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The Prospects and Challenges of Waste Wood Biomass Conversion to Bioelectricity in Nigeria

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Abstract

Nigeria is challenged with the twin problems of solid waste management and insufficient power generation. Becasuse of the lack of better management approaches, wood wastes particularly sawdusts are variously disposed of along road sides and rivers, abandoned at the sawmills or openly combusted. These practices negatively impact humans in addition to the loss of useful energy into the environment. The Federal Government of Nigeria therefore plans to install two 1 MWe waste wood biomass to electricity plants in Nigeria. But Nigeria has no previous experience in the operation of a wood gasification power plant. Hence, the aim of this paper is to highlight the prospects of wood gasification and their potential challenges and suggest ways of handling these barriers.

Key words: Bioenergy, biopower, gasification, green electricity, renewable energy, wastes-to-power, sawdust

Introduction

Wood wastes abound in Nigeria owing to the activities of saw millers. The saw millers typically cut wood (logs) from the forest, transport them to their mills and saw the wood into lumbers of various dimensions. In the process, saw dust and other wood waste such as wood bark, slab, log-ends etc. are produced. And because of lack of better ways of handling these wood wastes, they are commonly disposed without treatment into the environment, where they cause environmental impacts. Common disposal methods including heaping/abandonment at the mills, open air combustion, disposal along roadside and water bodies. Abandonment of saw dust at the saw mills causes aesthetic impacts while abandonment along the road side causes air quality impact as a result of wind which often blows and suspends the wood dusts into the atmosphere. This practice could cause respiratory problem in human. The open air combustion of saw dust often causes air pollution with the release of CO_2, smoke, NO_x etc. and loss of potentially useful energy into the environment. Many saw mills especially those located at the banks of rivers particularly in Ogun, Lagos, Edo, Delta, Bayelsa, and Rivers states often disposed waste wood into water bodies. Arimoro et al (2007) reported that saw wood waste negatively impact the quality of the receiving waters with parameters such as dissolved

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oxygen, BOD, phosphate, nitrate, transparency and conductivity being significantly different from background values. Such alteration in the physico-chemical properties of the water was also reported to cause alterations in the distribution and abundance of fish species in the water. Similarly, Nwankwo (1998) reported the wood waste affect diatom population in Lagos. In nature, sawdust degrades slowly releasing methane and CO_2 into the atmosphere, thus contributing to climate change.

On the other hand, electricity supply in Nigeria is inadequate and unstable. Blackouts and brownouts are common features of electricity supply in Nigeria (Adenikinju, 2003). As at 2005, the name plate capacity for electricity generation in Nigeria is 6500 MW (Ibitoye and Adenikinju 2007). However, due to several reasons including poor maintenance, ageing equipment, lack of fund, etc the plants are operated at sub-optimal levels. While Ibitoye and Adenikinju (2007) reported that only 3959 MW electricity is actually generated, Ikeme and Ebohon (2003) reported between 1500–2500 MW. Because energy is a pre-requisite for development, the lack/ slow development in Nigeria is linked to the poor electricity situation. Hence, the government of President Goodluck Jonathan has declared an emergency in the power sector. The government is determined to revolutionize the energy sector by diversifying the energy sources. Nigerian electricity is mostly sourced from petroleum i.e. oil and gas (64.6%) hydro power (35.6%) and to a lesser extent coal (0.4%) (Ikeme and Ebohon, 2005). Now the Federal Government wants to explore other sources of energy and also increase the renewable energy share of the nation's energy. The Federal Government and the private sector has commenced the installations of wind electricity, production of green electricity from emerging bio-ethanol plants (Ohimain 2010a, 2010b)| and planned to install waste wood biomass to electricity plant.

The extent of the problem caused by wood wastes in Nigeria is widespread. Kehinde (2009) reported that 50% of the saw log is wasted during processing in Nigerian sawmills. There are about 44 saw mills in Abeokuta alone generating about 2288 m^3 of wood waste daily, which averaged 52 m^3 $mill^{-1}$ day^{-1} (Aina 2006). A study shows that about 12 – 30 logs of wood are converted to lumber per day in Ogun State (Aina et al 2005). A breakdown of wood waste shows that about 20.64%, 10.28%, 7.3% and 6.31% comprise of slabs, saw dust, wane and bark respectively (Izekor and Kalu 2008). And with about 2000 saw mills in the country, the total volume of wood waste sum up to 104,000 m^3 day^{-1}. Using 312 working days in a year i.e. including Saturdays, the total volume of waste wood generated per annum is 32.45 million cubic metres. Since saw dust has a bulk density of 160 kg m^3 (Francescato et al., 2008), it is therefore estimated that the total mass of waste wood generated in Nigerian sawmills is 5.2 million tonnes $year^{-1}$. Though, Sambo (2009) estimated that Nigeria has sawdust resources of 1.8 million tonnes. This quantity is enormous.

Meanwhile, waste particularly wood waste can be converted to wealth through the production of mushroom production (Adejoye and Fasidi, 2009), chemicals (Balat et al., 2009), enzymes

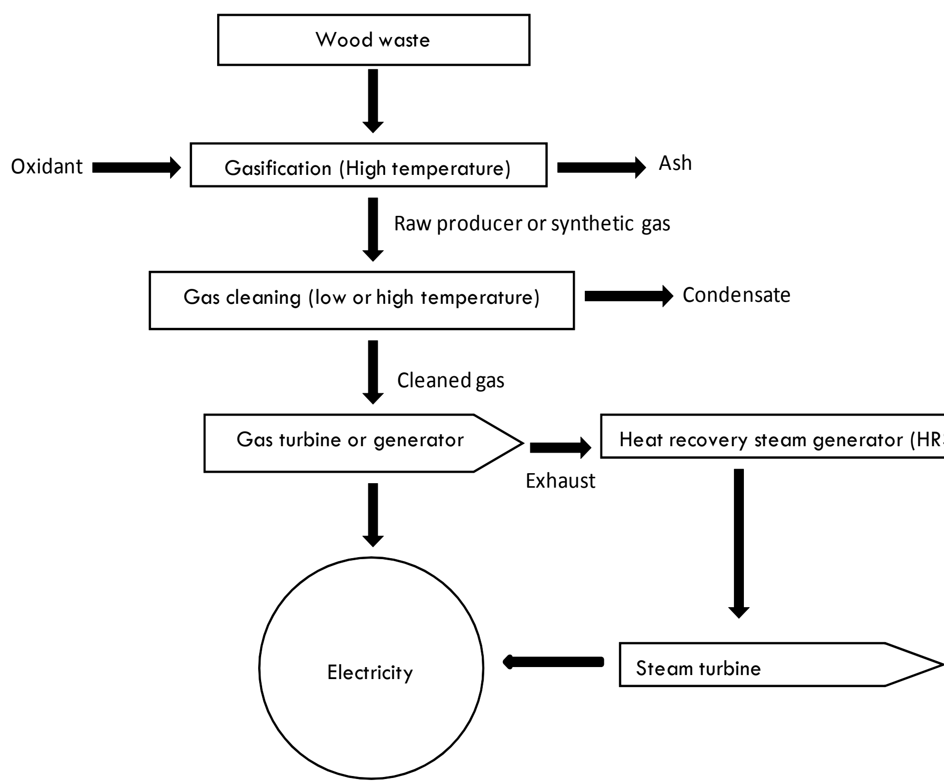

Figure 1. Integrated biomass gasification combined cycle.

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(Isikhuemhen and Mikiashivili, 2009), wood briquettes (Adegoke, 2006), charcoal (Dionco-Adetayo, 2001), electricity (Chang et al., 1999; Haq, 2002) and liquid biofuels especially methanol and ethanol (Zhang, 2009). By utilizing wood waste for energy purposes has several advantages, namely it prevent environmental pollution, produce useful energy, and generate both income and employment. It will also permit the diversification of Nigeria energy mix while increasing the renewable share of the nation's energy in compliance with the Kyoto protocol. Because of the aforementioned advantages, Nigeria plans to establish a 1 MW wood gasification plant at Odogbolu, Ogun State and Pategi, Niger State and has invited companies' to submit bids for the proposed project. Meanwhile, Nigeria has not got any experience in the installation and operation of a wood gasification power plant. Hence, the aim of this paper is to present the prospects and potential challenges of waste wood biomass conversion to electricity in Nigeria.

Prospects of Wood Waste Gasification for Power Production

Nigeria wood waste energy potential is huge. Only a small fraction of the wood waste is used as fuel wood for cooking especially in the rural areas. Biomass gasification therefore offers a credible alternative for the utilization of wood waste for the production of power, heat and biofuels. The use of biomass to generate heat and power is crucial in achieving energy independence and increasing the use of renewable energy sources, thus increasing the renewable share of the nation's electricity mix. In the transition to renewable energy, gasification could play a major role in large part because its products can make use of existing infrastructure and equipment associated with fossil fuel use. Traditionally, electricity is produced from biomass waste by direct biomass combustion producing steam, which drives a steam turbine to generate electricity. This is a common practice in the sugar industries, where bagasse are fired in a boiler producing steam for driving steam turbine for electricity production. It has been widely reported that the efficiency of direct biomass combustion to electricity is quite low in the order of 25%, but with biomass gasification technology efficiencies in the range of 40–50 % have been variously reported (Chang et al; 1999; Balat 2008; OECD/IEA, 2007; Demirbas, 2001; Tsai et al 2004). Ohimain (2010c) recently reviewed the available technologies for the conversion of wastes into useful products including electricity, gasoline, ethanol, methanol, biodiesel, dimethyl ether (DME) etc.

Gasification is a thermal treatment of biomass for the production of gas (H_2, CO, CO_2, CH_4) other volatile hydrocarbon) tar (liquid hydrocarbon containing PAHs), char and ash (mineral). The composition of the resulting gas from gasification process is dependent on several factors including the biomass feedstock type, gasifier type (fixed bed, fluidized bed or entrained), oxidant type (pure oxygen, air, CO_2, steam or combination of these) etc. Balat et al. (2009) reported that the composition of produced gas is dependent on wood fuel composition, gasifying medium, operating pressure, temperature, moisture content of the wood fuel and the mode of bringing the reactants together. In integrated gasification combined cycle (IGCC), the resulting gas from the reactor is cleaned and used as fuel to run the gas turbine or generator to generate electricity, while the exhaust or waste heat is recovered by the heat recovery steam generator (HRSG) to produce steam to run a steam turbine for electricity generation (Figure 1).

Globally biomass electricity is emerging as a formidable alternative to fossil based electricity. For instance, in 2000, biomass played a major role among renewable energy sources by providing 48% of the energy coming from renewable energy sources (Haq, 2002). EIA (2002) projected that biomass energy is the largest source of non-hydroelectric renewable generation including cogeneration and co-firing in coal-fired power plants. Electricity generation from biomass is projected to increase from 38 billion kilowatthours in 2000 to 64 billion kilowatthours thus accounting for1% of total electricity supply in 2020. Biomass is considered as one of the key renewable energy resources of the future because of its large potential economic benefit and environmental advantages. As at 1990, biomass is the fourth largest sources of energy in the world, accounting for about 13% of primary energy use (Hall, 1997).

Table 1. Global bio-electricity production by country between 1995 and 2005. Source: Balat et al. (2009).

Country	1995	2002	2003	2004	2005
USA	51.30	54.00	54.80	55.30	56.30
Germany	2.43	5.76	7.98	9.36	13.44
Finland	6.60	9.80	9.60	10.40	8.90
UK	1.64	5.14	6.21	7.27	8.54
Spain	1.00	2.60	3.20	6.30	7.80
Sweden	2.35	4.18	4.51	7.17	7.45
The Netherland	0.99	2.91	2.56	3.32	5.32
France	1.82	3.22	3.36	3.51	3.45
Denmark	0.80	2.20	2.80	3.20	2.90
Italy	0.22	1.93	2.29	2.66	2.88
Austria	1.84	1.67	1.77	1.91	2.34
Portugal	0.99	1.47	1.39	1.54	1.68
Hungary	0.06	0.04	0.16	0.73	1.66
Poland	0.07	0.43	0.46	0.85	1.51
Belgium	0.32	0.72	0.86	1.04	1.13
Rest of EU total	0.47	0.93	0.85	1.14	0.90
Total EU	21.60	43.00	48.00	60.40	69.90
Brazil	5.60	11.40	12.80	12.80	13.40
Japan	12.10	13.90	14.50	15.00	9.40
Canada	5.50	8.90	8.90	8.70	8.50
Thailand	0.26	2.04	2.26	3.43	3.68
Mexico	-	0.47	2.46	2.52	2.52
China	2.90	2.50	2.50	2.50	2.50
India	-	1.82	1.90	1.90	1.90
Taiwan	-	-	1.84	1.84	1.84
Chile	0.70	1.55	1.70	1.76	1.82
Argentina	0.12	0.88	1.05	1.25	1.49
Australia	0.69	1.54	1.39	1.50	1.12
Rest of the world	4.03	6.20	7.71	7.97	9.03
World total	104.80	148.20	162.20	176.60	183.40

Table 2. Cost comparisons of electric, thermal, and combined heat and power facilities. Source (USDA Forest Products Laboratory, 2004).

	Size (mw)	Fuel use (green ton/yr)	Capital cost (million $)	Operation & maintenance	Efficiency (%)
Electrical					
Utility plant	10 – 75	100,000 – 800,000	20 – 150	2 – 15	18 – 24
Industrial plant	2 – 25	10,000 – 150,000	4 – 50	0.5 – 5	20 – 25
School campus	N/A	N/A	N/A	N/A	N/A
Commercial/institutional	N/A	N/A	N/A	N/A	N/A
Thermal					
Utility plant	14.6 – 29.3	20,000 – 40,000	10 – 20	2 – 4	50 – 70
Industrial plant	1.5 – 22.0	5,000 – 60,000	1.5 – 10	1 – 3	50 – 70
School campus	1.5 – 17.6	2,000 – 20,000	1.5 – 8	0.15 – 3	55 – 75
Commercial/institutional	0.3 – 5.9	200 – 20,000	0.25 – 4	0.02 – 2	55 – 75
Combined Heat and Power					
(CHP)	25 (73)[a]	275,000	50	5 – 10	60 – 80
Utility plant	0.2 -7 (2.9 – 4.4)	10,000 – 100,000	5 – 25	0.5 -3	60 – 80
Industrial plant	0.5 – 1 (2.9 – 4.4)	5,000 – 10,000	5 – 7.5	0.5 – 2	65 – 75
School campus	0.5 – 1 (2.9 – 7.3)	5,000	5	0.5 – 2	65 – 75
Commercial/institutional					

[a] sizes for the CHP facilities are a combination of electrical and thermal; the first figure is electrical and the figure in parentheses is thermal. 1MW = 3.413 million Btu/h.

Wood biomass gasification technology has been commercialized during the Second World War (1939–1945) but because of cheap oil, the applications of wood biomass technology have been limited. However, some countries have installed biomass to electricity plants. The global production of bio-electricity between 1995 and 2005 is presented in Table 1. The USA is topping the list followed by Germany, and Brazil. In the US, there are several independent power plants (IPP) using wood waste as fuel. For instance, a 1 MWe power plant using wood waste was installed in a Marine Corps base in North Carolina (Cleland and Purvis, 1996). In the US, many schools use wood combustion to produce space heat in the range of 1–5 MW (Bergman and Zerbe, 2004). The total biopower generation in the USA in the range of 1–5 MW is about 310 MW. In Brazil, from 1997 – 2004, the amount of electricity generated from biomass sold to the national grid increased from 80–1320 GWh due to the retrofitting energy supplied by only 30 sugar mills from over 300 mills operating in Brazil (Moreiva 2006, 2007). India is one of the countries that have taken giant leaps in biopower generation. As a result of Government promotional incentive and R & D support, gasification technologies have made significant progress in India (Bhatacharya, 2001). From 1995–1996, about 1750 gasifier systems were installed in India. By 1999, the total capacity of biomass gasification electricity was 34 MW (Ministry of Non- Conventional energy (MNES, 2000). By 2004, biomass power, co-generation and gasifiers commissioned in India was 290 MW, 437 MW and 44 MW from 52, 57 and 1817 projects respectively (Abe, 2005). Nigeria therefore plans to join the League of Nations producing bioelectricity using wood as fuel source by installing 1 MW wood gasification electricity power plant in Ogun state and Niger state. Experience gained from the installation and operation of these two plants will either encourage or mar the expansion of biomass to electricity projects in Nigeria. Therefore, the next section of the paper shall focus on possible challenges of bioelectricity projects in Nigeria; options to address these challenges are suggested.

Potential Challenges

There are several possible challenges that could affect the installation and operation of a 1 MW biomass fired electricity plant in Nigeria. First, Nigeria has no previous experience in the installation and operation of biomass plant. Many countries before embarking on biopower had installed pilot/demonstration plants. Experience gained from these demonstration plants were fine-tuned before the installation of full scale plants. Without, this experience, Nigeria will probably purchase and install a turn-key plant. Hence, the country could be faced with the challenges of maintenance. Direct biomass combustion technology is mature but biomass gasification technology though has been commercialized to a limited extent, the technology is still undergoing research, development and demonstration (RD & D) in many countries. We therefore suggest that during procurement phase of the project Nigeria should source for gasifier manufacturers from the list of countries with proven capacity and track records of biomass gasification and biopower production (Table 1).

Another potential challenges is the availability of waste wood feedstock. Typically, about 980 kg per hour of wood waste will be required as feedstock to produce 3.8 MW of thermal energy and 1 MW of electricity, thus, requiring 8,584.8 tonnes of waste wood per year (Schmitt Enertec, 2010). This quantity would not have been a challenge, since the quantity of wood waste production nationwide is 5.2 million tonnes per year. But biomass re-

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sources in the country is not localized or concentrated in a small area. It is widely distributed around the country. Therefore, considerably energy and efforts will be expended gathering wood waste around the country. Fortunately biomass to power support decentralized generation of electricity. Though, two sites (Odogbolu, Ogun state and Pategi, Niger state) have been selected by the Federal Government for the sitting of the biomass gasification plant, we suggest that the Government should also carry out feasibility studies to ascertain the availability of enough feedstock within 30 km radius of the power plant. Also, we suggest that the government should consider the installation of small capacity modules such as 10 units of 100 KW spread close to different clusters of saw mills instead of installing a single unit of 1MW. Note that the smaller units are less energy efficient. Also, during equipment selection, preference should be given to gasifiers that can run on a variety of biomass feedstock apart from wood or sawdust. Gasifiers that are able to run on locally available agricultural residues such as cornstover, rice husk, cassava peels, plantain peels, etc. should be selected.

Another barrier is the issue of cost. All over the world, biomass to electricity projects are expensive to install (Table 2). Though, this appears expensive, but the cost of operation might be very low if the plant is located close to saw mill districts where wood wastes are in excess. The cost of electricity from wood-fired power plants is highly variable ranging from $0.06 (low) to more than $0.11 (high) per kWh (USDA Forest Products Laboratory, 2004). Besides, the biomass plant have other advantages including converting waste to wealth and effectively mitigating methane emissions from abandoned and decomposing wood wastes. The avoided environmental impacts of the project could offset the high costs. Although, the conversions of waste wood to electricity have several environmental benefits, it also has several environmental challenges as well. Biomass gasification results in the production of wastes including char, tar, ash spent catalysts, and other air emission and noise. We suggest that a technology and Environmental Impact Assessment (EIA) should be carried and mitigation measures implemented. There are proven technologies for addressing all these impacts. Equipment selection is very important in addressing most of the impacts. For instance, during equipment selection, gassifiers types such as the circulating fluidized bed (CFB) reactors with proven capability of low tar production should be selected. Also, by using steam or pure oxygen as oxidant in preference to air could increase generational cost, but will reduce emissions and even increase the calorific value of the resulting synthetic gas. Besides, tar crackers could be installed that will effectively handle tars. Chars are also energy sources; they could either be re used or sold. Ash if not contaminated with heavy metals can be an excellent inorganic fertilizer. On the other hand, if the ash is contaminated with heavy metals it could present disposal challenge. Also spent catalyst could be a challenge to handle. Though, catalyst can be reused several times, but when they are spent or poisoned, they have to be changed.

Another potential challenge of biomass electricity plant in Nigeria is lack of policy framework for the effective and sustainable operation of the plant. Now that the Federal Government is venturing into biopower by the installation of two plants, they have to create the enabling policy framework to allow public participation. There should be established power purchase agreement/frameworks. The rates for these agreements should be more favourable than fossil fuel electricity because biomass electricity is renewable and performs additional function of ridding the environment of wastes, thus precluding the associated impacts. There should also be other policy incentives such as tax holidays, tax exemption and waivers, subsidies, grant etc.

Conclusion

The Federal Government of Nigeria wants to join the league of countries producing electricity via biomass gasification. The projects have the added advantages of converting waste wood to power, thereby preventing environment pollution. Waste to wealth processes therefore offer alternative ways of protecting the environment. However other environmental issues and barriers arising from project needed to be adequately addressed for the project to be sustainable.

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