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Agricultural Wastes as Potential Energy Resource in Nigeria: Current Status, Prospects and Constraints

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Abstract: Agricultural wastes are by-products of agricultural activities and take the form of crop residues (residual stalks, straw, leaves, roots, husks, shells etc.) and animal waste (animal faeces, droppings, etc.). In Nigeria, large quantities of these wastes are produced daily and are widely under-utilized. The traditional practice is to burn these residues or leave them to decompose. Agricultural wastes or residues are stock piles of energy that could be processed into liquid fuels or combusted/gasified to produce electricity and heat. This study reviews the energy potentials of common agricultural wastes like cassava peel, sugarcane bagasse, yam peel, plantain peel, wood sawdust and livestock droppings. Nigeria is currently the largest producer of cassava in the world with about 52.4*106 tons of cassava in 2011 and about 5.24-7.86*106 tons of cassava peels which have energy potential of about 85.83-128*109 MJ and 3.14-4.72*106 m^3 of biogas. About 2.1*106 tons of corn cob is generated annually which can generate 3,922.45 MW of power, 1.062*09 m^3 of biogas, 0.67*109 of methane (CH4) and 27.824*09 MJ of energy. About 4.74-6.42*106 tons of yam peel can generate about 77.79 -100*109J of energy. Plantain peel generated is about 0.95-0.96*106 tons and can generate 15.3-15.5*109 MJ of energy. About 2.09-2.5*103 kJ can be derived from 0.12-0.14*106 tons of sugarcane bagasse that is currently discarded. Also about 1.8 million tons of sawdust is generated annually and it has an estimated energy value of 31,433 MJ that is capable of generating 2.57*106 MWh that can provide electricity for about 347,297.3 homes/yr, assuming that each residential home consumes 7.4 MWh per year. Nigeria currently produces about 4.57*106 tons/day (chicken-broiler), 147.72*106(goat) tons/day, 84.2*106 (sheep) tons/day, 311.4*106 (cow) tons/day, 27.18*106 (pig) tons/day totaling 575.1*106 tons/day of animal wastes which is capable of generating 1.73*107 m^3/day of biogas that can provide 1.94*104 MWh for about 262.2 homes/year for residential homes.

INTRODUCTION

Energy is an essential component for socio-economic development and economic growth. Therefore, the level of a country's development is a direct result of the level of development in the energy sector, the amount and quality of energy generated and distributed the effectiveness and reliability of the distribution (NBS., 2012). Energy is vital for the internal and external security of a country and energy issues are at the core of social, environmental and economic security challenges (Ladanai and Vinterback, 2009). Energy is also described as the oil that lubricates the engine of growth of national economies and the objective of the energy system is to provide energy services such as for lighting, provision of air-conditioned indoor climate, transportation, cooking, washing, etc. (Sambo, 2009).

The standard of living of a given country can be directly related to the per capita energy consumption. The per capita energy consumption is a measure of the per capita income as well as the prosperity of a nation (Rai, 2004). Energy consumption is usually expressed in power per capita. Generally, countries that have higher per capita energy consumption are more developed than those with low level of consumption. The average power per capita (in watts) in USA, Japan, South Africa, China, India and Nigeria are 1,363, 774, 496, 397, 85 and 12, respectively. This portrays the poor level of economic development and industrialization. Energy, specifically, oil and gas has continued to contribute over 70% of Nigeria's federal revenue (Sambo, 2009). The heavy reliance of Nigerian economy on the fossil fuel market makes it vulnerable to any little instability in global oil market as currently being experienced now following the recent halt in the importation of Nigerian crude oil by the US due to the shale oil revolution (Akinbomi *et al*., 2014). This has affected the Nigerian economy, national developmental programmes, budget, expenditure and security. For example, non-passage of the national budget is attributed to the fall in benchmark of oil price which has fallen from $110 per barrel in February 2014 ->$60 in December 2014. Energy, especially crude oil, has over the past five years contributed an average of about 25% to Nigeria's Gross Domestic Product (GDP), representing the highest contributor after crop production (Sambo, 2009). The contribution of energy to GDP is expected to be higher when we take into account renewable energy utilization which constitutes about 90% of the energy used by the rural population (NPC, 1997, 2012).

Nigeria is an energy-resource rich nation, blessed with ample and abundant resources of non-renewable and renewable energy resources, though it has depended almost on non-renewable energy resources because it is the major source of income and foreign exchange for the country. It is universally accepted that fossil fuels are finite and it is only a matter of time before their reserves become exhausted. The need for supplementary or even alternatives non-depletable energy sources cannot be overemphasized. The search for energy alternatives involving locally available renewable resources is one of the main concerns of governments, scientists and individuals worldwide. The present dependence on fossil fuel (petroleum) is not enough to meet the energy needs of the country because of the recent increase in oil prices, unavailability of electricity to majority of the populace as well as high cost and energy losses associated with grid extension. Many countries of the world (producers and importers of crude oil) are keen to either partly or completely replace petrol from fossil fuel with bioresources obtained from plant materials.

Biomass, the fourth largest energy source after coal, oil and natural gas is currently the most important renewable energy option (Ladanai and Vinterback, 2009). However, taking into account the growing concern among scientists and people regarding the increasing importance of environmental issues and energy potentials of biomass, it is obvious there is an urgent need to change the current situation. Hence, biomass holds great potential and a viable option for the solution. Biomass is any organic matter that is available on a renewable or recurring basis and includes agricultural wastes or residue, wood and wood wastes and residues, plants (including aquatic plants), grasses, residues, fibres and animal wastes, municipal wastes and other waste materials.

Agricultural or crop residues are the biomass that is discarded during harvesting. They can be collected and prepared as pellets, chips, stacks or bales. Agricultural crop residues include corn cobs (stalks and leaves), cassava peelings, rice husks, wheat straw, rice straw, yam peel, cocoa pods, groundnut shells, sawdust, bagasse, sawdust, coconut shell, cow dung, swine dung and poultry droppings. Agricultural wastes are widely available, renewable, free and most times constitute nuisance in the environment, hence they can be an important energy resources. However, many of the agricultural wastes are still largely underutilized and left to rot or are openly burned in the field, especially in developing countries like Nigeria. Huge volumes of agricultural wastes are produced daily in Nigeria and can be converted to energy if proper technology is applied. This paper seeks to

Table 1: Non-renewable energy resources in Nigeria

Resource type	Reserves		Production	Domestic Utilization (Natural units)
	Natural units	Energy units (Btoe)		
Crude oil	35 billion barrels	4.76	2.5 million barrels/day	450,000 barrels/day
Natural gas	187 trillion SCF	4.32	6 billion SCF/day	3.4 billion SCF/day
Coal and lignite	2.175 billion tonnes	1.92	(Insignificant)	(Insignificant)
Tar sands	31 billion barrels of equivalent	4.22	‘’	‘’
Nuclear element	Not yet quantified	‘’	‘’	‘’

ECN (2005)

Table 2: Renewable energy resources in Nigeria

Resource type		Natural units	Energy units	Production	Domestic utilization (Natural units)
Hydropower, large		11,250 MW	0.8 (over 36 years)		
Small hydropower		3,500 MW	0.25(over 38 years)	30 MW (2.6 million Mwh/day	2.6 million MWh/day
Solar radiation		3.5-7.0 kWh/m/day	15.0 (38 years and 0.1%	Excess of 240 Kwp of solar	Solar PV
			Nigeria land area)	PV or 0.01 million Mwh/day	
Wind		2-4 m/s at 10 m	8.14 8.14 (4 m/sec at 70 m height) F20 m windmill, 0.1% land		
Biomass	Fuel wood	11 million hectares of	Excess of 1.2 million tons/day	0.120 million tons/day	0.120 million tons/day
			forest and woodland	0.781 million tons of waste/day	Not available
	Animal waste		211 million assorted animals	0.256 million tons of assorted crops/day	Not available
	Energy drop and Agric. Residue	72 ha of Agric. Land			

ECN, 2005

address the energy potentials of agricultural wastes. Hence, the specific objectives of this study include to review the energy potentials of cassava peel, corn cob, sugarcane bagasse, yam peel, plantain peel, sawdust and animal wastes to review the current and prospects of these agricultural wastes as a potential energy resource in Nigeria based on the current production and projected production and to evaluate the constraints and challenges of agricultural waste as potential energy resources and provide appropriate recommendations especially the need for its integration in the energy mix of the Nigerian energy supply.

Energy resources in Nigeria: Non-renewable and renewable energy resources of Nigeria are presented in Table 1 and 2, respectively. The fossil energy resource is an input to all economic activities and also the mainstay of Nigeria's foreign exchange earnings through the export of crude oil and more recently, from natural gas exports. The estimated total energy consumption in Nigeria in 2009 was about 4.6 EJ or 111 Mtoe. The energy consumption mix in Nigeria is dominated by fuel wood (81.2%), natural gas (8.2%), petroleum products (5.3%), crude oil (4.8%), hydro (0.4%) while coal and peat (<0.01%) as given by Anyanwu *et al*. (2013).

Electricity situation in Nigeria: Currently, electricity is generated through a mix of both thermal and hydro systems. All the power, distribution and substations are specially interlinked by a transmission network popularly known as the national grid. The national electricity grid presently consists of 14 generating stations (3 hydro and 11 thermal) with a total installed capacity of about 8,039 MW (Oyedepo, 2012).

The currentnation's available electricity generating capacity is about 3801.19 MW (Okere, 2015) with per capita power capacity of 12 Watts and this is grossly inadequate even for domestic consumption. This energy consumption per capita is very small, about one-sixth of the energy consumed in developed countries. Individuals and companies are the sole provider of their electricity by using power generating sets. Power distribution in Nigeria is abysmally irregular and erratic. For Nigeria to meet up its energy needs, it requires per capital power capacity of 1000 Watts or power generating/handling capacity of 140,000 MW as against the current capacity of 3801.19 MW. Consequently, availability of power in the country varied from about 27-60% of installed capacity while transmission and distribution losses accounted for about 28% of the electricity generated in the country.

Agricultural wastes as renewable energy resources are currently not part of Nigeria's energy mix as they have either been neglected not discovered or are currently at their early stage of development. The absence of reliable energy supply has brought untold hardship on Nigerians,

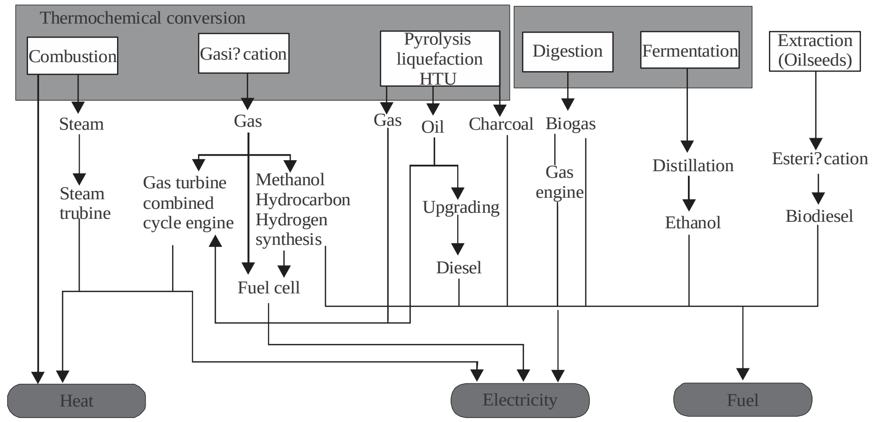

Fig. 1: A summary of various methods for producing power and heat from biomass

high cost of running businesses and health effects. For Nigeria to meet up with its energy needs, it must look for alternative energy source to augment the current production. With the large quantity of biomass present together with its enormous energy content, particularly agricultural waste, Nigeria can meet her growing energy requirements. If agricultural waste is properly harnessed, it could meet a significant proportion of energy demand with little or no deteriorating effects on the environment.

Bioelectricity from agricultural wastes: Bioelectricity is derived from various biological sources, called biomass. Agricultural waste has been employed by different countries for generating heat and electricity. For example, Brazil uses sugarcane bagasse to supply 1,382 MW (3%) of Brazil's electricity requirements in 2012 while Thailand have an installed capacity of over 780 MW with almost 300 MW are sold back to the grid. Also, biogas is a product of anaerobic digestion of agricultural wastes and is composed mainly of methane (around 65-70%) and carbon dioxide (25-30%), it can be used as fuel for a gas engine or a gas boiler to generate electricity and or steam.

The Combined Heat and Power (CHP) plants generate both electricity and useful heat and steam (Bushnell *et al*., 1988; Alanne and Saari, 2004; Franco and Giannini, 2004; Dong *et al*., 2008; De Paepe *et al*., 2006). In biomass powered CHP facilities, steam turbines are used to generate electricity. The steam condition, temperature and pressure, depends on the type of biomass used as boiler fuel. Chemically untreated wood-like biomass can generate steam at 540°C, whereas the steam produced using waste wood is approximately 450°C. CHP plants can achieve efficiencies greater than 35% by using biomass (Ghosh and Prelas, 2011). A summary of various methods for producing power and heat is shown in Fig. 1.

Energy potentials of agricultural waste: This section reviews the energy potential of wastes derived from Cassava, Corn, Sugarcane, Yam, Banana, Wood and Animals that can complement the present energy production while reducing the nuisance caused from these wastes.

Cassava peel: Cassava, Manihotesculenta Crantz, is a perennial woody shrub with an edible root which grows in tropical and subtropical areas of the world. Cassava was first introduced to the Africa continent, close to the mouth of the Congo River by Portuguese explorers and traders from Brazil, South America in the course of the 16th and 17th centuries. From there it was diffused by Africans, to many parts of sub-Saharan Africa over a period of two to three hundred years(Adeniji *et al*., 2005). In Africa, cassava provides a basic daily source of dietary energy. In the early 1960's, Africa accounted for 40% of world cassava production and Brazil was the world's leading cassava producer. However, 30 years later in the early 1990's, Africa produced half of the total world cassava output and Nigeria replaced Brazil as the leading producing country globally. Currently, about half of the world production of cassava is in Africa. Cassava is cultivated in around 40 African countries, stretching through a wide belt from Madagascar in the Southeast to Senegal and to Cape Verde in the Northwest. Around 70% of Africa's cassava output is harvested in Nigeria, the Congo and Tanzania (Adeniji *et al*., 2005).

Cassava production figures in Nigeria have risen steadily from 7.4 million in 1961-32 million tons in 2001. By 2008 it has reached 45 million tons (FAOSTAT., 2009). This increase has been attributed to several factors which include: increase in human population and favorable agro climate for the crop, presidential cassava initiatives, increased research and development, increased business opportunities, greater access to loans and other

Table 3: Estimated energy potential of Cassava wastes in 2011

Biomass	Estimated annual production (million tons)	Biomass energy potential	Total energy potential
Cassava peels	[a]5.24-7.86	[b]Biogas yield: 0.6l kg-TS	3.14-4.72*109 L/TS of biogas
		[b]Biogas yield when blended with piggery waste: 35 L/kg-TS	183.4-275.1 *109 L/TS of biogas
		[c]Energy:16.38 MJ/kg	85.83-128.75 *109 MJ/kg
Cassava	52.4	Bioethanol production: 0.05 /kg	2.62 million tons

[a]IITA in (2009; [b]Adelakan in (2012); [c]Onwuka *et al*. (2013)

Table 4: Estimated energy potential of cassava wastes in 2020

Biomass	Estimated annual production (million tons)	Biomass energy potential	Total energy potential
Cassava peels	6-9	Biogas yield: 0.6l /kg-TS	3.6-5.4 $*10^9$ L/TS of biogas
		Biogas yield when blended with piggery waste: 35 l/kg-TS	126-189$*10^9$ L/TS of biogas
		Energy:16.38 MJ/kg	98.28-147.42$*10^9$ MJ
Cassava	60	Bioethanol production: 0.05/kg	3 million tons

Table 5: Estimated energy potential of sugarcane wastes for 2010

Biomass	Estimated annual production	Biomass energy potennntial	Total energy potential
Sugarcane bagasse	[a]120,378-144,453	[b]Heating Value: 0.0173 kJ/kg	Energy: 2.09-2.5$*10^3$ kj
Molasses	[a]21,667.95-24,075.5	Bioethanol production: 0.00026 m^3/kg	Ethanol:5.63-6.3$*10^6$ m^3

[a]Asian Biomass Handbook in 2008; [b]Gaur and Reed (1998), sugarcane has a measured heating value = 17.33 kJ/g (0.01733 kJ/Kg)

farm inputs, increased infrastructure especially in rural area, the renewed interest in the crop for the production of biofuels and as important industrial feedstock for the production of starch, beverages, flour, glucose syrup etc. and currently the present government Agricultural Transformation Agenda (ATA).

Extrapolating from estimates for cassava production in Africa (Scott *et al*., 2000), Nigeria's production is targeted at 40 million tons by 2005 and 60 million tons by 2020. Statistics from the National Root Crops Research Institute (NRCRI) indicate that Nigeria is the largest producer of cassava in the world with an annual estimate of 52.4 million metric tons in 2011produced on 3.85 million hectares by about 4.5 million smallholder farmers.

The processing of cassava tubers yields the following by-products that can be valuable livestock feeds when properly processed: Cassava peels (5-15% of the root), Cassava pomace, also called (cassava fibre, cassava bran, cassava bagasse, cassava starch residue), Cassava pulp (up to 17% of the tuber), Cassava sievate or garri (15-17% of the root in weight), Cassava stumps, Cassava whey and discarded tubers (Heuze *et al*., 2014).

Cassava waste can be converted to useful products including fuel ethanol (Agbro and Ogie, 2012; Akpan *et al*., 1988, bio fertilizer (Eze, 2010), animal feeds (Phillips *et al*., 2004), biogas and electricity (Ofoefule and Uzodinma, 2008, bio-surfactants and raw materials for several industrial applications for the production of mushrooms, single cell protein, enzymes, organic acids, amino acids and other buck chemicals (Pandey *et al*., 2000; Sriroth *et al*., 2000).

Energy potential of cassava peels: In Nigeria, annual production of cassava was discovered to be about 52.4 million metric tons in 2011 (Oluyinka, 2013). IITA reveals that the increase in production of cassava roots is also generating up to 7.5 million metric tons of wet peels annually (which is 10-15% of the whole tuber). According to Ohimain *et al*. (2013), during the processing of cassava tubers >10% of the tubers result in peelings whereas 3.25% pulp is produced. With current production of about 52.4 million tons, 5.24-7.86 million tons of cassava peel is generated. Also, with projected 60 million tons of cassava in 2020, 6-9 million metric tons of waste results. This is a large quantity of waste can generate a lot of beneficial products for a country with Nigeria, struggling with consistent electricity supply.

Onwuka *et al*. (2002) gave the chemical composition of household wastes. They reported that cassava peels contain 5.4% crude protein, 31.75% crude fibre, 8.0 ash and energy content of 16.38 MJ/kg. With 5.24-7.86*106 tons of cassava peel, 85.8-128.75*109 MJ is generated and 98.28-147.42*109 MJ for 2020 projected production.

Biogas potential: According to Adelekan, average biogas yield from digested cassava peels is 0.6l/kg-TS. With 5.24-7.86*106 tons of cassava peel, this translates to 3.14-4.72*109 L/TS of biogas and 3.6-5.4*109 L/TS of biogas for 2020. Cassava waste can be blended with livestock wastes such as cattle, poultry and pig to increase the quantity of biogas produces. Cassava peels gave higher quantity of biogas when blended with piggery waste (Ofoefule and Uzodinma, 2008, Oparaku, 2013). Adelekan reports that biogas yield increased to 35 L/kg-TS when blended with piggery waste. Applying it to the above, 183.4-275.1*109 L/TS and 210-315*109 L/TS of biogas for present and projected production in 2020.

Also, from the characterization of its waste water, 1liter of cassava wastewater has a potential to generate from 2-3.5 L of biogas (RCPMI, 2010).

Ethanol potential: Adelekan, found a correlation between ethanol production and mass of cassava. With 52.4 million tons of cassava production in 2011, Nigeria's bioethanol production stands at about 2.62 million tons of ethanol while with 60 million tons of cassava production in 2020, Nigeria's bioethanol production stands at about 3 million tons of ethanol.

Some of cassava products, waste and their energy and biogas potential are explained in Table 3-5 for 2011 production and 2020 production.

Corn cob: Corn (Zea mays) is a major food crop in many parts of the world. All parts of the crop can be used for food and non-food products. In Nigeria, corn is processed to a variety of diets such as pap, Agidi, corn flakes, etc. It is a major component of animal feeds and is consumed by many Nigerians as snack, either boiled or roasted. The capacity for corn production in Nigeria is high and efforts towards improvement are being made at various quarters. Worldwide production of maize is 785 million tons, with the largest producer, the United States, producing 42%. Africa produces 6.5% and the largest African producer is Nigeria with nearly 8 million tons, followed by South Africa. Africa imports 28% of the required maize from countries outside the continent. According to 158 million hectares of maize are harvested worldwide. Africa harvests 29 million hectares with Nigeria, the largest producer in sub-Saharan Africa, harvesting 3% followed by Tanzania. Corn is also one of the commodities promoted under the GON's ATA program tagged the Growth Enhancement Support Scheme (GES) and the e-wallet.Currently, about 8 million metric tons of cornisproduced annually and a production forecast for 2010-2015 envisage a 23% growth. The maize plant comprises the stalks, husks, shanks, silks, leaf blades, leaf sheaths, tassels and cobs. The corn cob carries the grain and together with associating husks, shanks and silks are harvested from the farm. The other parts are left on the farm to rot (Kludze *et al*., 2010). Corn cobs form about 30% of maize agro-wastes (Rangkuti and Djajanegara, 1983). Corn cobs contain 32.3-45.6% cellulose, 39.8% hemicelluloses, mostly composed of pentosan and 6.7-13.9% and can be converted to fermentable sugar for ethanol production (Saliu and Sani, 2012). It also contains 36.10% dry matter, 97.30% organic dry matter, 28.32% crude fibre, 0.88% acetic acid, 36.55% carbon etc.

Energy potential of Maize cob: Current maize production in Nigeria is about 8 million metric tons. With a production forecast for 2010-2015 envisage a 23% growth will generate about 9.84 million tons of maize. Under the ATA agenda, the drive is to increase maize production to 20 million metric tons in 2020. Corn cobs form about 30% of maize agro-wastes while (Suberu *et al*., 2012) specifically reports that corn cob form about 21% of maize plant. This will result in about 2,066,400 m tons and 4,200,000 tons of maize cob for 2010-2015 and ATA 2020 projection. According to Suberu *et al*. (2012), 2,066,400 m tons and 4.2 million tons will produce 3,922.45 and 7, 972.5 MW of power respectively. Corn cob is used for electricity generation in countries like Thailand, Indonesia and China where they are either gasified or combusted for energy. Also, according to Adebayo *et al*., maize cob have a potential of 0.51431 m^3/Kg and 0.32454 m^3/kg for biogas and methane respectively. This translates to 1.062*109 m^3 of biogas and 0.67*109 of methane and 27.824*109 MJ of energy for the 2010-2015 projection. For the ATA projection, this translates to 2.16*109 m^3 of biogas, 1.36 *109 m^3 of methane and 56.7*109 MJ of energy. Also, Adebayo reports that maize cob have a potential of 0.12 g/L of ethanol. This translates to 247.9 and 504 m^3 of ethanol for 2010-2015 and ATA 2020 projection.

Corn cob can used to produce biogas (Eze and Ojike, 2012), ethanol (Akpan *et al*., 2005, Naja, 2009, Saliu and Sani, 2012), pulp and paper making (Fagbemigun, 2014), electrical power (Suberu *et al*., 2012). Maize stalk also has biogas and ethanol potential (Eze and Ojike, 2012).

Yam peel: Yam (*Dioscorea* spp.) is a major staple food in humid and sub-humid tropical countries of the world such as Nigeria. It is a root tuber crop like cassava and is widely cultivated in Nigeria and other parts of the world including Asia and the Caribbean. Worldwide yam production in 2007 amounted to 52 million tons, of which Africa produced 96%. Most of the world's production comes from West Africa representing 94% with Nigeria alone producing 71%, equaling >37 million tons. This approximates to three-quarters of the World total output of yam (NBS, 2010). Nigeria is the world's leading producer of cassava, yams and taro root and the second largest producer of sweet potatoes. Yam production stood at around 35 million tons in 2008. Before being consumed, yam tubers are peeled and prepared for consumption by boiling, roasting, grilling, frying or pounding boiled tubers and plantain into dough. Yams are starchy staples in the form of large tubers produced by annual and perennial vines grown in Africa, the Americas, the Caribbean, South Pacific and Asia. In West and Central Africa tubers are planted between February and April, depending on whether in humid forest or on the savanna and are harvested 180-270 days later. Yams are primary agricultural commodities and major staple crops in Africa where yam cultivation began 11,000 years ago. In West Africa they are major sources of income and have high cultural value. They are used in fertility and marriage ceremonies and a festival is held annually to celebrate its harvest. Yam tubers consist of about 21% dietary fiber and are rich in carbohydrates, vitamin C and essential minerals. Worldwide annual consumption of yams is 18 million tons with 15 million in West Africa. Annual consumption in West Africa is 61 kilograms per capita.

Yam peel is one of the waste products that can be obtained from yam tuber. Yam peel is composed of two important parts, starchy and cellulose components. Yam peel is also considered as a waste material that can cause nuisance to the environment but can serve two purposes as an animal feed and as a raw material for bio-ethanol production (Okolo and Agu, 2013). Until now, yam has provided a suitable food source for human consumption but with future proposals for yam to be used as a raw material for bio-ethanol production, competition for this commodity may put this food supply under threat. Even though several studies have shown that the waste peels from yam can be used as ingredient for animal feeding, the peels are still largely discarded (Okolo and Agu, 2013). Fasina (2014) analyzed the yam peel and gave the following properties: Ash (8.49), Heating value (16.39 MJ/kg), Carbon (39.40), Hydrogen (6.12), Cellulose (9.67), Hemicellulose (21.98), Lignin (3.19).

Energy potential of Yam peel: According to Onwuka *et al*. (2002), 1 tuber of yam with an approximate weight of 1035.6-1085.2 g, produces about 12.8-16.6% of waste. So therefore, in 2007, the estimated yam peel waste is 4.74-6.142*106 tons. Also, according to Scott *et al*. (2000) annual growth of yam production is 1.3%. This amounts to 54.4 million tons of yam tubers and 6.96-9.05 million tons of yam peel in 2020. The heating value of yam peel is given as 16.39 MJ/kg. Given that the estimated yam peel waste is 4.74-6.142 million tons in 2007, this amounts to about 77.6-100*109 MJ while for the estimated waste for 2020 amounts to 114-148.3*109 MJ of energy.

Abimbola and Olumide also revealed that yam peels can be used to produce biogas. It also can be used as a raw material for bio-ethanol production (Okolo and Agu, 2013).

Plantain peel: *Plantain, musa* spp. is also one of the major food staples in developing countries and in Western and Central Africa. About 70 million people are estimated to depend on Musa fruits for a large proportion of their daily carbohydrate intake (Swennenand Wilson, 1983). Plantains and bananas represent the world's second largest fruit crop with an annual production of 129,906,098 m tons (FAOSTAT, 2010). Plantain and banana rank fourth as the most important global food commodity after rice, wheat and maize in terms of gross value of production. Plantain is ranked third among starchy staples. Plantains are plants producing fruits that remain starchy at maturity (Marriot and Lancaster, 1983; Robinson, 1996) and need processing before consumption. Plantain production in Africa is estimated at more than 50% of worldwide production. About 82% of plantains in Africa are produced in the area stretching from the lowlands of Guinea and Liberia to the central basin of the Democratic Republic of Congo. West and Central Africa contribute 61 and 1%, respectively (FAO, 1986). It is estimated that about 70 million people in West and Central Africa derive more than 25% of their carbohydrates from plantains, making them one of the most important sources of food energy throughout the African lowland humid forest zone.

Nigeria is one of the largest plantain producing countries in the world. Despite its prominence, Nigeria does not feature among plantain exporting nations because it produces more for local consumption than for export. The crop ranked third among starchy staples after cassava and yam. It is a major source of carbohydrate for more than 50 million people (Akinyemi *et al*., 2008). In Nigeria, all stages of the fruit (from immature to overripe) are used as a source of food in one form or the other. The immature fruits are peeled, sliced, dried and made into powder and consumed as 'plantain fufu'. The mature fruits (ripe or unripe) are consumed boiled, steamed, baked, pounded, roasted or sliced and fried into chips. Overripe plantains are processed into beer or spiced with chili pepper, fried with palm oil and served as snacks ('dodo-ikire'). Industrially, plantain fruits serve as composite in the making of baby food ('Babena' and 'Soyamusa'), bread, biscuit and others (Akyeampong, 1999). Also, plantain peels are used as feed for livestock while the dried peels are used for soap production. The dried leaves, sheath and petioles are used as tying materials, sponges and roofing material. Plantain leaves are also used for wrapping, packaging, marketing and serving of food (Akinyemi *et al*., 2008).

Between 1990 and 1994, production increased by 37%. Ten years later, between 1995 and 2004, production increased by 0.47 million tons. The overall production has doubled in the last twenty years. As of 2004, the country produced 2.103 million tons harvested from 389,000 ha. According to NBS (2012), total production of plantain stands about 2,675,530 tons harvested from 449,220 ha. The following products results from the processing of plantain crop. They are Plantain crop, Plantain peel, Plantain leaves, sheath and petioles.

Energy potential of plantain peels: According to Coker *et al*. (2008), about 35.4-35.9% of plantain peelsare produced as waste. With a production of 2,675,530 tons, plantain peel waste is estimated to be 947,137.62-

960,515.27 tons. In recent times there has been a tremendous increase in the consumption of plantain. This is evident in the number of small scale plantain processing plants. Assuming a 1.5% annual increase, total production of plantain in 2020 will results in 3.1 million tons of plantain. This translates to 1.0974-1.113 million tons of plantain peels. According to (Fasina, 2014), the heating value of plantain peel is given as 16.12 MJ/kg. Given the above plantain peel waste, this results in 1.53 -1.55*1010 MJ of energy in 2010 and an estimated 1.77-1.794*1010 MJ of energy in 2020. Plantain peels also have the potential of bio ethanol production as reported by Itelima *et al*. (2013).

Sugarcane bagasse: Sugarcane is a tall perennial grass and cultivated widely in tropical and subtropical regions of the world. It belongs to the genus Saccharum. Two types of sugarcane are grown in Nigeria, namely, industrial and soft (chewing) cane. The industrial cane is the hard or tough type generally processed into sugar by the sugar estates. The soft cane is mainly chewed raw for its sweet juice. Some of it is also processed into different crude sugar products. Soft cane production accounts for about 60% of total sugarcane production in Nigeria. An estimated area of production is between 25,000-35,000 ha, out of which soft cane covers 18,000 ha (Nmadu *et al*., 2011). Globally, sugarcane is majorly cultivated for the manufacture of sugar. Sugar is used universally as a sweetener, blender and as a preservative. It also has industrial application in pharmaceutical industries, food and beverages industries, bakeries, soft drinks bottling plants as well as biscuit and other confectionery manufacturers. Domestically, it is used in large amounts as a table sweetener. Sugar has also been used for production of fuel (ethanol).

In 2006, total sugarcane production of the world was 1.392 million tons in 20.4 million ha of harvested area and the biggest sugarcane producer is Brazil, followed by India, China, Mexico and Thailand. The Nigerian sugar industry is largely under developed in spite of its untapped resources and potentials (Daniel, 2014). According to Bichi, over 500,000 ha of land suitable for sugarcane cultivation exist in about 40 different locations across the nation which is capable of producing 30 million tons of sugarcane or about 3 million tons of refined sugar. In 2007/2008 an estimate of 100,000 tons were produced compared to 80,000 tons in 2006/2007. NBS (2012) reports that Nigeria's sugar production is 481,510 tons cultivated in 45,680 ha. Nmadu *et al*. (2013) projected that sugar production in Nigeria can be put at 2.8 million tons in 2020.

By products from sugar mill are bagasse, filter cake (sugar juice residue) and molasses. Approximately, 1 ton of sugarcane gives 105 kg of sugar, 500 kg of water, 280 kg of bagasse, 30 kg of filter cake and 55 kg of molasses .

Energy potential of sugarcane: Bagasse is the fibrous waste produced after stalks of sugarcane are crushed to extract sugar juice and is usually fed back into the boiler to generate team within the sugar mill. It makes sugar mill self-sufficient in energy. According to, about 25-30% of sugar cane production is bagasse. Therefore, bagasse production in 2010 is between 120,378 and 144,453 tons while in 2020, an estimated 700,000-840,000 tons of bagasse is produced. According to Gaur and Reed (1998), sugarcane has a measured heating value of 17.33 kJ/g (0.01733 kJ/Kg). So, the bagasse waste in 2010 will amount to 2.09-2.5*103 kJ. For the projected bagasse in 2020, this will amount to 12.13-14.6*103 kJ of energy.

Also, according to Asian Biomass Handbook (2008), the most valuable by product of sugar cane is molasses. This is because it can be further processed to ethanol or monosodium glutamate. Ethanol which is produced from both molasses and sugar juice is blended with gasoline, called gasohol for transportation fuel. Also, according to 1 ton of sugarcane would yield 40-45 kg of molasses (4.5-5%) and 1 ton of molasses can be processed to produce 260L (0.26 m^3) of ethanol. Applying this into the above, in 2010, 21,667,950-24,075,500 kg of molasses was produced. This resulted in 5.63-6.3*103 m^3 of ethanol. For the projected sugar production in 2020, about 0.126-0.14* 109 kg of molasses will be produced. This will result in 32.8-36.4*103 m^3 of ethanol. Sugarcane products and its energy potential for current and projected production are given in Table 5 and 6.

Sawdust: As stated earlier, primary energy consumption in Nigeria is dominated by fuel wood (81.2%). About 95% of the total fuel wood consumption is used in households for cooking, household activities and for cottage industrial activities.

Wood wastes abound in Nigeria owing to the substantial forest residues and activities of saw millers. After trees are felled and harvested they are taken to sawmill. These woods from the forest are cut and sawn into logs of wood. In the process, saw dust and other wood waste such as wood bark, slab, log-ends, etc. are produced Ohimain (2012). The extent of the problem caused by wood wastes in Nigeria is enormous. Usually, most of the wood wastes are poorly handled. In Nigeria, it is a common practice to dispose wastes without treatment into the environment. Common disposal methods include heaping/abandonment at the mills, open air combustion, disposal along roadside and water bodies. Abandonment of saw dust at the saw mills causes environmental pollution, air pollution, surface and ground water resources pollution and aesthetic impacts.

Table 6: Estimated energy potential of sugarcane wastes for 2020

Biomass	Estimated annual production (ton)	Biomass energy potential	Total energy potential
Sugarcane bagasse	700,000-840,000	Heating Value: 0.0173kJ/kg	2.09 -2.5*10^3 kJ
Molasses	126,000-364,000	Bioethanol production: 0.00026m^3/kg	Ethanol: 32.8-36.4*$10^6 m^3$

Table 7: Estimated energy potential of animal wastes

Livestock average weight	Population	Daily dung production (kg/animal/day)	Daily dung production (tons/day)	Energy content (MJ/Ton)	Daily energy potential (GJ/day)
Chicken (1.5 kg)	101,676,710	0.045	4575452	13000	0.05945
Goat (45 kg)	65,651,252	2.25	147715317	15350	2.26743
Sheep (45 kg)	37,422,554	2.25	84200747	15570	1.31101
Cow (550 kg)	18,871,399	16.5	311378084	16650	5.18445
Pig (150 kg)	6,040,820	4.5	27183690	15380	0.418085
Total			575,053,289		9.235

Energy potentials of sawdust: Sambo (2009) estimated that Nigeria has sawdust resources of 1.8 million tons while Ohimain (2012) estimated that the total mass of waste wood generated in Nigeria sawmills is 5.2 million tons/yr. According to Sambo (2009), 1.8 million tons of sawdust has an energy value of 31,433 MJ. With 5.2 million tons this translates to 90,806.44 MJ.

Nigeria has substantial quantities of forest residues (dry biomass) from the timber industry that could be utilized to generate renewable energy. Residues resulting from wood harvesting are currently often not utilized. Some of these residues are currently utilized inefficiently for heating and cooking, but not for electricity.

According to Ajoku (2012), to produce 1 MWh of electricity in a 30 MW power plant requires approximately 0.7 dry tons of wood waste. Applying this to the above, we have 2.57*106 MWh and 7.43*106 Mwh. Also, according to Ajoku (2012) which assumes that in Nigeria, an average residential home consumes about 7.4 MWh/year, therefore, 2.57*106 MWh will provide electricity for 347,297.3 homes/yr and 7.43*106 MWh will supply 1,004,054.1/year homes with electricity.

Energy potentials of livestock waste: From Table 6 and 7, it is seen that Nigeria generates about 575,053,289 kg/day of animal dung from the commercially reared animals. This translates to 1.73*107 m^3/day of biogas. The average calorific value of biogas is about 21-23.5 MJ/m³, so that 1 m³ of biogas corresponds to 0.5-0.6 l diesel fuel or about 6 kWh. Eze (2010) reports that 0.041 m3/day of biogas can produce 1.12 kWh of electricity. It therefore, implies that on daily bases, Nigeria is capable of generating 1.94*107 kWh of electricity. According to Mathew (1982), 2.4 kWh of electricity is needed to power a single 100W light bulb for 1 day. It can therefore, be inferred that biogas production in Nigeria can light about 8,083, 333.3 bulbs in a day if properly harnessed. At an average of 4 bulbs per rural home, it implies that this lights about 2,020,833 homes of Nigeriansthat are not within the national electricity grid. Also according to Ajoku (2012) which assumes that in Nigeria, an average residential home consumes about 7.4 MWh per year, therefore, 1.94*107 kWh will provide electricity for about 262.2 homes/year.

Current status: The energy consumption mix in Nigeria is dominated by fuel wood (81.2%); natural gas (8.2%), petroleum products (5.3%), crude oil (4.8%), hydro (0.4%) while coal and peat (<0.01%) as shown in Fig. 2. It is clearly seen that renewable energy in all forms (solar, wind, hydro, biomass, etc.,) are completely not captured and absent, despite their abundance in Nigeria. Also, the current sources of electricity in Nigeria are gas, hydro power, oil and coal. A large populace of Nigerians lives in the rural area and they rely on firewood, crop residues and charcoal for cooking because electricity availability in Nigeria is unavailable, inaccessible and erratic.

Despite the fact that agricultural waste is a proven and established technology in many parts of the developed world such as America, Germany, China, France, Brazil, etc., the use of agricultural waste as an alternative energy source in developing country like Nigeria is still insignificant. According to Akinbomi *et al*. (2014), the adoption of renewable energy by developing countries could be linked to various strategies and most especially the renewable energy directives proposed by the European Union which sets a binding target for all member states to reach 20% share of renewable energies in the total energy consumption by 2020. This is also coupled with the increase in Green Houses Gases (GHG) concentration as a result of the use of natural gas resulting in climate change and the dwindling decrease in non-renewable energy sources (Table 8).

However, in Nigeria, there have been small or household scale research on the use of agricultural wastes for biogas production such as construction and performance evaluation of biogas plant constructed at NCERD University of Nigeria, Nsukka with digester capacity of 11 m^3 and 0.1 m^3, construction of biogas plants at Zaria prison in Kaduna, Ojokoro in Lagos,

Table 8: Estimated energy potential of animal wastes in 2020

Livestock average weight	Population	Daily dung production (kg/animal/day)	Daily dung production (tons/day)	Energy content (MJ/Ton)	Daily energy potential (GJ/day)
Chicken (1.5 kg)	139,321,601.50	0.045	6,269,472.1	13000	0.08150
Goat (45 kg)	89,958,040.23	2.25	202,405,591	15350	3.10693
Sheep (45 kg)	51,277,919.55	2.25	115,375,319	15570	1.79639
Cow (550 kg)	25,858,365.51	16.5	426,663,031	16650	7.10394
Pig (150 kg)	8,277,379.52	4.5	37,248,208	15380	0.5728
Total			787,961,620		12.662

Mayflower school Ikene in Ogun state and a biogas plant at Usman Danfodiyo University in Sokoto with capacity of the digesters between 10 and 20 m^3 (Eze *et al*., 2011; Mayflower school Ikene in Ogun state and a biogas plant at Usman Danfodiyo University in Sokoto with capacity of the digesters between 10 and 20 m^3 (Eze *et al*., 2011; Eze and Ojike, 2013; Sambo, 2005; Akinbomi *et al*., 2014). Most of these projects are yet to be commercialized because they are either non-operational or still at the research stage.

Meanwhile as encouraged by Akinbomi *et al*. (2014), all hope is not lost as this is a common experience with the introduction of new technologies which in the course of time, continued research, development and government policies would receive appropriate attention.

Prospects: Brighter future and greater prospect abound for agricultural wastes as potential energy sources and there is need to incorporate them in the Nigeria National Energy Mix (NNEM). The available and estimated number of agricultural wastes such as cassava peels, maize cobs, sugarcane bagasse, yam peel, plantain peel, sawdust, oil palm waste, Rice husk, Cotton stalks and animal wastes, etc. in Nigeria offer great potential for energy development for Nigeria. There is no doubt that agricultural wastes having considerable potential to become more important in total energy consumption and its increased utilization could have signifficant impact on agriculture and the rural poor. The efficient exploitation of existing agricultural wastes presents signifficant potential for bioenergy development.

Also, the availability of 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.

Constraints: Akimbami highlighted the barrier hindering renewable energy in Nigeria. Some of these constraints are also applicable to agricultural waste as an energy resource in Nigeria. They include:

- Low level of public awareness: Most of the Nigerian populace is not even aware that common waste they dispose indiscriminately can solve their energy (electricity) problems or can be used to generate biogas which can be used to cook their food
- Lack of technical know how
- Lack of policy formulation
- Ineffective implementation of existing renewable energy policies like the National Energy Policy (NEP) 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
- Lack of government support and political will
- Lack of continuity of renewable energy policies when there is a change in government
- Absence of comprehensive national energy policy

CONCLUSION

Through a review of existing data and literature, it is established that Nigeria is an energy rich country, both renewable and non-renewable energy resources, though it has depended almost on non-renewable energy resources and neglected the renewable energy resource. The agricultural wastes or residue is a stock pile of energy which can contribute meaningfully to the national grid supply of electricity in Nigeria if it will be properly harnessed. From this study, agricultural waste from cassava, corn, sugarcane, yam, plantain, wood and animal wastes could be harness to provide biogas, ethanol and electricity.

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