

The prospect of electricity generation from biomass in the developing countries

Chidiebere Millicent Igwebuike ^{a *}, Sary Awad ^a, Yusuf Afolabi Olanrewaju ^b,
Yves Andr  s ^a

^a IMT-Atlantique, GEPEA UMR CNRS 6144, Nantes, France.

^b Department of Materials Science and Engineering, African University of Science and Technology (AUST), Abuja, Nigeria.

Abstract

One of the utmost challenges faced by developing countries is its energy sector. The epileptic power supply in some of these countries is becoming alarming and this is somewhat due to its over-reliance on fossil fuels which is not reliable enough to meet the energy needs of the populace. Fossil fuels are well-known to be dangerous to the environment as it leads to its deterioration by pollution resulting from the emission of greenhouse gases. It is high time these countries focused their strength on a clean and renewable energy source such as the energy derived from biological materials (biomass). Africa as a continent has a sufficient supply of waste biomass, yet, it has not gone far in terms of Renewable Energy Sources (RESs) exploration which could have been of immense importance to her economic growth and reduce her problem of erratic power supply. This study aims in looking at where Africa stands in terms of plant biomass production and some of the steps taken so far for effective biomass utilization for energy generation, using Nigeria as a case study.

Keywords: Nigeria, fossil fuels, renewable energy, biomass (biofuels)

1. Introduction

Biofuel refers to fuel generated from biomass materials such as algae, plants, or even animal waste. Biomass is a clean energy source that is readily available, cheap, and pose no environmental risk in comparison to fossil-based fuels like natural gas, petroleum, and coal. Fossil fuels are toxic to the environment; it emits dangerous greenhouse gases that render the environment unpalatable hence the need for it to be substituted by renewable energy sources [1]. Biofuel is applicable in the transport sector as well as in the generation of electricity. The various techniques used in the conversion of biomass to electricity are direct combustion, gasification, pyrolysis, and biochemical degradation [2]. The most common form of biofuel used at present includes bioethanol and biodiesel. Ethanol is basically produced from plant materials that contain carbohydrates and can be used as blends in gasoline to boost its octane number and reduce carbon monoxide and carbon dioxide emission. While biodiesel can be generated from vegetable oil, recycled cooking grease, or animal fat. Biodiesel can be used as a clean, non-toxic, and biodegradable fuel in compression-ignition engines to substitute fossil-based diesel fuel. It can also be blended with petroleum-based diesel [3]. In essence, the utilization of biofuels helps to decrease both the amount of consumption and the rate of importation of refined fuels from other nations.

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Corresponding author. Tel.: +33644916972; E-mail address: chidiebere.igwebuike@imt-atlantique.fr

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2. Electricity Challenges in Nigeria

Adequate and efficient electricity supply is very essential for the proper functioning of the agricultural, industrial, and mining sectors of any nation. If shortcoming, it negatively impacts the economic growth and development of the concerned country. Nigeria has the largest economy and market in Africa. It is well-endowed with rich natural resources viz. crude oil and natural gas, limestone, iron ore, coal, zinc, lead, tin, arable land including renewable energy sources which has the potential of solving energy needs of the country but these are underutilized [4]. Nigeria has a total area of 924 000 km² which stretches from latitude 4 °N to 14 °N and from longitude 3 °E to 14 °E [5] and an overall population of approximately 200 million people [6]. As a consequence of this large population, there is a high electricity demand but the nation has not been able to completely fulfill this basic requirement of her populace. Access to electricity has been impossible for the majority of Nigerians (more than 60%) while the relatively fortunate few who have access to the national grid (40%) often experience power shortage (failure) [7]. The electricity demand of the nation is approximately 40,000 MW [8] whereas, the total capacity of the installed generating plants is about 12,000 MW and an average of less than 4000 MW power is generated per day [9]. The over-reliance on crude oil for electricity production has not given the opportunity for the exploitation and development of alternative energy forms such as energy from biomass (biofuels), solar energy, wind energy, and water. The majority of the grid-connected power generating plants in Nigeria are fired by (fossil) natural gas thermal power (85%) and the rest operates by hydroelectric power (15%) [10]. Nigeria is geographically classified into two seasons viz. dry (including harmattan period) and wet season. The water levels of the hydro generating stations in the country fall during the dry period and this has often led to a great decline in the electricity produced from hydro sources [11]. Nigeria's electricity grid faces many challenges, including the insufficient grid-connected capacity to meet demand. The world bank's projection on electricity demand presented in Fig. 1, explains that the on-grid demand for electricity will experience continued growth in each passing year from 2020 onwards, also from off-grid demand [12]. In addition, an estimated 50 percent of the electrical energy consumed in the country is currently produced off-grid by diesel and gasoline generators of all shapes and sizes. To meet the demand for electricity in the country, individuals including companies/organizations have resorted to the use of fossil-based fuel-powered generators [13]. This not only renders the air unpleasant but also causes noise pollution and high energy cost. Also, unmet demand is high, particularly amongst the many citizens of the country who have no access to the grid and cannot afford off-grid power. Hence, the use of renewable energy could help to curb the erratic supply of electricity in the country and improve the health and safety of the environment.

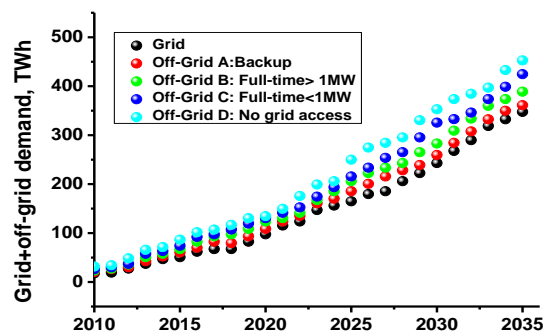


Fig. 1. Estimated grid and off-grid demand of electricity (TWh) in Nigeria; FMP and Power Holding Company of Nigeria data and UN 2010 rural/urban population data (for off-grid D projections) [12].

3. Moves on Sustainable Biofuel Development in Nigeria

August 2005, saw the establishment of the Renewable Energy Division of the Nigerian National Petroleum Corporation (NNPC) that was after NNPC had received a directive from the federal

government to begin the development of biofuel industries as well as other clean energy sources in the country. Its main goal was to improve the country's energy capacity and economic prospects to further global investment. A renewable energy program has also been set-up by the federal government of Nigeria via the Federal Ministry of Environment and it aims at making certain the growth and development of the sector [14]. The Nigeria biofuel policy received approval from the federal executive council to promote and enhance biofuel production in the country. This policy includes fiscal incentives for investors such as bestowing pioneer status for registered businesses involved in activities associated with the production of biofuels and/or biomass for biofuel generation, withholding tax on interest, dividends, and services, waiver on import and customs duties as well as on value-added tax, long term preferential loans, and insurance services [15]. It's been reported that NNPC has entered into two Memorandum of Understanding (MoU) in China; one of which was between the NNPC and the OBAX-COMPLANT Consortium, and the other was between NNPC and the CAPEGATE-NANNING Consortium. The purpose of such agreements was to build over ten large biofuel complexes across the nation. The implementation of such a project was expected to assist in realizing the development of the first biofuel production complex in Nigeria [16]. About seven bankable feasibility studies have been performed by NNPC viz. three integrated sugarcane fuel ethanol projects in Benue, Kebbi, and Gombe States, two integrated cassava fuel ethanol projects in Ondo and Anambra States and two integrated oil palm biodiesel projects in Rivers and Cross River States. It has been conveyed that NNPC entered into a consensus with some states in Nigeria to build processing plants. The agreed processing plant capacity for the various states are 84 million liters of biofuel per annum for Kogi state (plant to also co-generate 64 MW of power) with sugarcane feedstock plantation managed on 19,000 hectares, 65 million liters of biofuel per annum for Ondo state (plant also to generate about 40 MW of electricity) with cassava feedstock plantation on 15,000 hectares of land, and 84 million liters of biofuel per annum for Benue state (plant to co-generate 64 MW of power) with sugarcane feedstock plantation on 20,000 hectares of land [17]. NNPC also collaborated with the Kebbi State Government to build an 84 million liters per annum capacity bioethanol plant that utilizes sugarcane and cassava as a feedstock. This agreement was signed in November 2017. According to the corporation, the project would involve the development of 20,000 hectares of an integrated plantation and plant complex. It was expected that this project will create some benefits such as the creation of one million direct and indirect employment, generation of rural wealth, co-generation of approximately 64 MW of electricity to power the plant, and also provide lightening to the environment, decrease in the release of harmful gases, production of feeds for animals, generation of refined sugar, as well as industrial starch. The investment in biofuels by the Nigerian government is to expand its economy and decrease the dependence on oil [18]. The Sona ethanol plant which is situated at Sango-Ota, Ogun State is believed to be the largest single ethanol plant in Nigeria. The plant has a capacity of generating 120,000 liters per day (about 43.8 million liters in a year) and so, needs about 300 tons of cassava per day. The idea of the India-headquartered Sona Group is to discourage more importation of liquor and other alcoholic products into the country. The Sona ethanol plant was expected to feed both Nigeria and the African market. However, its use as fuel ethanol is not yet obvious. This project was made possible owing to the encouragement of the government for local industries [19].

4. Biomass Sourced in Nigeria with Biofuel-Production Potentials

At present, majority of the biofuel projects in Nigeria are centered on the use of food crops known as first-generation biomass for the generation of biofuel. This poses a significant drawback in biofuel production due to the competition that exists between food crops for human consumption and food crops for biofuels [20]. However, lots of waste is being generated in Nigeria on a daily basis from which biofuel can be derived and which could solve the problem associated with the use of food crops as feedstock for biofuels. These wastes could serve as added income to farmers thus encouraging farming occupation in the country.

Table 1. Biomass crop production in Nigeria (2016 – 2018) [21].

Biomass (crops)	Year	Production Quantity (tonnes)	Area Harvested (ha)	Yield (hg/ha)	Yield (tons/ha)
Cassava	2016	59,565,916	6,167,296	96,584	9.66
	2017	59,350,878	6,629,632	89,524	8.95
	2018	59,475,202	6,852,857	86,789	8.68
Maize	2016	11,547,980	6,579,692	17,551	1.76
	2017	10,420,000	6,540,000	15,933	1.59
	2018	10,155,027	4,853,349	20,924	2.09
Oil palm fruits	2016	7,808,866	3,052,166	25,585	2.56
	2017	7,743,722	3,033,892	25,524	2.55
	2018	7,850,000	3,015,530	26,032	2.60
Coconuts	2016	283,140	39,094	72,426	7.24
	2017	281,626	38,418	73,306	7.33
	2018	285,200	38,297	74,470	7.45
Sugarcane	2016	1,487,173	93,690	158,734	15.87
	2017	1,489,379	93,890	158,631	15.86
	2018	1,423,086	91,943	154,778	15.48
Yam	2016	49,384,352	5,789,107	85,306	8.53
	2017	47,934,183	5,840,577	82,071	8.21
	2018	47,532,615	5,990,184	79,351	7.94
Plantains and others	2016	3,032,054	494,210	61,351	6.14
	2017	3,062,963	498,157	61,486	6.15
	2018	3,093,872	502,087	61,620	6.16
Pineapples	2016	1,565,185	189,989	82,383	8.24
	2017	1,622,989	195,950	82,827	8.28
	2018	1,664,510	199,891	83,271	8.33

Author's compilation via FAOSTAT 2020 data.

The efficient exploration of these waste could as well help to preserve the aesthetics of the environment by lowering the rate of pollution of both land and water bodies, could also generate employment by sensitizing the locals on the usefulness of biomass, the importance of abstinence from incessant disposal of such waste, and the need for its preservation for energy generation. Some of the waste from plant origin includes cassava peels, yam peels, oil palm residues (wood, fronds, fibers, shells, empty bunches), coconuts waste (wood, fronds, husks, shell), plantain waste, pineapple waste, sugarcane bagasse, maize plant (corn stalk, corn husk, corncob, leaves) bamboo, and elephant grass in which case are termed second-generation biomass as they are mainly composed of lignin, hemicellulose, and cellulose components. Also included are wastes from animal origin such as cow dung, poultry dropping, pig dung, and goat dung [22]. But for this article, we are concentrating more on some of the plant biomass wastes that could be sourced in Nigeria. Therefore, the key characteristics of major energy crops in the country, together with production data from 2016 to 2018 are presented in Table 1.

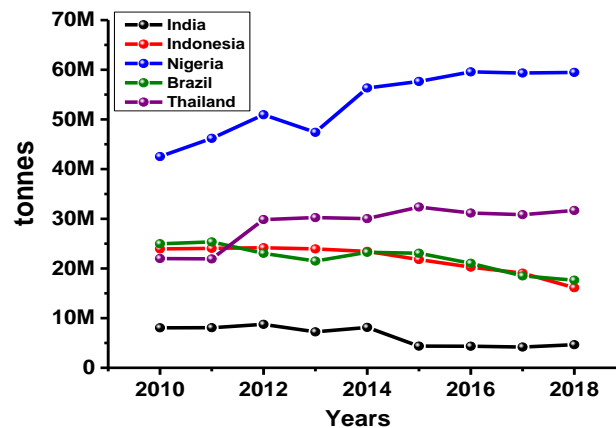


Fig. 2. Data comparison of cassava production in different countries. Source: Author'S graph from FAOSTAT 2020 [21] data.

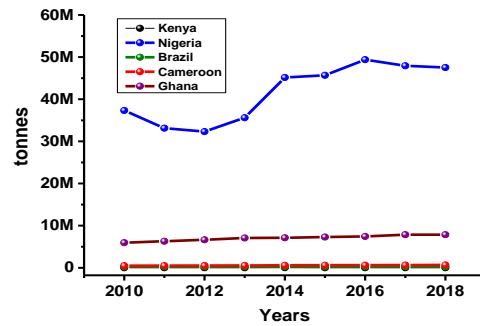


Fig. 3. Data comparison of yam production in different countries. Source: Author's graph from FAOSTAT 2020 [21] data.

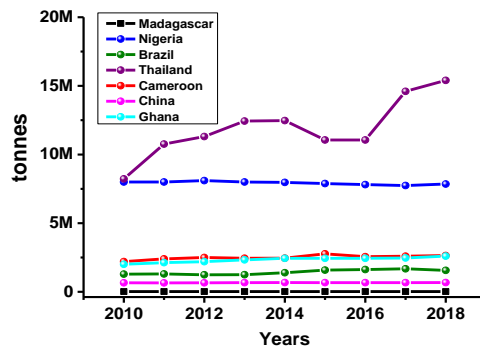


Fig. 4. Data comparison of oil palm fruit production in selected countries. Source: Author's graph from FAOSTAT 2020 [21] data.

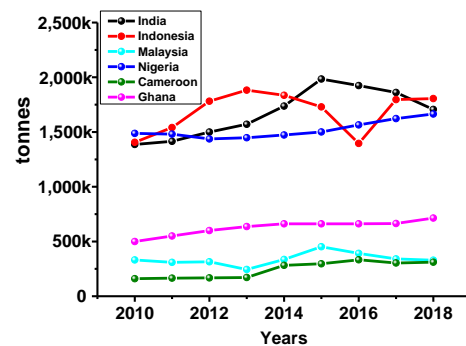


Fig. 5. Data comparison of pineapple production in selected countries. Source: Author's graph from FAOSTAT 2020 [21] data.

The four types of crop production outputs shown in Fig. 2-5, in both developed and developing countries, such as African countries, South America and Asia countries, Nigeria has shown great impact in terms of high crop production of cassava, yam, palm fruit, and pineapple. Ethanol production has been going on since 1973 using cassava as the main feedstock in the country. Already, the government has adopted a 10% blending policy. The Nigeria Yeast & Alcohol Manufacturing Company is one of the major biofuel companies that plans to establish a US\$200 million ethanol plant, with an annual production target of 30 million L [23].

Table 2. Energy potential of some common crop residues in Nigeria based on FAO statistics, 2010. source: [24].

Biomass (crops)	Residue Generated	Production Quantity (10 ³ t)	Calculated Residue Generated	Energy Potential (TJ)
Maize	Stalk	7306	10,959	169.65
Rice	Straw	3219	4829	75.14
Sorghum	Stalk	4784	12,534	213.08
Wheat	Stalk	34.2	51.3	0.99
Coconut	Shell	170	102	1.08
Oil palm fruits	Empty fruit bunch	8500	2125	32.96
Sugarcane	Bagasse	1414	424.3	5.68
Cocoa	Husk	428	428	6.63
Millet	Stalk	4125	12,375	191.94

It has been estimated that Nigeria can generate 2.01×10^6 Terajoule [TJ] of energy per year from about 168.49 million tonnes of agricultural residues and wastes that could possibly be produced each year [24], which meet the Nigerian Vision 2030 as a target of 45,000MW required per year for the country [25]. The generation of energy from the waste biomass presented in Table 2, could be ascribed to the properties and composition of the plant's cell wall. Also to compare with other sources of energy, hydro resources (small and large hydropower) are estimated at 14,750 MW, solar radiation is estimated at 3.5–7.0 kWh per square meter per day, wind energy potential of 150,000 Terajoule per year (generated by an average wind speed of 2.0–4.0 m/s) [26]. It may be said from a clear indicator that the country's potential in terms of electrical power supply could be maximized from biomass of which it has not yet to be fully tapped.

5. Conclusion

This study critically focuses on biomass resources currently available in developing countries such as Nigeria, and the potential to utilize them for the production of various types of biofuel. The tables and figures presented in this paper have shown that Nigeria, a representative developing country has enough supply of plant biomass which, once properly harnessed, could go a long way in reducing the importation of fuels from foreign countries, satisfying the basic electric power need of her populace, and ultimately contributing to her GDP growth. It has been forecasted that the demand for electricity in Nigeria will increase as the year goes by. It then becomes necessary for the on-grid to be supported by an off-grid system such as generators which should be constructed in such a way that it operates with the most minimal noise and runs smoothly on clean fuels instead of petroleum-based fuels. Also highlighted in this article are some of the moves made by the government of Nigeria to encourage/boost the production of biofuels in the country to reduce the country's consumption of fossil fuels and save the environment from further depletion. If Nigeria could take the advantages of being one of the largest producers of some of these biomasses outlined herein to produce biofuels from the resultant waste, it could avail much for the country and the surrounding nations.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All authors' contributions are the same.

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