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ELECTRICITY PRODUCTION FROM BIOMASS IN NIGERIA: OPTIONS, PROSPECTS AND CHALLENGES

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ABSTRACT

Biomass power, also called bio power, is electricity produced from biomass fuels. Biomass consists of plant materials and animal products. Biomass fuels include residues from food production and processing, trees and grasses grown specifically as energy crops, and gaseous fuels produced from solid biomass and wastes.

This paper highlights the various biomass materials available in the country and the available technologies that are used for converting biomass to electricity. The paper also highlights the broad policy objectives of government with regards to the development of renewable energy in general and biomass development in particular.

The paper concludes by exploring based on global experiences and best practices, the various options, and their resulting prospects and challenges in producing electricity from biomass. The paper highlighting the fact that though the prospects of using biomass for electricity generation is high; land availability, plant location, scale and choice of technology and distribution of economic benefits are factors that have to be considered in deploying biomass for electricity generation in Nigeria.

Keywords: Energy, Biomass, Electricity production

1.0 Biomass and Bioenergy

Biomass is defined as organic material, available on renewable basis, which are produced directly or indirectly from living organisms without contamination from other substances or effluents. 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 feedstocks available for utilization is very wide. A general categorization can be considered which comprises:

1. **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.
2. **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.
3. **Agricultural Wastes –** This are biomass wastes produced by agricultural farming practices for food production such as straw, bagasse and poultry litter.
4. **Municipal Waste –** This 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,

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commonly known as dRDF (densified Refuse derived Fuel).

5. **Specialized Industrial Wastes –** These are a range 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 et al, 2007).

Table 1: Types of Plant Biomass

Woody Biomass	Non – Woody Biomass	Processed Waste	Processed Fuels
Trees	Energy crops such as sugar cane	Cereal husks and cobs	Charcoal (wood and residues)
Shrubs and Scrub	Cereal straw	Bagasse	Briquetted or densified biomass
Bushes such as coffee and tea	Cotton, cassava, tobacco stems and roots (partly woody)	Wastes from pineapple and other fruits	Methanol and ethanol (wood alcohol)
Sweeping from forest floor	Grass	Palm oil cakes	Plant oils such as palm, rapeseed (canola) and sunflower
Bamboo	Bananas and Plantains	Sawmill waste	Producer gas
Palms	Soft stems, such as those of pulses and potatoes	Industrial wood bark and logging wastes	Biogas
	Swamps and water plants	Black liquor from pulp mills	
		Municipal wastes	

1.1 The Nigerian Biomass Resources

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 acquatic 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 (REMP, 2005) Table 2 shows the total area of Nigeria, distributed among the various uses.

Table 2: Nigeria's Size and land use parameters

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

ISSN2305-8269
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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

Source: (REMP, 2005)

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 m^3 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.

1.2 Bioenergy – Energy from Biomass

Transformation of biomass and waste materials into a source of energy is closely related to biomass potential and availability (Leskoviku, 2006) and is generally accomplished through biological, thermal and chemical processes. There are four major ways in which biomass is converted into usable energy sources. These are:

1. **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.
2. **Burning:** Biomass is burned in waste – to – energy plants to produce steam for making electricity or for providing heat for industries and homes.
3. **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.
4. **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.

In recent times, there has been renewed interest in biomass energy development due to several factors, some of which include:

ISSN2305-8269
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1. Growing concerns about climate change – biofuels can be carbon – neutral if they are produced in a sustainable way.
2. Technological advances in biomass conversion, combined with significant changes in the global energy market.
3. Biofuels have the unique characteristics of being the only source of renewable energy that are available in gaseous, liquid and solid states.
4. Increasing focus on security of energy supply and
5. 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/year of energy, but technical and economic factors limits its current practical potential to just 270EJ/year. 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.

Biomass energy brings numerous environmental benefits—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. Sulphur dioxide 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.

This paper is an exploratory study of the options, prospects and challenges of generating electricity from biomass in Nigeria. The paper is divided into five parts. The first part includes the introduction to biomass and Bioenergy, while the second part discusses various Biomass - to - electricity conversion options. The third part introduces the assessment indicators for evaluating energy conversion processes, while the fourth part evaluates the options, challenges and prospects of developing biomass based power plants in Nigeria. The fifth part concludes.

2.0 Biomass Power

Biopower or biomass power is electricity produced from biomass fuels. Biomass – fired plants have been explored, both in developed and developing countries. For example in India, biomass power – generated capacity of about 302Mw have been commissioned through 54 projects by India's ministry of New and Renewable energy Sources (MNRE, 2009). There are also several biomass – fired and co – fired plants across Europe and America (Wiltsee, 2000). The Energy Information Administration (EIA) in its annual energy outlook of 2002, projected that biomass will generate 15.3 billion kilowatts of electricity or 0.3% of the projected 5,476 billion kilowatts of total generation in 2020 (EIA, 2001). Biopower is a natural fit for the electric power industry and is good for the environment. This is because biomass fuels are renewable, they help reduce greenhouse gas emissions from fossil fuels and make productive use

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www.eaas-journal.org

of crop residues, wood – manufacturing wastes, and the clean portion of urban wastes.

Biomass-based power systems are unique among nonhydro renewable power sources because of their wide range of applicability to a diverse set of needs. Biomass systems can be used for village-power applications in the 10–250 kW scale, for larger scale municipal electricity and heating applications, for industrial application such as hog-fuel boilers and black-liquor recovery boilers, in agricultural applications such as electricity and steam generation in the sugar cane industry, and for utility-scale electricity generation in the 100 MW scale. Biomass-based systems are the only nonhydro renewable source of electricity that can be used for base-load electricity generation.

2.1 Converting Biomass to Electricity: Technical Options

There are basically two modes of utilizing biomass for electricity production. The first is by a dedicated use of biomass, while the second is by co – firing biomass with an existing fossil fuels plant. The technology for the primary direct use of biomass for electricity production is direct combustion, gasification, pyrolysis and biochemical degradation.

2.1.1 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.

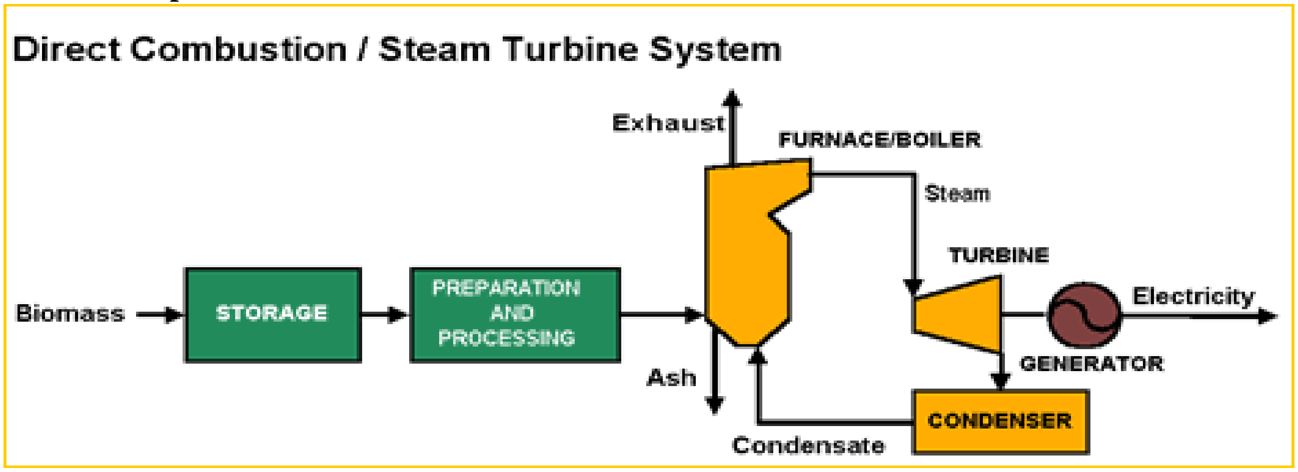

Figure 1: Direct Combustion system

2.1.2 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

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www.eaas-journal.org

through a heat transfer surface. The second variable affecting gasification – based power systems performance is gasifier operating pressure. A pressurized gasifier will produce gas at a pressure suitable for direct turbine application and provide the highest overall process efficiency. Alternatively, the gasifier can be operated at low pressure and the cleaned product gas compressed to the pressure required for gas turbine applications.

The third major variable is reactor type. For biomass gasification four primary types of reactor systems have been developed. These are: Fixed – bed reactors; bubbling fluid – bed reactors; circulating fluid – bed reactors and entrained flow reactors. Gasification reactors operate under the same principles as comparable combustors. Figure 2 shows the Battelle biomass gasification process.

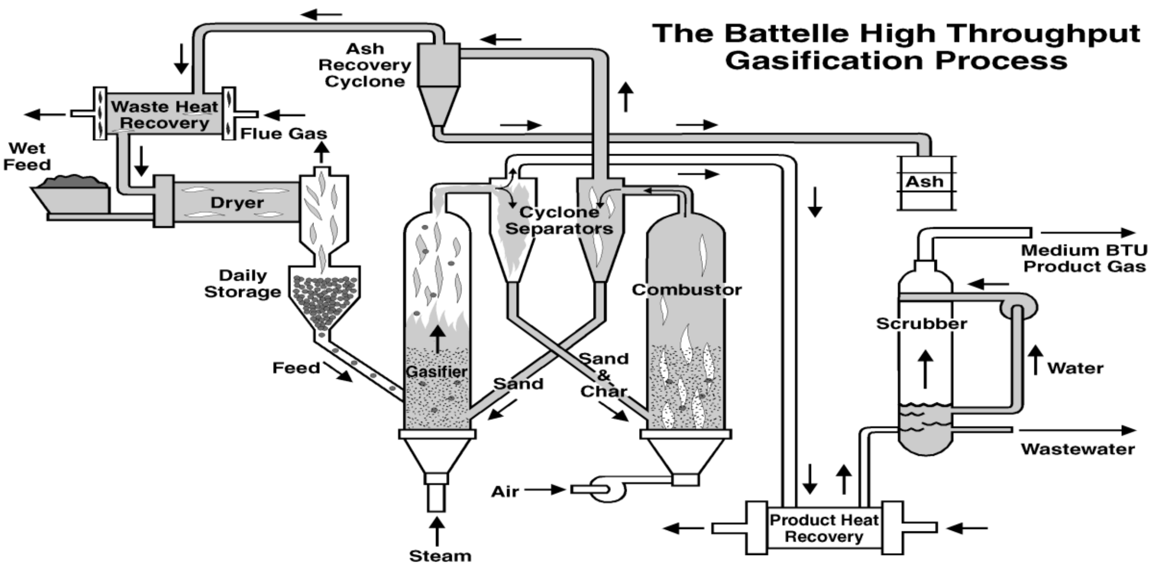

Figure 2: The Batelle Biomass Gasification Process

2.1.3 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. Table 3 shows the main operating parameters for the various pyrolysis processes (Demirbas, 2009).

Table 3: Main Operating Parameters For Pyrolysis Processes

Parameters	Conventional Pyrolysis	Fast Pyrolysis	Flash Pyrolysis
Pyrolytic Temperature (K)	550 – 900	850 – 1250	1050 - 1300
Heat rate (K/s)	0.01 – 1	10 – 200	>1000
Particle Size (mm)	5 – 50	<1	<0.2
Solid residence time (sec)	300 – 3600	0.5 – 10	<0.5

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.

2.1.3 Biochemical Processes

Biochemical processes is another major method of using biomass for electricity generation. This involves the production of biogas for electricity generation and other uses by digesting food or animal wastes in the absence of oxygen, as shown in Figure 3. This process, called anaerobic digestion, will occur in any air tight container containing a mixture of bacteria normally present in animal waste. Different types of bacteria work in sequence to break down complex chemicals, such as fat and protein, into progressively simpler molecules. The final product is a biogas containing methane and carbon dioxide. The biogas can be used for heating or for electricity generation in a modified internal Combustion engine. However, advanced gasification technologies are necessary for converting animal waste to a biogas with sufficient energy to fuel a gas turbine. As seen in Figure 3, the process takes place in three stages and it must be noted that different kinds of micro – organisms are responsible for the process that characterize each stage. Landfills also produce a methane rich biogas from the decay of wastes containing biomass. However, landfill gas must be cleaned to remove harmful and corrosive chemicals before it can be used to generate electricity.

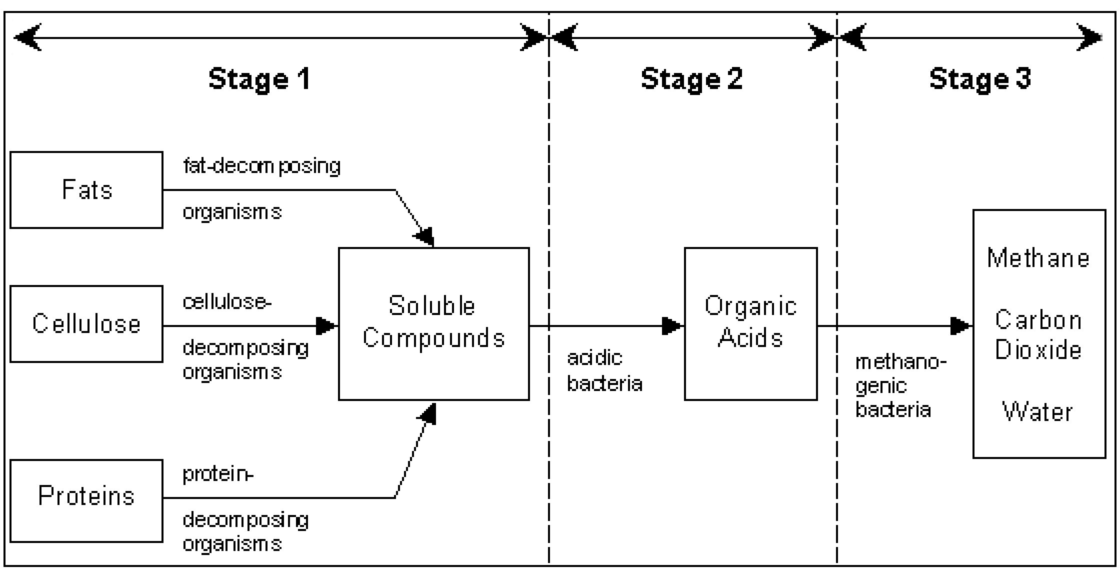

Figure 3: Anaerobic Digestion

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3.0 Assessment Indicators for Evaluating Biomass Energy Conversion Systems

In assessing the options, challenges and prospects of using biomass for electricity production, five major indicators were considered. These are the Political, Economic, Environmental, Technological and Social indicators.

3.1 Political Indicator

The Political indicator refers to the political will and determination of the Nigerian government to formulate and implement policies and programmes that will lead to project conception, implementation and development of biomass – based power production.

3.2 Economic Indicator

The Economic indicator comprises the economic assessment of the energy system; among those are: efficiency, electricity cost and investment cost. The efficiency of the system is considered as the integral parameter which reflects the performance of the system as thermodynamic system. The electricity cost sub-indicator represents the total energy cost and is a measure of the quality of the system. The investment cost comprises material cost, design and construction cost of the system.

3.3 Environmental Indicator

The environment indicator has become a governing parameter in the evaluation of energy system. Among the Green House Gases the CO_2 concentration in flue gases of the power plant is the most important characteristic for the environment assessment of energy system (Bain *et al.* 2003). The CO2 cycle in utilization of biomass shows one of the main advantages of the biomass system in power plant systems. NO*x* and SO*x* concentration in flue gas is contributing to the adverse effect of the utilization of biomass. For this reason, the evaluation of concentration of these gases in the biomass energy system is of primary interest for the quality assessment of the biomass energy system.

3.4 Technological Indicator

Renewable technologies include modern biomass, solar, wind, hydro and geothermal technologies. The R&D data for the development of renewable technologies are not well defined because there is no universally accepted definition of R&D. The technological indicator comprises two sub-elements: Development Capital and Market elements. The Development capital sub-indicator is determined by the amount of research and development going on in the development of biomass – based power plants, while the market segment is based on the forecast of energy consumption in the period of the next 50 years.

3.5 Social Indicator

Currently, it is becoming very urgent to take into consideration the social aspect in the evaluation of power plants. In this respect, in this analysis, the following social sub-indicators are taken into consideration: New Job opportunity, Area required and Health effect on the surrounding population. The New Job sub-indicator comprises the number of jobs to be open per unit MW (World Energy Council 2000). The high requirement for the area to be used for the construction of a power plant is imminent for any power generation system. In this evaluation, the health parameter is derived from the NO*x* concentration in the surrounding of the power plant.

4.0 Evaluation of Biopower in Nigeria

4.1 Prospects

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,

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infrastructure and market to ensure that the visions and targets are realized. Among other things, the master plan has the following specific objectives:

1. Expanding access to energy services and reducing poverty, especially in the rural areas, through renewable energy development;
2. Stimulating economic growth, employment and empowerment;
3. Increasing the scope and quality of rural services, including schools, health services, water supply, information, entertainment and stemming the migration to urban areas;
4. Reducing environmental degradation and health risks, particularly to vulnerable groups such as women and children;
5. Improving learning, capacity building, research and development on various renewable energy technologies in the country; and
6. 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% (REMP, 2005).

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 (Sambo. 2007)

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.

4.2 Options

With respect to selecting the best options in technology for the development of Biopower, the country has to be guided by best global practices and the experience of other countries in this area. Currently .With prices ranging from 7.5 to 16.4 c/kWh and an average price of 6.9 c/kWh, biomass power production is not cost effective at present, where fossil fuel technologies are available for an average of 4.2–4.8 c/kWh (Evans et al, 2009). However, according to Sa´ez et al, 1998; when externalities, such as human health, soil erosion, etc. are included, the total price of biomass is cheaper than coal.

Hatje and Ruhl, 2000; state that biomass is the most profitable renewable energy source after hydropower, with respect to total energy and carbon reduction costs. Comparing to the median electricity costs of the remaining renewable electricity technologies shown by Evans et al, 2009; biomass is cheaper than photovoltaic (24 c/kWh), approximately equal with geothermal (6.8 c/kWh) but more expensive than wind (6.6 c/kWh) and hydro (5.1 c/kWh). Investment costs for biomass to energy conversion exceed other thermal technologies by a factor of 3–4 due to higher processing volumes and increased handling requirements. The capital intensive nature of biomass technology can deter investment. Also, financing biomass plant construction can be complicated because many conversion technologies are still in pilot scale (Clean Energy Council, 2008).

When selecting between different technologies, combustion based technologies are more profitable over their life cycle than gasification and pyrolysis, despite higher operating costs (Caputo et al, 2005). Capital costs for direct combustion are around $1.9–2.9/kW. For pyrolysis, costs are much higher at $3.5–4.5/kW, making it one of the most capital intensive electricity generation technologies (Yoshida et al, 2003), comparable with nuclear.

Efficiencies of energy conversion from biomass also vary widely across different technologies. This is an area under intense development, with many new, highly efficient technologies emerging. Table 3 summarizes efficiencies found in literature; the Table shows that average efficiencies stands at about 27%, with combined cycle gasification processes showing the greatest efficiencies of up to 43% (Gustavsson, 2003).

According to most authors, electricity generation from biomass produces low net carbon emissions, mostly in the form of carbon dioxide, as shown in Table 4. Other greenhouse gases, such as methane and nitrous oxide are emitted in smaller amounts (2% or less of total emissions Wihersaari, 2005). Where emissions include methane and nitrous oxide, figures are reported as carbon dioxide equivalent, or CO2eq. The average carbon emission in Table 4 is 62.5 gCO2/kWh. The highest emission, 132 gCO2eq/kWh (Styles and Jones, 2007) is less than one third of the lowest natural gas and one fifth of the lowest coal fired power station emissions proven at present. Wihersaari, 2005 calculated the minimum greenhouse gas reduction when substituting biomass in the place of fossil fuels at 74%, up to a maximum of 98%.

Table 3: The Efficiency of energy Conversion from Biomass to Electricity

Author/s	Year	Efficiency %	Comment
Craig and Mann	1996	35.4 – 39.7	Gasifier
Gustavsson	1997	36	Combustion
Faaij et al	1997	35.4 – 40.3	Gasifier
Bain et al	1998	35	
Stahl and Neergaarf	1998	32	Gasifier
Chum and Overend	2001	17.2	Gasifier
Berndes	2001	20 – 25	combustion
Ganesh and Banerjee	2001	26	Combustion
Ganesh and Banerjee	2001	40	Combustion
Ganesh and Banerjee	2001	28	Gasifier
Ganesh and Banerjee	2001	31	Pyrolysis
Bain and Overend	2002	20	
IEA Bioenergy	2002	25	5 – 10 MW
McKendry	2002	30	Gasifier
Gustavsson and Madlener	2003	30	Combustion
Gustavsson and Madlener	2003	43	Combustion
La Cour Jansen	2003	24	
Yoshida et al	2003	19 – 26	Combustion
Yoshida et al	2003	16 – 30	Gasifier
Benetto et al	2004	22	
Corti and Lombardi	2004	35	Gasifier
Siewert et al	2004	35	Foster Wheeler, high efficiency

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Franco and Giannini	2005	15 – 30	Small to large depends on steam temperature
Ahrenfeldt et al	2006	25	Wood to electricity
WEC	2007	20	

Source: Evans et al, 2009

Table 4: Full Life Cycle Carbon Dioxide Emissions from Biomass Power Production

Author/s	Year	gCO_2/kWh	Comment
Faaij et al	1998	24	
Norton	1999	30 – 40	
Gustavsson and Madlener	2003	48	Steam turbine
Gustavsson and Madlener	2003	37	CC
Chatzimouratidis and Pilavachi	2007	58eq	
Styles and Jones	2007	131eq	miscanthus
Styles and Fones	2007	132	SRC willow

*eq denotes CO_2 equivalent in these values, soutce: A. Evans et al, 2009.

4.3 Challenges

Even though the prospects are high, the following broad factors have to be considered in using biomass for electricity production.

4.3.1 Land Availability

Growing biomass for electricity production on a significant scale consume both land and labour. Land use in particular is a key issue in the production of Bioenergy resources, because using land for energy crops means that less land is available to grow crops. Thus it is imperative to ensure that sufficient cropland is available to produce food for the rapidly growing Nigeria's population, taking into consideration that biomass energy can help enhance development and food production.

Bioenergy production for electricity purposes can be a way to rehabilitate marginal and degraded land and bring it back into profitable use. This will only happen, however, if it is supported by policy. Without policy, there is danger that Bioenergy production will seek good land, where yields are higher and so compete directly with food production. However, in places where there is almost no spare land that could be used for bioenergy agro forestry, efficient energy conversion technologies and the use of agricultural waste could create significant amount of bioenergy for electricity production.

4.3.2 Biomass Plant Location

Since biomass is a low energy density fuel, the biomass conversion facility should be located near the source of the bioenergy to avoid high transport cost. Also measures have to be put in place to protect small farmers near such a plant. However, this consideration must be considered along with the benefits of sighting such a plant such as increased rural employment at all skilled levels, a secure market for agricultural production and the provision of cheap indigenous supplies of energy.

4.3.3 Scale and choice of Technology

The biomass conversion facility should be evaluated based on both the number of acres that can be treated and the demonstrated capacity to sustain this treatment over the duration necessary to amortize biomass facility investment. Also the biomass project should demonstrate a collaborative multi – stakeholder commitment for developing ecologically defensible strategies.

The choice of technology for biomass conversion should be based on demonstrated minimum efficiency of at least 35% or higher. The facility should be able to capture and reuse of otherwise wasted losses. The projects should demonstrate that they are capable of being economically self – sustaining in current and anticipated markets. The selection of technology for biomass conversion should consider minimum investment risk and maximum financial returns; consideration should also be given for at least a part of the project being funded by local investment, because biomass projects represent an important opportunity for building local capacity and local economic assets. This should not however lead to selection of antiquated biomass technology systems, though reliable but are less efficient and often have high level of pollutant emissions.

4.3.4 Distribution of Economic Benefits

Most biomass facilities require harvesting operations, sometimes using highly mechanized operations often conducted by non – local contractors. Thus the value of economic activity should be geared towards sharing the benefits of the economic activity with the objective of a high value/high return community based approach. Projects which can demonstrate the highest contribution to local economic development in disadvantaged areas should be encouraged.

The creation of local economic value is substantially affected by the degree to which value – added enterprises are integrated with biomass utilization facilities. Proposals which develop or encourage co – location of value – added enterprises with biomass facilities will generate significant greater economic value while reducing the local demand on resources.

5.0 Conclusion

Biomass energy represents a veritable renewable energy source for electricity generation. The paper has examined the options, prospects and challenges 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.

References

1. Bain RL, Overend RP, Craig KR. Biomass-fired power generation. Fuel Process Technol 1998; 54:1–16.
2. Ganesh A, Banerjee R. Biomass pyrolysis for power generation a potential technology. Renew Energy 2001; 22:9–14.
3. IEA Bioenergy. Sustainable production of woody biomass for energy; 2002, available from http://www.ieabioenergy.com/library/157_PositionPaper- Sustainable Production of Woody Biomass for Energy.pdf accessed 1/11/2009.
4. Thornley P. Increasing biomass based power generation in the UK. Energy Policy 2006; 34: 2087–99.
5. Goor F, Davydchuk V, Ledent JF. Assessment of the potential of willow SRC plants for energy production in areas contaminated by radionuclide deposits: methodology and perspectives. Biomass Bioenergy 2001; 21:225–35.
6. McKendry P. Energy production from biomass. Part 1. Overview of biomass. Bioresour Technol 2002;83:37–46.
7. Tampier M, Smith D, Bibeau E, Beauchemin PA. Stage 2 report: life-cycle GHG emission reduction benefits of selected feedstock-to-product threads. Identifying Environmentally Preferable Uses for Biomass Resources; 2004.
8. Abbasi SA, Abbasi N. Likely adverse environmental impacts of renewable energy sources. Appl Energy 2000;65 :121–44.
9. McCarl BA, Adams DM, Alig RJ, Chmelik JT. Competitiveness of biomass-fueled electrical power plants. Ann Oper Res 2000; 94:37–55.
10. Heller MC, Keoleian GA, Volk TA. Life cycle assessment of a willow Bioenergy cropping system. Biomass Bioenergy 2003;25:147–65.
11. Clean Energy Council (CEC). Australian bioenergy roadmap: setting the direction for biomass in stationary energy to 2020 and beyond; 2008.
    A. Evans et al. / Renewable and Sustainable Energy Reviews 14 (2010) 1419–1427 1425

12. Clean Energy Council (CEC). Biomass resource appraisal; 2002.
13. Strezov V, Evans T, Hayman C. Thermal conversion of elephant grass (Pennisetum Purpureum Schum) to biogas, bio-oil and charcoal. Bioresour Technol 2008;99: 8394–9.
14. Hoogwijk M, Faaij A, de Vries B, Turkenburg W. Exploration of regional and global cost-supply curves of biomass energy from short-rotation crops at abandoned cropland and rest land under four IPCC SRES land-use scenarios. Biomass Bioenergy 2009;33: 26–43.
15. Koh MP, Hoi WK. Sustainable biomass production for energy in Malaysia. Biomass Bioenergy 2003;25 :517–29.
16. Alonso-Pippo W, Luengo CA, Koehlinger J, Garzone P, Cornacchia G. Sugarcane energy use: the Cuban case. Energy Policy 2008; 36:2163–81.
17. Bain RL, Overend RP. Biomass for heat and power. For Prod J 2002; 52:12–9.
18. Bakos GC, Tsioliaridou E, Potolias C. Technoeconomic assessment and strategic analysis of heat and power co-generation (CHP) from biomass in Greece. Biomass Bioenergy 2008;32 :558–67.
19. Blanco MI, Azqueta D. Can the environmental benefits of biomass support agriculture? The case of cereals for electricity and bioethanol production in Northern Spain. Energy Policy 2008;36:357–66.
20. Braunbeck O, Bauen A, Rosillo-Calle F, Cortez L. Prospects for green cane harvesting and cane residue use in Brazil. Biomass Bioenergy 1999;17: 495– 506.
21. Bridgwater AV. The technical and economic-feasibility of biomass gasification for power generation. Fuel 1995; 74:631–53.
22. Bridgwater AV, Toft AJ, Brammer JG. A techno-economic comparison of power production by biomass fast pyrolysis with gasification and combustion. Renew Sust Energy Rev 2002;6:181–248.
23. Craig KR, Mann MK. Cost and performance analysis of biomass-based integrated gasification combined-cycle (BIGCC) power systems. National Renewable Energy Laboratory; 1996.
24. Elliott P. Biomass-energy overview in the context of Brazilian biomass-power demonstration. Bioresour Technol 1993;46:13–22.
25. Faaij A, Meuleman B, Turkenburg W, van Wijk A, Bauen A, Rosillo-Calle F, et al. Externalities of biomass based electricity production compared with power generation from coal in the Netherlands. Biomass Bioenergy 1998; 14:125–47.
26. Faaij A, van Ree R, Waldheim L, Olsson E, Oudhuis A, van Wijk A, et al. Gasification of biomass wastes and residues for electricity production. Biomass Bioenergy 1997;12:387–407.
27. Fung PYH, Kirschbaum MUF, Raison RJ, Stucley C. The potential for Bioenergy production from Australian forests, its contribution to national greenhouse targets and recent developments in conversion processes. Biomass Bioenergy 2002; 22:223–36.
28. Gustavsson L, Madlener R. CO2 mitigation costs of large-scale Bioenergy technologies in competitive electricity markets. Energy 2003; 28: 1405–25.
29. Hamelinck CN, Suurs RAA, Faaij APC. International bioenergy transport costs and energy balance. Biomass Bioenergy 2005;29: 114–34.
30. Kumar A, Cameron JB, Flynn PC. Biomass power cost and optimum plant size in western Canada. Biomass Bioenergy 2003;24: 445–64.
31. Kumar A, Flynn P, Sokhansanj S. Biopower generation from mountain pine infested wood in Canada: an economical opportunity for greenhouse gas mitigation. Renew Energy 2008; 33:1354–63.
32. McKendry P. Energy production from biomass. Part 3. Gasification technologies. Bioresour Technol 2002;83 :55–63.

33. Siewert A, Niemela¨ K, Vilokki H. Initial operating experience of three new high efficiency biomass plants in Germany. In: PowerGen Europe Conference 2004; 2004.

34. Dornburg V, Faaij APC. Efficiency and economy of wood-fired biomass energy systems in relation to scale regarding heat and power generation using combustion and gasification technologies. Biomass Bioenergy 2001; 21:91– 108.

35. Sa´ez RM, Linares P, Leal J. Assessment of the externalities of biomass energy, and a comparison of its full costs with coal. Biomass Bioenergy 1998; 14:469 – 78.

36. Hatje W, Ruhl M. Use of biomass for power- and heat-generation: possibilities and limits. Ecol Eng 2000;16:41–9.

37. Evans A, Strezov V, Evans TJ. Assessment of sustainability indicators for renewable energy technologies. Renew Sust Energy Rev 2009;13 :1082–8.

38. Caputo AC, Palumbo M, Pelagagge PM, Scacchia F. Economics of biomass energy utilization in combustion and gasification plants: effects of logistic variables. Biomass Bioenergy 2005;28 :35–51.

39. Yoshida Y, Dowaki K, Matsumura Y, Matsuhashi R, Li D, Ishitani H, et al. Comprehensive comparison of efficiency and CO2 emissions between biomass energy conversion technologies—position of supercritical water gasification in biomass technologies. Biomass Bioenergy 2003;25:257–72.

40. Stucley CR, Schuck SM, Sims REH, Larsen PL, Turvey ND, Marino BE. Biomass energy production in Australia: status, costs and opportunities for major technologies. Rural Industries Research and Development Corporation (RIRDC); 2004.

41. McIlveen-Wright DR, Williams BC, McMullan JT. A re-appraisal of wood-fired combustion. Bioresour Technol 2001;76:183–90.

42. Ahrenfeldt J, Henriksen U, Jensen TK, Gobel B, Wiese L, Kather A, et al. Validation of a continuous combined heat and power (CHP) operation of a two-stage biomass gasifier. Energy Fuel 2006; 20:2672–80.

43. Benetto E, Popovici E-C, Rousseaux P, Blondin J. Life cycle assessment of fossil CO2 emissions reduction scenarios in coal-biomass based electricity production. Energy Convers Manage 2004;45:3053–74.

44. Berndes G, Azar C, Ka˚ berger T, Abrahamson D. The feasibility of large-scale lignocellulose-based bioenergy production. Biomass Bioenergy 2001;20: 371–83.

45. Chum HL, Overend RP. Biomass and renewable fuels. Fuel Process Technol 2001;71: 187–95.

46. Corti A, Lombardi L. Biomass integrated gasification combined cycle with reduced CO2 emissions: performance analysis and life cycle assessment (LCA). Energy 2004;29: 2109–24.

47. Franco A, Giannini N. Perspectives for the use of biomass as fuel in combined cycle power plants. Int J Therm Sci 2005;44: 163–77.

48. Gustavsson L. Energy efficiency and competitiveness of biomass-based energy systems. Energy 1997; 22: 959–67.

49. la Cour Jansen J. Toxicity of wastewater generated from gasification of woodchips 2003. Lunds Tekniska Hogskola Lunds Universitet 2003.

50. McKendry P. Energy production from biomass. Part 2. Conversion technologies. nBioresour Technol 2002;83:47–54.

51. Stahl K, Neergaard M. IGCC power plant for biomass utilisation, Va¨rnamo, Sweden. Biomass Bioenergy 1998;15: 205–11.

52. World Energy Council. 2007 survey of energy resources; 2007.

53. Vande Walle I, Van Camp N, Van de Casteele L, Verheyen K, Lemeur R. Shortrotation forestry of birch, maple, poplar and willow in Flanders (Belgium). II. Energy production and CO2 emission reduction potential. Biomass Bioenergy 2007;31: 276–83.

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54. Matthews RW. Modelling of energy and carbon budgets of wood fuel coppice systems. Biomass Bioenergy 2001; 21:1–19.

55. Lettens S, Muys B, Ceulemans R, Moons E, Garcia J, Coppin P. Energy budget and greenhouse gas balance evaluation of sustainable coppice systems for electricity production. Biomass Bioenergy 2003; 24:179–97.

56. Matthews R, Robertson K. Answers to ten frequently asked questions about bioenergy, carbon sinks and their role in global climate change. Greenhouse Gas Balances of Biomass and Bioenergy Systems; 2005 [IEA Bioenergy Task 38].

57. Mann MK, Spath PA. Summary of life cycle assessment studies conducted on biomass, coal, and natural gas systems. In: Milestone Report for the U.S. Department of Energy's Biomass Power Program Systems Analysis Task Milestone Type C (Control); 2000.

58. Chatzimouratidis AI, Pilavachi PA. Objective and subjective evaluation of power plants and their non-radioactive emissions using the analytic hierarchy process. Energy Policy 2007; 35: 4027–38.

59. Norton B. Renewable electricity—what is the true cost? Power Eng J 1999;13:6–12.

60. Styles D, Jones MB. Energy crops in Ireland: quantifying the potential life-cycle greenhouse gas reductions of energy-crop electricity. Biomass Bioenergy 2007;31: 759–72.

61. Wihersaari M. Greenhouse gas emissions from final harvest fuel chip production in Finland. Biomass Bioenergy 2005;28: 435–43.

62. Balat M. Electricity from worldwide energy sources. Energy Source Part B 2006;1: 395–412.

63. Edmonds J, Wise M, Dooley J, Kim S, Smith S, Runci P, et al. Global energy technology strategy—addressing climate change. Battelle Memorial Institute; 2007.

64. St Clair S, Hillier J, Smith P. Estimating the pre-harvest greenhouse gas costs of energy crop production. Biomass Bioenergy 2008;32: 442–52