction takes place at high temperature, higher than 800°C in presence of a controlled amount of oxidizing agent. The material or feedstock is converted into a Synthesis gas also called Syngas which is combustible and suitable for several use [13].

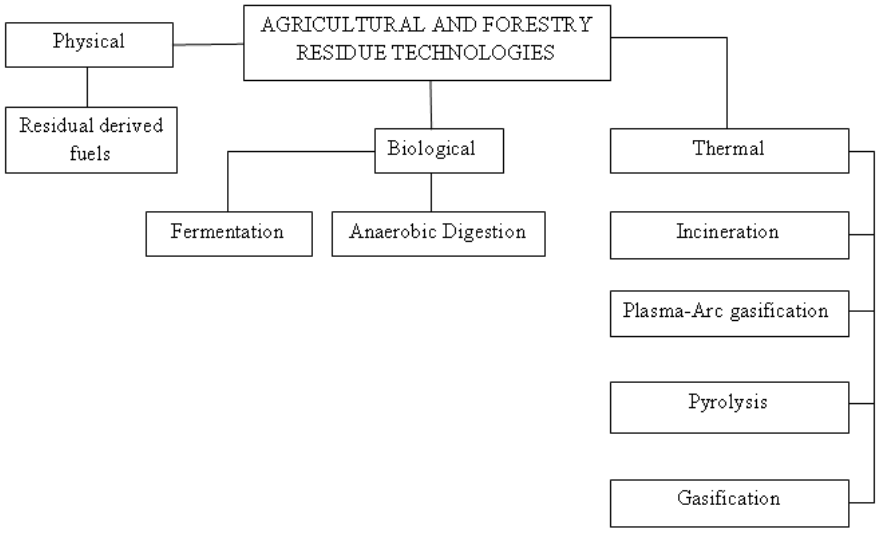

Figure 3: Conversion Technologies for Agricultural and Forestry residues

- Pyrolysis: Is the thermal decomposition of the waste occurring in the absence of oxygen or air. It requires an external heat source since the waste must be dried before the pyrolysis process. Reaction Temperature is within 250°C – 700°C. The conversion of wood to charcoal is also a destructive distillation of waste in the absence of oxygen (Alam and Ahmade, 2013). Main products of pyrolysis include, solid/ash coke residue, condensable oils, Waxes and Tar and Gas such as CO, H_2, Hydrocarbons, N and H_2O. All known biomass feed stocks can be subjected to pyrolysis to obtain fuel and chemical products. According to [1], few researchers on renewable energy have worked on pyrolysis of agro- residues. Examples of these are oil palm waste, maize cob, wood residue and many others. It was concluded that gaseous fuel released from pyrolysis of wood includes four main gases which are H_2, CO, CH_4 and CO_2. Pyrolysis processes are of several types: Slow pyrolysis or torrefaction which produce a coal like materials and fast pyrolysis which produce a liquid similar to crude oil.
- **Plasma:** Is the process of using a plasma arc torch to produce high temperature arc that breaks down waste and forming syngas, electricity and slag.

3.2 Biological Methods

According to [15], the process is based on enzymatic decomposition of organic matter by microbial action to produce methane gas or alcohol. The bio-chemical conversion process, are preferred for wastes having high percentage of organic bio- degradable matter and high moisture content, which aids microbial activity. The application of waste technology such as fermentation and anaerobic digestion is the application of this process.

- **Anaerobic Digestion:** Is when bacterial converts degradable organic materials into gas such as methane (CH_4) and carbon dioxide (CO_2). In this process, cattle manure is the major feedstock
- **Fermentation:** By using yeast the biomass fraction of agriculture and forestry residues waste can be fermented to generate ethanol which can be used to run internal combustion engines [10].

Biomass is a mixture of lignin, cellulose and hemicelluloses. The function of lignin during process is to serve as glue and also help biomass gains its strength while the hemicelluloses and cellulose build the block of fibers. During the biological process and in the conversion of hemicelluloses and cellulose to sugars biomass structures are attacked and the hemicelluloses is disrupted [11].

3.3 Other Methods

3.3.1 Liquefaction

This is a process of extracting liquid from biomass for generation of energy. This process can also be defined as basic intermediates for production of high value chemicals. There are a number of processes which can be used to liquefy solid biomass such as pyrolysis, hydrothermal liquefaction or other thermal chemical technologies [16]. The liquid substances obtained from these processes are hydrocarbons, also known as bio-oils and are basically ethanol and methanol. Methanol is obtained from wood and crops residues, while ethanol is produced from grass and starch crops [9]. [17] point out that, there are four basic steps for the production of ethanol which are: Production of a simple sugar solution, Fermentation of the sugar produced, Fractional distillation of the liquor to produce 95% ethanol solution and hence the chemical

distillation of that 95% ethanol to remove the remaining water content. Methanol is obtained from distillation of the raw pyroligneous acid obtained from the pyrolysis of biomass, can also be obtained from natural gas and the other method is the use of hydrogen and carbon monoxide when gasifying the biomass [1].

3.3.2 Briquetting

Briquetting is the process of converting low bulk density Agricultural and forestry residues (biomass) into high density and energy concentrated fuel briquettes. When biomass is converted into briquettes is easy to use, transport and store [18]. Materials that are not stable or have low density are compressed into a solid fuel of a convenient shape which is burnt like wood [1 & 18]. Briquettes made from biomass are a great substitute for coal, since they are made of natural materials. It does not emit green house gases or any toxic chemicals. Briquettes are better than loose biomass since they are compressed. This compression allows them to burn for a lot longer than if it was loose. Briquetting solve the disposal and pollution problem caused by biomass residues. Rice straws, maize cobs, sugar cane waste (bagasse), saw dust, cowpea chaffs and groundnuts shells are raw materials suitable for briquettes [19].

3.3.4 Pelletizing

Wood pellets are a manufactured biomass fuel. They are made from wood waste materials that are condensed into pellets under heat and pressure. Natural plant lignin holds the pellets together without glues or additives. The process is quite similar to briquetting. The difference is that, pellets are much smaller than briquettes produced. On the other side, Agriculture waste and residue are pelletized for the purpose of animal foodstuffs. It is said that agricultural wastes have higher fiber which cause the digestion complicated. Animals face difficult when given to eat them in its natural form. Animals make better gains on pelletized feed than a meal ration.

The most logical reasons are that (a) the heat generated in conditioning and pelletizing make the feedstuffs more digestible by breaking down the starches, (b) the pellet simply puts the feed in a concentrated form, and (c) pelletized minimizes waste during the eating process. When pelletized feed is fed, each animal receives a well-balanced diet by preventing the animal from picking and choosing between ingredients. Tests have shown that most animals, if given the choice between the same feed in pellet or mash form will prefer the pellets.

Commercial application of pellets are found in industrial boilers because of easy of handling and better burning characteristics, which is advantage compared to coal. According to [1], the main advantages of pellets that it has higher energy density, are convenient and easy to use, and can be bulk stored in less space than other biomass fuels, are a clean-burning renewable fuel source, are produced from such waste materials as forestry residues and sawdust, are price stable compared to fossil fuels.

3.3.5 Oil Extraction from Agricultural Biomass

Oil crops are the base for biodiesel production. Biodiesel is a non fossil alternative to petro diesel which can be obtained from vegetable oil. The oil can be extracted from different types of biomass including sunflowers, Soya beans, Oil palm and rape. The oil can be used alone or mixed with diesel oil for running compression ignition engines. Many other crops

such as canola, mustard, flax, jatropha, coconut, hemp and pennycress are good resources of oil. Cultivation of oil plants such as macaw palm tree, jatropha, and camelina sativa shown on Figure 4 (a-d) would be very useful for the production of biodiesel which can be used in various application purposes and therefore, reduce energy poverty in Tanzania.

Figure 4: Various oil plants for biodiesel production

4. Areas of application of Agricultural and forestry residues in Tanzania

Biodiesel is a non fossil fuel which can be obtained from vegetable oil and animal fats by transesterification, and it is alternative to petro-diesel [20]. The production of biofuel such as ethanol can significantly replace the use of fossil fuel. Ethanol is a grain alcohol that can be blended with a gasoline and used in motor vehicles, tractors and harvesters in farms. High grade solid fuel in the form of wood and other forestry residues are converted into briquettes and used in domestic and industrial applications [9]. A number of agricultural and forestry residues can be used to generate electricity in a small scale societies.

The production of biogas and direct combustion of agricultural and forestry residues can be used to generate heat and steam. Heat produced will be used in domestic applications such as cooking and steam can be used to drive the steam turbine for electricity generation, as well as in boilers for other industrial purposes. Internal combustion engines can be run using the gas produced by anaerobic digestion, pyrolysis and gasification. The gas can also be used in various applications including manufacturing of chemicals and is applied as basic chemical feedstock in petrochemical industries [22].

The ash by product of combustion can be stabilized and solidified by encasing in concrete prior to disposal. It also used in production of road bedding, concrete bricks, cinder blocks and cubing. The product of composting is very rich in organic matter and the soil needs it back to continue producing healthy crops [23]. Deficit of foodstuffs for animal is overcome by agricultural residues. Agricultural wastes also produce chemicals which are useful adhesive tar for wood binding particles.

4.1 Advantages of Agricultural Residues and Forestry residues in Tanzania

Agricultural waste and forest residues are biomass, renewable source of energy and once used as a source of energy, do not pollute the environment in a sense that it does not contributes to global warming. According to [1], it reduces the carbon dioxide in the atmosphere by acting as a sink. Sulphur content in biomass fuels is negligible and therefore, when burnt does not contribute much sulfur dioxide emission which cause acid rain. Also agricultural and residues when burnt,

have less ash compared to coal combustion. The ash from agricultural and residues can be used in farms as soli additive for potassium and phosphorus [21].

The practical and economic use of agricultural waste as well as forestry residues will create job opportunities and hence help the growth of sustainable economy and build a Bioeconomy. Bioeconomy is an economy which uses biological resource from the land, as well as waste as inputs to food and feed industrial and energy production [24]. Bioeconomy is the substitution of fossil fuel materials with renewable. The increase of the use of renewable resources for industries and for energy purposes will bring benefit in many areas, by providing more income to individuals, society and the nation as a whole.

5. Conclusion

The Techniques analyzed in Figure 3, and others which have been explained above are the methods of converting agricultural wastes to form a product which is valuable such as briquettes, pelletizes, biogas, biofuels, animal fodder, fertilizers, and other chemicals. These products do not contribute to global warming and furthermore, the Bioeconomy will be built by creating more jobs which in turn delivers strong and sustainable economy as key outcomes. However there are still great efforts and campaigns needed to be done by government and other stakeholders because these technologies for biomass conversion as well as its utilization have not yet given much concern and priorities in Tanzania. If this is done, more people will be aware and rely on biomass for their energy generation, and as a result reducing the cost of fossil fuel. Also environmental pollutions, mostly caused by conversional sources of energy will be minimized.

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