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Potentials of biomass briquetting and utilization: the Nigerian perspective

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Nigeria can reduce its carbon dioxide (CO2) and other greenhouse gas emissions by switchingfrom fossil based to biomass derived fuels. This abundant renewable resource with great potential is currently the most widespread form of renewable energy with comparatively little pollution emissions. Its utilization is further increasing globally due to the concerns over the deleterious effect of the use of fossil fuels on climate change, global warming and on human general well-being. Biomass can be converted into gaseous, liquid and/or solid biofuels as well as other raw chemical materials and products. Among the biomass conversion technologies, biomass briquetting is one of the means that is storable and portable with low heating cost. There is huge biomass briquetting feedstock in Nigeria but the technology and market isgrossly underdeveloped. The gains ofapproving the ratification of the Doha Amendment of the Kyoto Protocol on climate change would help Nigeria attract financial assistance and develop its home-grown technologies for biomass briquetting.In line with that, the present study reviews the different sources of biomass available, biomass briquetting feedstock potentials and the glaring energy paucity. It also highlighted the need for government to provide appropriate policy framework for the growth of the industry.
Keywords: Nigeria, Biomass briquettes, bio-energy, utilization, emissions

Introduction

The growth in the world populationand, as a result, its increase in energy demand, as well as the growing global awareness about the inadequacy of the earth's natural resources, has turned energy into a precious commodity. Renewable energies play a key and unique global role in solving the energy deficit since they are obtained from natural, regenerative sources and they also cause insignificant to no environmental snags, such as environmental change, radioactive waste, acid rain and air pollution [1].

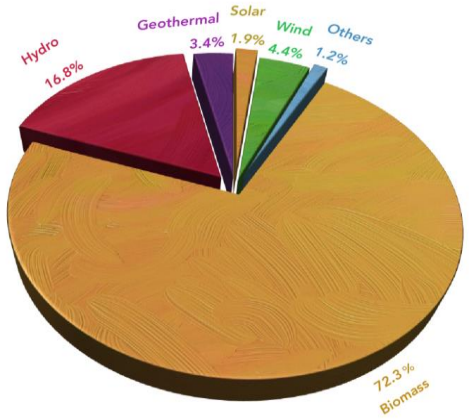

Figure 1: Global renewable energy resources.(Source: [2])

Nigeria, a federal constitutional republic made up of thirty-six (36) autonomous states and a Federal Capital Territory (FCT), Abuja is considered a developing country. It is situated in the sub-Saharan region of West Africa. The country has a land area of 923, 770 km^2 and a population in June 2019 of about 200,705,014 million people [3], growing at an average of 2.54% annually[4]. The economy is largelyreliant on the export of crude oil products and develops at an average of 6% annually. The country is enriched with a tropic rainforest and savanna climate in the south and central belt correspondingly as well as a dry/semi-dry climate in the north [5]. Nigeria, worldwide comes third after China and India as the largest producer of bioenergy. The share of bioenergy of total primary energy supply in 2010 was over 80%[6]. Nigeria along with India, China, Brazil and Ethiopia was among the largest wood fuel producers in 2011.Unfortunately, the total installed electricity capacity generated in Nigeria is 12,522 MW, well below the current demand of 98,000MW . The actual output is about 3,900 MW, resulting in a demand shortfall of 94,500 MW throughout the country.

Table 1: Selected key and compound indicators for Nigeria.

Parameter	Unit	Value	Year
Population	Million	200,705,014	2019
Population growth rate	%	2.54	2018

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GDP (PPP)	Billion USD	1,089.41	2017
GDP	Billion USD	375.75	2017
GDP per capita (PPP)	USD	5,900	2017
GDP growth rate	%	0.8	2017
Total Primary Energy Supply (TPES) by source	Mtoe	149.96	2016
Total Final Consumption (TFC) by source	Mtoe	129.56	2016
Electricity consumption	TWh	26.26	2016
CO_2 emission	$MtCO_2$	104	2016
Unemployment rate	%	23.1	2018
Industrial growth rate	%	11.5	2018
Electricity generation	Billion KWh	30.90	2016

Source: [5], [8], [4].

As a result of this wide gap between demand and output, only 45% of Nigeria's population has access to electricity. Renewable energy contributed 19% of total electricity generated in Nigeria out of which biomass contribution is infinitesimal. On the other hand, biofuels and waste accounted for more than 80% the total energy consumption in Nigeria [8]. With such a huge population and a poor energy output, energy paucity is still a dire issue for Nigeria. The country however has rich energy resources, and its renewables potential can serve as a solution to tackle the power crisis in a viable way [7].This surge in population growth and CO_2 emissions has negative implication on greenhouse gas and the ozone layer. [9]. To further reduce these emissions, switching energy sources to low carbon substitutes such as biomass derived fuels is important. This is apparently so because, biomass at the moment offers the only renewable source of energy that can substitute for fossil fuels as well as reduce CO_2 emissions [10,11]. The huge biomass potential in Nigeria makes the option of exploring such innovative sources of energy as biomass briquetting attractive. This paper therefore hopes to review the potentials of briquetting biomass and its utilization in Nigeria.

Biomass And Biofuels

The European Technical Specification CEN/TS 14588 defines "biomass" as "any biological origin material excluding those that have been embodied in geological formations undergoing a process of mineralization." Biomass energy use is obtained by converting organic chemical energy through five basic processes: combustion, anaerobic digestion, fermentation, gasification and pyrolysis into fuels for transportation, heat and/or electricity. Biomass energy can be converted into liquid, gaseous and solid fuels as well as other feed stocks and products. This is a viable and renewable source of energy with relatively low pollution emissions compared to fossil fuels [12]. Biofuel refers to solid, liquid or gaseous fuel produced by the plant, animal and/or microbial biomass through thermal cracking and/or esterification reactions. Gaseous biomass fuel includes anaerobic digestion (methane production) and biomass gasification. Liquid biomass fuel mostly refers to fuel ethanol and biodiesel produced by bio-mass resources, and can be used to partially replace the petroleum to producegasolineanddiesel. Solid biomass fuel is divided into direct combustion biomass fuel, densified solid bio fuel and fuel mixed biomass with coal.

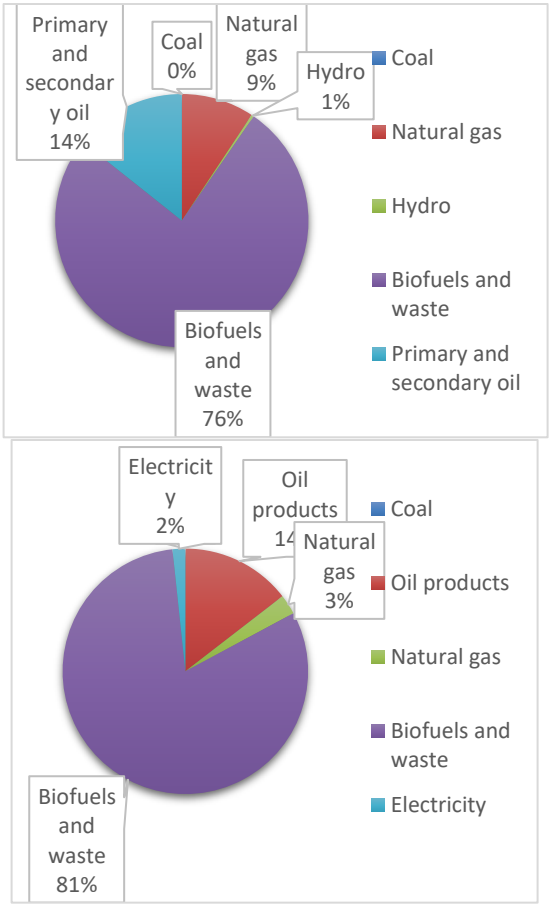

Figure 2: Energy supply by source (left) and consumption (right) in Nigeria. 2016. Source: [8].

Among them, densified solid biofuel has a textensive market and brightprojections [13].

Table 2: Biomass classification: groups, varieties and species [14].

Biomass group	Varieties and species

Wood and woody biomass	Coniferous or deciduous; Angiospermous or gymnospermous; Stems, branches, foliage, bark, chips, lumps, pellets, briquettes, sawdust, sawmill and others from various wood species.
Herbaceous biomass	Grasses and flowers (alfalfa, arundo, bamboo, bana, brassica, cane, cynara, miscanthus, switch grass, timothy, others); straws (barley, bean, flax, corn, mint, oat, rape, rice, rye, sesame, sunflower, wheat, others); other residues (fruits, shells, husks, hulls, pits, pips, grains, seeds, coir, stalks, cobs, kernels, bagasse, food, fodder, pulps, cakes, *etc*.).
Aquatic biomass	Marine or freshwater algae; macroalgae (blue, green, blue-green, brown, red) or microalgae; seaweed, kelp, lake weed, water hyacinth, *etc*.
Animal and human waste biomass	Bones, meat-bone meal; various manures, *etc*.

Solid biofuels are products derived from solid biomass that can be used in direct energy conversion processes, obtained from biomass by generally physical transformations, such as chipping, grinding or drying, as well as densification in the case of briquettes and pellets.

Classification Of Densified Solid Biofuel

Based on the shape, densified solid biofuel can be classified into pellet (small cylinder having diameter of 5–12 mm and length of 10–30 mm), briquette (square section of 30×30 mm^2 and length of 30–80 mm) and hollow rod (generally hexagonal cross-section type, with the diameter of 50–60 mm, length about 500 mm and a 20 mm central-through hole) [10]. Based on source of raw materials, densified solid biofuel can be classified into agricultural wastes (such as corn straw, soybean straw, cotton stalks, peanut shell, rice husk) and forestry wastes (such as wood chips) [12].

Briquettes And Other Commercial Solid Biofuels

Briquette- Briquettes are generally 50-80 mm diameter and 150 mm length sawdust cylinders compacted at a high heat, with a moisture content ranging between 10 to 20%. Other forms which include rectangular or prismatic, are also available, depending on the manufacturer. In some cases, they have holes in order to improve their combustion. Briquettes may be made up of crushed and densified wood or consist of crushed, dried and molded charcoal, under high pressure.

Pellet - It is a type of elongated pelletized fuel, smaller than briquettes, which is manufactured through sawdust pressing, where lignin serves as a binding agent for granules; therefore, there is no need to use any other substance than the wood itself to obtain this product. The pressing process gives the pellets a shiny appearance and makes them denser.

Charcoal- Solid residue derived from wood carbonization, pyrolysis and torrefaction (trunks and branches of trees) from wood by-products, resulting in a solid, fragile and porous fuel with higher calorific value when compared to wood. Its use by mankind goes back to ancient times, practically associated with the use of fire itself.

Firewood - Product resulting from forest intervention and the use of small-sized wood or wood that has features that makes it unsuitable for the timber industry. It is generally used to make simple fires in stoves, fireplaces, and boilers. It is one of the simplest forms of biomass and is mostly used for heating and cooking.

Figure 3: Bio-mass briquettes of various shapes and sizes.

GENERAL CONTEXT FOR BRIQUETTE USE

With reference to the international ISO 17225 Standard, solid biofuels, fuel specifications and classes, a briquette is a "densified biofuel made with or without additives, having a cubic, prismatic or cylindrical shape, with a 25 mm diameter, produced from woody biomass compression or crushed herb." Briquettes are made of ignitable material got from agricultural, forestry waste, or coal powder. Briquettes are produced by the densification of these raw materials. The densification process is mainly composed of two parts: 1. Compaction (reduction of raw material volume) and 2. Sealing (ensuring that the product remains in a stable, compacted state). Current protocols (for example ISO 17225), allow the use of specific additives to boost and retain

briquettes' compaction. These additives comprise starch (rice flour, cassava flour, mashed sweet potato), or molasses and Arabic gum to give greater stability to the resultant product. The materials used for biomass briquette making are summarized in Table 3. Briquettes have high thermal value, low ash content and uniform and low rate of combustion. Low moisture and high density of briquettes gives it better boiler efficiency. Oil, coal, lignite once used cannot be replaced, but bio-mass briquettes can be recycled as compost. The absence of sulphur, fly ash in briquettes makes them eco-friendly [15]. The briquettes have low smoke with no odour and a steady flame. There is a good will to carry an eco-friendly label because of reducing the hitherto polluting waste forms a major quote for marketing and its popularity. On the other hand, briquettes can be an alternative to diesel, kerosene, furnace oil, lignite, coal and firewood [16]. Every industry and residential home use fuel and energy; a means of using an alternative fuel like the bio-mass briquette can be very encouraging for the renewable energy sector of the world. The ready market, high profit, good growth potential, wide choice of raw materials, easily available of raw materials make briquetting easy choice. Ease in storage and transportation, substitute for coal is major reasons to consider bio-mass briquettes as an energy alternative.

Table 3: Most common materials used for briquette production.

Origin	Raw materials that can be used
Agricultural wastes	Cassava stalk, coconut frond, cotton stalks, corn stalks, straw, millet, oat straw, frond palm oil, rice straw, rye straw, sorghum straw, soybean straw, sugar reed leaves, wheat straw
Industrial processing residues from agriculture	Cocoa beans, coconut shells, coffee husks, cotton seed hulls, peanut shells, cobs and wrap corns, oil palm stalks, waste from olive pressing, rice ball, sugar cane bagasse
Forestry development	Leaves, branches and twisted trunks.
Plantation and forestry residues	Leaves, branches, stumps, roots, etc.
Wood industry wastes	Sawdust
Bioenergy crops	Acacia spp, Cunninghamialanceolata, Eucalyptus spp, Pinus spp., Populus spp., Platanus spp., Robiniapseudoacacia y Salix spp.

Source: [17].

Biomass Briquetting Potentials In Nigeria

Statistics covering biomass projects or companies active in the briquetting sector is unavailable, since there is no central body responsible for this segment, which cuts across various ministries as well as federal, state and local government levels. While there are numerous very small-scale projects proposed, any figures on total volume would be guesses. However, a variety of biomass resources exist in Nigeria in large quantities with opportunities for expansion. Biomass resources include agricultural crops, agricultural crop residues, forestry resources, municipal solid waste and animal waste. Agricultural crop residues include those produced from the processing of crops. The agricultural crops that have potential as biomass feedstock for biofuel production include sugar cane, cassava, rice, maize and sorghum for ethanol and oil palm, groundnut, coconut, cotton, soybean, Jatropha and sesame (locallycalled biniseed) for biodiesel [18]. From the perspective of available land and wide range of biomass resources, Nigeria has significant potential to produce biofuels and even become an international supplier. Bioenergy feedstock is not only abundant in Nigeria; it is also widely distributed. Nigeria is the largest producer of cassava in the world. Nigeria could also become a major player in the biofuel industry given the enormous magnitude of various waste / residues (agricultural, forestry, industry and municipal solid) available in the country. As summary of the biomass potentials in Nigeria are given in Tables 4and 5. In spite of the fact that the significance of biomass briquettes as substitute fuel for wood, coal and lignite is well acknowledged, the numerous failuresof briquetting machines in almost all developing countries have inhibited their extensive exploitation. Briquetting technology is yet to get a strong foothold in many developing countries, such as Nigeria because of the technical constraints involved and the lack of knowledge to adapt the technology to suit local conditions. [19]. Recognition however must be given to some business ventures already in the biomass briquetting business like Middlebrook Farms with an installed briquette manufacturing plant in Oyo Southwest Nigeria,Makamashi Energy Nigeria Limited and many others.

Table 4: Renewable Energy Potentials in Nigeria.

Resource	**Potential**	**Current utilization and further remarks**
Large hydropower	11,250 MW	1,900 MW exploited.
Small hydropower	3500 MW	64.2 MW exploited.
Solar	4.0 KWh/m^2/day – 6.5 KWh/m^2/day	15 MW dispersed PV installations (estimated).
Wind	2-4m/s @ 10m height mainland	Electronic wind information system (WIS) available.

Biomass (non-fossil organic matter)	Municipal waste	18.5 million tonnes produced in 2005 and now estimated at 0.5kg/capita/day
	Fuel wood	43.4 million tonnes/yr. fuel wood consumption.
	Animal waste	245 million assorted animals in 2001.
	Agricultural residues	91.4 million tonnes/yr. produced.
	Energy crops	28.2 million hectares of arable land; 8.5% cultivated.

Source: [20]

BIOMASS BRIQUETTING MARKET IN NIGERIA

Currently, it is safe to say that briquette market in Nigeria is non-existent. Thus with present near energy crisis, there is high potential of biomass briquette becoming a preferred substitute fuel for nearly all energy uses for cooking and commercial process heat. There is however a well-established trade for transporting, stocking, wholesaling, and retailing of charcoal and wood that already exists. This is encouraging as any intending entrepreneur could leverage on the existing structure. [21]. The Federal Institute for Industrial Research (FIIRO Lagos) has fabricated some biomass briquetting machines which can be ordered by the public.

Table 5: Residues estimate from agricultural crops, 2010

Crop	Production(' 000 t)	Component	Weight available in million tons	Total energy available (PJ)
Rice	3,368.24	Straw	7.86	125.92
		Husk	1.19	23.00
Maize	7,676.85	Stalk	10.75	211.35
		Cob	2.10	34.19
		Husk	0.92	14.32
Cassava	42,533.17	Stalks	17.01	297.68
		Peelings	76.56	812.30
Groundnut	3,799.25	Shells	1.81	28.35
		Straw	4.37	76.83
Soybean	365.06	Straw	0.91	11.27
		Pods	0.37	4.58
Sugar cane	481.51	Bagasse	0.11	1.99
		Tops/Leaves	0.14	2.21
Cotton	602.44	Stalk	2.25	41.87
Millet	5,170.45	Straw	7.24	89.63
Sorghum	7,140.96	Straw	7.14	88.39
Cowpea	3,368.24	Shell	4.89	95.06
Total			**145.62**	**1,958.94**

Source: [21].

Figure 4: Smokeless biomass briquettes stove and biomass briquettes marketed by Middlebrook Farms, Lagos, Nigeria. (http://www.middlebrookfarms.com.ng/briquette.html.)

Conclusion

Africa's most populous country needs more than 10 times its current electricity output to guarantee supply for its 200,705,014 million people – nearly half of whom have no access at all, according to former Power Works and Housing Minister BabatundeRajiFashola.Biomass energy potential in Nigeria is enormous and promising. Positive impacts will be felt in the environment, health and economy of the country when fossil fuel utilization is replaced with biomass energy. Homemade biomass briquetting technologies however have not been fully exploited. It is expected that commercial success of biomass briquettes will comewith heavy investment, stake holder cooperation and development of indigenous technologies and the deployment of large-scale

biomass energy systems especially briquettes for industrial and residential uses. This is expected not only to significantly increase Nigeria's energy and consequentelectricity capacity, but would also ease power shortages in the country.Biomass briquetting as well as other renewable energy options could be regarded as an efficient means of enabling Nigeria meet some of the main Sustainable Development Goals (SDGs) established by the United Nations General Assembly in 2015 for the year 2030 in particular Affordable and Clean Energy.

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