Electricity Generation through Biomass in Nigeria: Options, Benefits and Prospect

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***Abstract*-Biomass as a type of renewable energy is readily available in virtually everywhere because of the availability of animal dung, waste however its rich availability is not yet tapped in Nigeria and some part of the world. This paper highlights the various biomass materials available in the country including the various technologies that is used in converting biomass into electricity. The benefits, challenges and prospect of biomass in Nigeria are also explored**

Keywords—component; Biomass, Renewable energy, Electricity production

INTRODUCTION

Biomass is defined as the total of living material in a given habitant, population, or sample. Specific measure of biomass is generally expressed in dry weight (after removal of all water from the sample) per unit area of land or unit volume of water. Renewable organic material such as wood, agricultural crops or wastes, and municipal wastes, especially when used as source of fuel or energy. Biomass can be burned directly or proceed into biofuels such as ethanol and methane.

Other examples of biomass includes forest and mill residue, agricultural crops and wastes, wood and wood wastes, animal waste, livestock operation residues, aquatic plants, fast growing trees and plants, municipal and industrial waste. The various types of plant biomass are shown in Table 1.The range of biomass and waste feedstock available for utilization is very wide. A general categorization can be considered which comprises:

i. Energy Crops

Biomass fuels grown specifically for use as fuels for energy production. These include trees, grasses and oil plants. Trees used as energy plants are usually those that can grow back after being cut off close to the ground and can be harvested every 3 – 8 years for a period of 20 – 30 years such as willow, popular and eucalyptus). Grasses used as energy crops are usually thin stemmed grasses which can grow in hot and wet climates such as sugar cane, sweet sorghum, elephant grasses and phalaris. Oil plants such as soybeans and sunflowers can be used for producing fuel for energy production. (1)

ii. Forestry Residues

This are wood fuels produced from existing lumbering and coppicing operations in established forestry such as wood chips, forestry trimmings, sawdust and bark.

iii. Agricultural Wastes

These are biomass wastes produced by agricultural farming practices for food production such as straw, bagasse and poultry litter.

iv. Municipal Waste

These are wastes generated from household, industrial and commercial sources. This waste can be raw, i.e. unsegregated or segregated (glass, metal paper etc). It can also be in its ‘as produced’ form or densified to form a pellet, commonly known as DRDF (Densified Refuse Derived Fuel).

v. Specialized Industrial Wastes

This area ranges of waste materials generated by industry that have the potential to be used for energy production. Examples include tyres, clinical waste, waste solvents and other chemicals, car fragmentation waste, meat processing wastes and waste derived products.

In terms of their physical and chemical characteristics, the various biomass material differ from other conventional energy sources in a number of ways that include lower density; higher moisture content, often up to 50%; lower calorific value; broader size distribution, unless pre – conditioned by screening, crushing or pelletizing; the variability of the materials as fuels and the sulphur and nitrogen contents are often lower. Biomass provides 14% of the world’s energy resources or about 28 million barrels of oil equivalent per day (Mboe/day) and is the most important source of energy in developing countries (Afgan, 2007) (2).

Table 1: Types of Plant Biomass (REMP 2005)

Woody Biomass	Non Woody Biomass	Proceed Waste	Proceed Fuel
Tress	Energy crops such as sugar cane	Cereals husks and cobs	Charcoal (woods and residue)
Shrubs and Scrub	Cereal straw	Bagasse	Briquetted and densified biomass
Bushessuch as Coffee and Tea	Cotton, cassava, tobacco stems and roots (partly woody)	Waste from other pineapples and other fruits	Methanol and ethanol (wood alcohol)
Sweeping from forest floor	Grass	Palm oil cakes	Plant oil such as palm oil rapeseed (canola) and sunflower
Bamboo	Bananas and plantains	Sawmill wastes	Producer gas
Palms	Soft stems such as those softs and potatoes	Industrial wood bark and logging wastes	Biogas
	Swamps and water plants	Black liquor from pulp mills	
		Municipal wastes	

2. Biomass Resources in Nigeria.

The biomass resources of Nigeria consist of wood, forage grasses and scrubs, animal wastes arising from forestry, agricultural, municipal and industrial activities, as well as aquatic biomass. Previously, biomass dominated Nigeria's energy landscape, contributing 37% of total energy demand, and the energy of choice for the vast majority of rural dwellers and the urban poor. However, the resource base is under pressure from both human activities and natural factors such as drought. The biomass energy resources of Nigeria have been estimated to be 144million tonnes/year. Nigeria presently consumes about 43.4 x 10^9 kg of firewood annually. The average daily consumption is about 0.5 to 1.0 kg of dry wood per person (2) Table 2 shows the total area of Nigeria, distributed among the various uses.

Table 2: Nigeria's Size and land use parameters (REMP 2005)

NIGERIA	QUANTITY (Million ha)	PERCENTAGE %
A. SIZE		
Total Area	92.4	100
Land Area	79.4	85.9
Water bodies (rivers, lakes etc)	13	14.1

B. LAND USE		
Agricultural Land	71.9	77.8
Arable Cropland	28.2	30.5
Permanent Cropland	2.5	2.7
Pasture Land	28.3	30.6
Forest and Woodland	10.9	11.6
Fadama	2	2.2
Others	7.5	8.1

From Table 2 it can be seen that of the total Nigerian land area of 92.4 million hectares, 79.4million is occupied by land while the remaining 13.0million hectares are occupied by water bodies. Based on 1996 recorded crop production for Nigeria, there was an aggregate crop production of about 93.3 million tonnes for the major crops. This quantity refers to the harvested useful parts of the plants. This discarded parts consisting of roots, leaves, stalks, straws, chaff and other parts of plant shoot (otherwise called crop biomass) would be far in excess of this figure (REMP, 2005).The foregoing shows that Nigeria has a huge and enormous potential for production of agricultural biomass. The country's estimate of wood resources available has been provided by the Forestry Monitoring and Evaluation Coordinating Unit (FORMECU). The agency estimated that the supply possibility of Nigeria's fuel wood is 78.9 million cubic metres for 1994. Fuel wood production takes place in all parts of the Nigeria. Although the available fuel wood volume is much higher in the high forest zone, intensity of fuel wood extraction appears much greater in the northern states. Other possible biomass resource base includes aquatic plants such as water hyacinth and municipal wastes both of which constitute major environmental problems. These present opportunities for meeting energy needs sustainably potential and availability (2) and is generally accomplished through biological, thermal and chemical processes.

3. Transformation of Biomass to usage energy sources

Transformation of biomass and waste materials into a source of energy can be accomplished through biological, thermal and chemical processes. There are four major ways in which biomass is converted into usable energy sources. These are:

i. Fermentation: This involves the conversion of various plants, especially corn using several types of processes to produce ethanol. The two most commonly used process involves using yeast to ferment the starch in plants and using enzymes to break down the cellulose in the plant fibre. Ethanol is used as a fuel source in automobiles.

ii. Burning: Biomass is burned in waste–to–energy plants to produce steam for making electricity or for providing heat for industries and homes.

iii. Bacterial Decay: This involves the process of bacteria feeding on dead plants and animals for methane production. Methane is the main ingredient in natural gas. Methane is produced through many landfills and garbage's; and are used for electricity production.

iv. Conversion: Biomass can be converted into gas or liquid fuels by using chemicals or heat. In India, cow manure is converted to natural gas for electricity production. Methane gas can also be converted to methanol, a liquid form of methane. Renewed interest in biomass energy development is due to several factors, some of which include:

(i) Growing concerns about climate change – biofuels can be carbon – neutral if they are produced in a sustainable way.

(ii) Technological advances in biomass conversion, combined with significant changes in the global energy market.

(iii) Biofuels have the unique characteristics of being the only source of renewable energy that are available in gaseous, liquid and solid states.

(iv) Increasing focus on security of energy supply and

(v) Increasing interest in renewable energy generally.

Bioenergy could in principle provide all the world's energy requirements, but its real technical and economic potential is much lower. The World Energy Council (WEC) survey of energy resources (WEC,2001) estimates that Bioenergy could theoretically provide 2900EJ/yr. of energy, but technical and economic factors limits its current practical potential to just 270EJ/yr. According to the report, the practical potential is limited by several factors which include poor matching between demand and resources, and high costs compared to other energy sources. Benefits of Biomass include reducing air and water pollution, increasing soil quality and reducing erosion, and improving wildlife habitat. Biomass reduces air pollution by reducing carbon dioxide emissions by 90 percent compared with fossil fuels. Sulphurdioxide and other pollutants are also reduced substantially. Biomass energy also makes productive use of crop residues, wood-manufacturing wastes, and the clean portion of urban wastes. These "useless" wastes would otherwise be open-burned, left to rot in fields, or buried in a landfill. Wastes that rot in the field often produce methane, a greenhouse gas even more potent than carbon dioxide. Burying energy-rich wastes in a landfill is like burying petroleum instead of using it.

Water pollution is reduced because fewer fertilizers and pesticides are used to grow energy crops, and erosion is reduced. In contrast to high-yield food crops that pull nutrients from the soil, energy crops actually improve soil quality; since they are replanted only every 10 years, there is minimal ploughing that causes soil to erode.

Finally, biomass crops can create better wildlife habitat than food crops. Since they are native plants, they attract a greater variety of birds and small mammals. They improve the habitat for fish by increasing water quality in nearby streams and ponds. And since they have a wider window of time to be harvested, energy crop harvests can be timed to avoid critical nesting or breeding seasons. In addition to the many environmental benefits, biomass offers many economic and energy security benefits. By growing our fuels at home, we reduce dependence on fossil fuels and the problems associated with disruptions in their supply. Farmers and rural areas will gain a new and valuable outlet for their products and improve the rate of development in the rural areas.

4. Biomass conversion technologies to electricity

While several technologies for generating bioenergy heat and power already exist, there is a need to extend the use of most efficient technologies available today and to complete the development and deployment of a number of new technology options. Biomass can be converted to energy, fuels and products through two main conversion pathways- thermochemical and biochemical conversion pathways. The appropriate conversion technology for a biomass is influenced by factors such as type and quantity of biomass feedstock, the desired form of energy (end –use requirements, environmental standards, economic considerations and project specific factors) (Mckendry, 2002). Also, the biomass conversion efficiency depend on the use, material, size and shape of the particles, gas flow and types of reactors (Pereira et al., 2012). The biomass conversion technology should be tailored to the biomass type to achieve optimum outcomes (Barber and Warnken, 2008). A detailed discussion of each conversion pathway is given below. A number of modern biomass energy technologies (BETs) are currently at different stages of research, development, demonstration and commercialization. The global installed capacity of electricity generation from

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biomass as at 2000 was about 40,000MW (Turkenburg, 2000).

5. Converting Biomass to Electricity: Technical Options

i. Direct Combustion

Direct combustion involves the oxidation of biomass with excess air, giving hot flue gases which are used to produce steam in the heat exchanger sections of the boiler; the steam then turns a turbine, which is connected to a generator that produces electricity, as shown in Figure 1. Biomass can also be co –fired with coal in a boiler (in a conventional power plant) to produce steam and electricity. The majority of biomass electricity is generated by the direct combustion process.

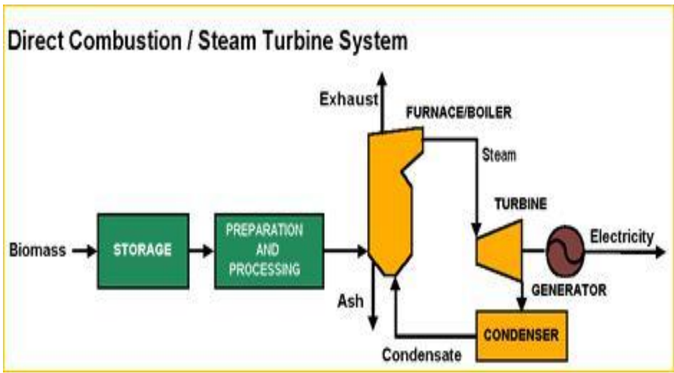

Figure 1: Direct combustion / steam turbine system. (Demirbas, 2008)

ii. Gasification

Gasification for power production involves the devolatization and conversion of biomass in an atmosphere of steam and /or air to produce a medium or low calorific value gas known as producer gas, which is used for power generation. A large number of variables affect gasification – based process design. Three major variables can be identified, these are: gasification medium, Gasifier operating pressure and reactor type. Gasification medium is an important variable. In air – blown or directly heated gasifier, the heat necessary to devolatize the biomass and convert the residual carbon – rich chars is derived by the exothermic reaction between oxygen and the organic material. In these directly heated gasifiers, the heat to drive the process is generated within the gasifier. Indirectly heated gasifiers accomplish biomass heating and gasification through heat transfer from a hot solid or through a heat transfer surface. The second variable affecting gasification – based power systems performance is gasifier operating pressure.

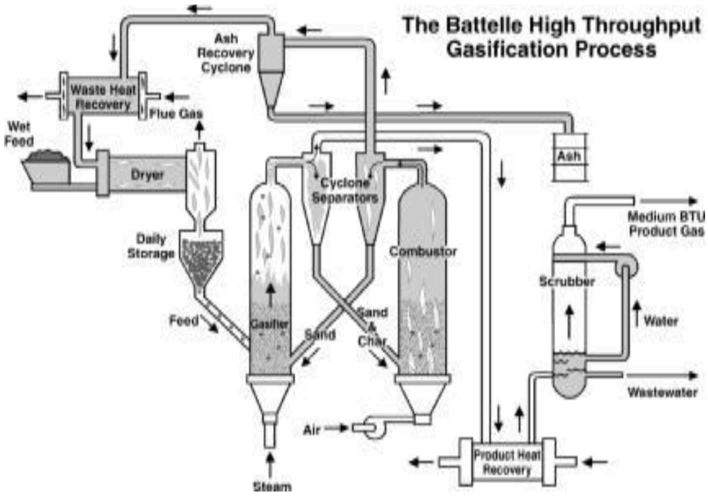

Figure 2: The Batelle Biomass Gasification Process **(Demirbas, 2008)**

iii. Pyrolysis

Pyrolysis is another emerging technology of using biomass for electricity generation. This process involves the conversion of biomass to liquids, gases and char – liquid fuels being the main target. Power generation using this technology is essentially the use of pyrolytic oils for the gas turbine integrated into a combined cycle (Katyal, 2007). Pyrolysis is the burning of solid fuels in the absence of oxygen and is the fundamental chemical reaction process that is the precursor of both the gasification and combustion of solid fuels. Conventional pyrolysis occurs under a slow heating rate. This condition permits the production of solid, liquid and gaseous pyrolytic products in significant portions. This is the process mainly used for the production of charcoal. Slow pyrolysis of biomass is associated with high charcoal content, but the fast pyrolysis is associated with tar at low temperature (675 – 775K), and /or gas at high temperature. However at present, the preferred pyrolysis technology is fast or flash pyrolysis at high temp with very short residence times (Demirbas, 2008). Fast pyrolysis (more accurately defined as thermolysis) is a process in which a material such as biomass is rapidly heated to high temperature in the absence of oxygen, while flash pyrolysis of biomass is the thermochemical process that converts small dried biomass particles into a liquid fuel (bio – fuel or bio – crude) for almost 75%, and char and non - condensable gases by heating the biomass to 775K in the absence of oxygen. Biomass pyrolysis is an attractive option because solid biomass and wastes can be readily converted into liquid products. These liquids, as crude bio – oil or slurry of char or oil, have advantages in transport, storage, combustion, retrofitting and flexibility in production and marketing.

6. Nigerian government policy towards Biomass energy development

The Federal Government of Nigeria sets out its vision, policies and objectives for promoting electricity derived from renewable energy sources in the Policy Guidelines in Renewable Electricity. A study conducted by the Presidential Committee on a 25 year Power development plan developed a projected electricity demand profile for the nation of about 15,000 MW, 30,000 MW and 190,000MW in the short, medium and long terms on the basis of a 10% economic growth rate scenario (Sambo, 2006). A study by the Energy Commission of Nigeria indicated that renewable electricity is expected to contribute about 14, 23 and 36% of the total electricity demand in the short, medium and long terms respectively as dictated by the National Energy Policy (ECN, 2003). There is now a consensus in Nigeria, that renewable energy can play a significant role in the overall energy development of the nation. These views were well articulated in the National Energy Policy (NEP) of the country which was promulgated in August 2002 and further amplified by the Renewable energy Master Plan (REMP) of the country which was developed by the Energy Commission of Nigeria (ECN), in conjunction with the United Nations Development Programme (UNDP) in November 2005.The overall objective of the Renewable Energy Master Plan (REMP) is to articulate a national vision, targets and a road map for addressing key development challenges facing Nigeria through the accelerated development and exploitation of renewable energy. It puts in place a comprehensive framework for developing renewable energy policies, legal instruments, technologies, manpower, infrastructure and market to ensure that the visions and targets are realized. Among other things, the master plan has the following specific objectives:

(i) Expanding access to energy services and reducing poverty, especially in the rural areas, through renewable energy development;

(ii) Stimulating economic growth, employment and empowerment;

(iii) Increasing the scope and quality of rural services, including schools, health services, water supply, information, entertainment and stemming the migration to urban areas;

(iv) Reducing environmental degradation and health risks, particularly to vulnerable groups such as women and children;

(v) Improving learning, capacity building, research and development on various renewable energy technologies in the country; and

(vi) Providing a road map for achieving a substantial share of the national of the energy supply mix through renewable energy, thereby facilitating the achievement of an optimal energy mix.

The master plan sets clear and verifiable national targets in the short, medium and long term. Short term targets will be achieved by the year 2007, medium term targets will be achieved by the year 2015 coinciding with the target year for the MDGs; long term targets are set for 2025, two decades after launching of the REMP. By 2007, the REMP envisages an aggregate electricity demand of 7000MW with new renewable energy (excluding large scale hydro) playing a marginal role. In 2015, the country will likely achieve a doubling of electricity demand to about 14,000MW of which new renewables will constitute about 5% (710MW). In 2025, aggregate electricity demand will increase to 29,000MW with new renewable energy making up 10% of the total energy demand of the country. Small hydro plants will represent over 66% of the entire new renewable energy contributions; solar PV 17%, biomass 14%, wind 1.3% and solar thermal 0.7% (2).

The REMP projects that biomass will be expected to contribute a total of 50MW of electricity in the medium term i.e. 2015 and 400MW in the long term i.e. by 2025. Currently, a lot of research efforts are going on in the area of exploiting biomass energy for electricity production, while substantial research results have been achieved by relevant agencies in the public and private sector in biogas production, the development of improved wood stoves and biomass briquetting technologies (2). The implications of these targets is a rapid scale up of most of the renewable energy technology applications, as the REMP envisions towards the coming decades a nation driven increasingly by renewable energy and this makes the prospects of biomass development for electricity generation very high.

7. Limitations of Bioenergy industry in Nigeria

Challenges of bioenergy in Nigeria include;

(i) Land ownership structure: Bioenergy industry would require large cultivation of energy crops. The current communally ownership of land, with a pocket of private ownerships would pose as hindrance to large scale farming which can affect the availability of raw material for the bioenergy production.

(ii) Lack of Infrastructure: Lack of basic amenities in rural communities would impede the effective development of bioenergy industry.

(iii) Fear of food shortage: There are likely fears that biofuel industry would threaten food security in rural areas.

(iv) Environmental problems: Some communities who are already suffering from pollutions due to the activities of agri- based industries may be exercising fear that bioenergy industry would do the same which may impede its development.

(v) Lack of skilled labour: There would be need for specialized skilled workers in the new bioenergy industry as workers with requisite knowledge which may not be readily available for smooth running.

(vi) Inadequate funds: Cultivation of energy crops requires long term loans and incentives. Presently, the poverty situation in rural areas impedes farmers from getting loans and government incentives are also inadequate thus affecting productivity.

8. Conclusion

The conversion of biomass to energy will be rewarding, given the large availability of the biomass resources in the country. Utilization of bioenergy has not been given serious implementation attention in Nigeria as if the fossil fuel will be continuing forever. It is important for Nigeria to look inward to see that the future generations will not be put at disadvantage through the continued exploitation of fossil resources by exploring alternatives energy sources. The paper has examined the options, benefits, challenges and prospect in Nigeria of using biomass for electricity generation in the country considering particularly the issues of land availability, plant location, scale and choice of technology and distribution of economic benefits.

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