Role Of Biomass Energy Technologies In Ensuring Energy Security In Nigeria

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Abstract—This paper presents the underlying dynamics governing the sustainable transition from fossil fuels to bioenergy for the attainment of energy security in Nigeria. In addition, it presents answers to the challenges hampering the long term practicality and sustainability of biomass energy technologies (BETs) to cater for Nigeria's growing energy demand and security. In analyzing the current status of BETs in Nigeria, the study also identifies the potential biomass resources, prospective conversion technologies and examines the role of implementation on the long term energy security of Nigeria. The results of the study indicate that despite Nigeria's vast biomass resources, the utilization of bioenergy cannot independently provide Nigeria's energy needs. The findings of the study also suggest that in order to safeguard the nation's energy security and ensure clean, renewable and sustainable energy supplies the current fossil fuel energy systems will need to be integrated with bioenergy generation in future hybrid systems. As a result, we infer that bioenergy can only complement fossils in the Nigerian energy economy in the nearest future.

Keywords—Biomass; Energy; Technologies; Security; Nigeria; Valorization; Policy.

I. INTRODUCTION

The deployment of energy resources in Nigeria is governed by the appositely termed National Energy Policy (NEP) established in the year 2003. The NEP is a strategic blueprint for the sustainable production, efficient supply and effective utilization of the nation's energy resources The policy presents modalities for the socioeconomic growth, sustainable development along with an economic apparatus for establishing international trade and cooperation between Nigeria and other partners in the global energy economy (GEE) [1]. In order to achieve this, the Federal Government of Nigeria (FGN) established a national framework for the optimal, reliable and secure energy supply from its abundant of reserves of petroleum, natural gas, coal and tar sands [2].

However, global concerns about the impending effects of climate change as well as rapidly depleting reserves and price volatility of fossil fuels have necessitated a policy shift towards renewables particularly in developing nations [3-6]. Consequently, the FGN aims to diversify its energy supply from fossil fuels to RETs thereby creating a low carbon energy mix [7]. In addition, the proposed energy transition aims to decrease the overdependence of the nation's economy on fossil fuels and establish an energy economy based on clean, renewable and sustainable energy technologies. Furthermore, it is envisaged the proposed low carbon energy transition will diversify Nigeria's energy mix, increase energy security and reduce energy poverty [8].

In view of this, the FGN enacted the Renewable Energy Master Plan (REMP) in 2005 with the task of directing the nation's drive for a low carbon energy economy. The policy provides the legal structure for accelerating the development and diffusion of renewable energy technologies (RETs) as well as articulating Nigeria's roadmap for the realization of the fossil fuels to renewables energy transition. The policy hopes to achieve its goals by adopting renewable portfolio standards; creating innovative fiscal market, and financial incentives for the sustainable growth and development of renewable energy industry in the country [9]. More importantly, REMP aims to identify, evaluate and stimulate the development and diffusion of the most viable renewable energy technologies (RETs) in the country. According to the NEP and REMP policy thrusts Nigeria can efficiently and adequately generate clean, renewable and sustainable energy from hydropower, solar, wind, geothermal and biomass resources. Furthermore, studies by researchers in Nigeria have identified biomass, solar and hydropower was the most viable energy source for establishing the proposed low carbon energy economy [10-13].

Currently, biomass is considered the most practical, cost effective and carbon neutral RETs for the establishment of low carbon energy economy in Nigeria [9, 14]. It is estimated that over 95 million people rely on traditional fuelwood biomass for their domestic energy needs in Nigeria [15]. Therefore the utilization of biomass for energy purposes in the country is widespread and established in the country [16].

However, the utilization of biomass resources for energy is beset by operational challenges such as low energy density, high moisture content, alkali content, bulky heterogeneous nature [17-20]. In addition, biomass utilization on a large scale particularly in power plants presents sociotechnical and environmental issues that need urgent attention before the nation can achieve a bioenergy economy [21-23].

In view of these dynamics, the transition from fossil fuels to a bioenergy energy economy and the attainment of energy security in Nigeria requires further comprehensive research. More so, this raises questions about the long term practicality and sustainability of biomass energy technologies (BETs) to cater for Nigeria's growing energy demand and security. Therefore, this study aims to identify the potential Biomass Resources, Biomass Conversion Technologies (BETs) and examine the role of their implementation on the long term energy security of Nigeria.

II. DISCUSSION

A. *Biomass Resources in Nigeria*

Biomass is considered to be a carbon neutral source of clean, renewable and sustainable fuels for the future [24]. In addition, its convertibility and versatility as a source of solid, liquid and gaseous fuels for application in future energy systems makes it an attractive option for establishing a low carbon energy economy [25].

Consequently, the conversion of biomass fuels into future energy fuels can theoretically mitigate the effects of climate change, stimulate low carbon development and ensure energy security [8, 26]. This is particularly important for Nigeria, an oil exporter and consumer, with high levels of annual GHG emissions. This is predominantly through anthropogenic activities in the agriculture and land use, oil and gas, power and transport sectors of the Nigerian economy.

According to the World Bank funded report [7], the establishment of a low carbon energy economy presents a practical solution for Nigeria's quest to address the issues of climate change and future energy security. It highlights the need for a dynamic climate resistant agriculture sector, more cost effective and geographical generation of power, more efficient use of oil and gas resources, better mass transport services which can result in low congestion and better air quality.

Therefore the valorization of biomass resources particularly from agriculture and land activities can effectively ensure the growth of a low carbon bioenergy economy in Nigeria. The biomass resources in Nigeria can be broadly categorized into; agricultural waste, forest residues, and municipal solid waste. Due to the abundance and low cost nature of agriculture residues in Nigeria, scientists opine that this category will contribute to the most to the bioenergy economy. According to the FAO, the top 10 cultivated agricultural crops in Nigeria are; Cassava, Cowpea, Groundnuts, Maize, Millet, Plantains, Oil Palm, Rice, Sorghum and Soybeans [27]. Table 1 presents an overview of the estimated amount of agricultural residues generated in Nigeria in 2013.

TABLE I: ESTIMATED AMOUNTS OF AGRICULTURAL RESIDUES IN NIGERIA [27-30].

Major Crop	**Crop Yield (10^6 t)**	**Residue to Product Ratio (RPR)**	**Residue Amount (10^6 t)**
Cassava	54.00	0.31	16.74
Cow peas	2.50	1.75	4.38
Groundnuts	3.00	1.39	4.17
Maize	10.40	1.70	17.68
Millet	5.00	1.75	8.75
Oil Palm	0.96	0.15	0.14
Rice	4.70	1.75	8.23
Sorghum	6.70	1.75	11.73
Soybeans	0.60	2.50	1.50
Total	**87.86**		**73.30**

The results in Table 1 indicate that the average total amount of residues generated in Nigeria is 73.30 million tonnes. At an average higher heating value of 13-15 MJ/kg [31-33] for biomass based agricultural residues the agricultural residues can generate an equivalent of 953 PJ or 22.8 Million Tonnes of Oil Equivalent (MToe). Consequently, there is huge potential for biomass resources for future bioenergy utilization in Nigeria. However this will require addressing the numerous technological, sociopolitical and environmentally challenges that perpetually beleaguer the bioenergy development. According to study Eleri *et al.,* (2011), the major factors hindering the development of a low carbon energy economy in Nigeria include, weak policy implementation and institutional framework, lack of financing, inadequate information and enlightenment, and non-existence of local manufacturing [9]. Section B of the paper will briefly outline the various established technologies that can be employed for the valorization of agriculture residues into bioenergy in Nigeria.

B. *Biomass Conversion Technologies*

The properties of biomass resources such as high moisture and alkali content, bulky heterogenous nature as well as low energy density are major barriers to its transformation into energy and transport fuels [25]. Consequently, the logistics of handling, storing or transporting biomass often necessitates its conversion (valorization) into liquid, solid and gaseous fuels [34]. This is typically achieved using two major conversion routes namely; thermochemical and biochemical [25, 35]. Figure 1 presents an overview of the outlined routes for conversion biomass resources such as agricultural residues into valuable energy and fuels for future energy systems.

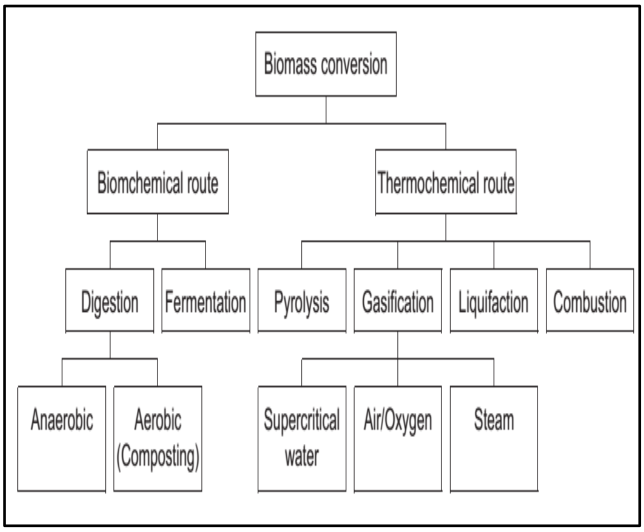

Fig. 1: *Biomass Conversion Routes* [25].

The thermochemical routes involve the conversion of biomass residues using thermal conversion systems such as boilers (or combustors), gasifiers, and pyrolyzer through thermal-chemical reactions such as combustion, gasification, liquefaction, carbonization and pyrolysis. The processes can convert agricultural residues into useful energy and fuels in solid, liquid and gaseous fuels forms. In addition, techniques such as torrefaction [36-38] and hydrothermal carbonization [39, 40] can be utilized to improve the fuel properties of agricultural residues for further applications in biomass conversion technologies.

The biochemical routes include more established technologies such as fermentation, enzymatic hydrolysis and digestion of biomass resources. This basically results in the production of liquid and gaseous biofuels such as bio-methanol, bioethanol, and biogas. However, the biochemical route for valorizing biomass resources is much slower than the thermochemical route [25].

C. *Biomass Energy Security in Nigeria*

Consequently researchers are exploring the various outlined biomass conversion routes to enable the establishment of a bioenergy energy economy in Nigeria. However, due to complexity of the process, there is an urgent need to address the barriers hampering this low carbon transition required for to ensure Nigeria's energy security. Accordingly, the outlined challenges enumerated by *Eleri et al.,* (2011) need to be addressed both on a policy as well as on the technological, socioeconomic and environmental level.

These challenges can be addressed by erasing the policy barriers hindering the development and diffusion of bioenergy and other RETs in the Nigeria energy climate. The institutions in the country must be encourage to stimulate discussions, debates and policies that create favorable policy environment for the growth of the proposed low carbon bioenergy economy.

Furthermore, policy implementation particularly, the National Energy Policy (NEP), Renewable Energy Master Plan (REMP) National Electric Power Policy (NEPP), National Policy and Guidelines on Renewable Electricity (NAPGRE) and the National Bio-fuels Policy (NBP) need to revised, harmonized and rejuvenated to cater current dynamics of the current energy climate in Nigeria.

In addition, the lack of adequate financing, monetary incentives and favorable tax regimes have contributed to the challenges of establishing a bioenergy economy in Nigeria. The high cost of equipment, logistics and R&D funding prevent potential investors and entrepreneurs from venturing into the bioenergy climate. Furthermore, the high cost of energy produced from RETs in general are typically high even with government incentives which are clearly lacking in the Nigerian bioenergy climate.

Hence the government must establish a regime of financial incentives to stimulate growth and development of companies, organizations and original equipment manufacturers (OEM) required to ensure RETs strive. Lastly, the FGN must needs increase awareness on the potential benefits of a low carbon bioenergy economy and its role in ensuring energy security in the country. This will increase participation in the growth, development and diffusion of bioenergy technologies as well as reduced GHGs from fossil fuels and promote environmental sustainability.

With these challenges abound in the Nigerian energy economy it is unlikely that bioenergy will replace fossil fuel systems in the near future. Instead, the proposed low carbon bioenergy economy will complement fossils fuels in future hybrid energy generation systems such as gasifier to gas turbines, gasifiers to solid oxide fuel cells (SOFC) among others.

III. CONCLUSION

This study was aimed at investigating the dynamics of the energy transition from fossil fuels to bioenergy in Nigeria. The study highlighted the role of the practicality of the proposed bioenergy economy on the long term energy security of Nigeria. Furthermore, the study categorized the nation's biomass resources, potential biomass conversion technologies (BETs) and their role long term energy security of Nigeria. The study infers that bioenergy cannot independently provide Nigeria's energy needs but can potentially complement fossil fuel based energy systems in future hybrid systems.

IV. REFERENCES

1. NEP, *National Energy Policy of Nigeria*. 2003, Energy Commission of Nigeria: Abuja, Nigeria. p. 1-89.
2. O. Jesuleye, W. Siyanbola, S. Sanni, and M. Ilori, "*Energy demand analysis of Port-Harcourt refinery, Nigeria and its policy implications.*" Energy policy, 2007. 35(2): p. 1338-1345.
3. A. Johari, B.B. Nyakuma, A. Ahmad, T.A.T. Abdullah, M.J. Kamaruddin, R. Mat, and A. Ali, "*Design of a Bubbling Fluidized Bed Gasifier for the Thermochemical Conversion of Oil Palm Empty Fruit Bunch Briquette.*" Applied Mechanics and Materials, 2014. 493: p. 3-8.
4. A. Iwayemi, "*Nigeria's dual energy problems: Policy issues and challenges.*" International Association for Energy Economics, 2008. 53: p. 17-21.
5. A.A. Mas'ud, A.V. Wirba, F. Muhammad-Sukki, I.A. Mas'ud, A.B. Munir, and N.M. Yunus, "*An assessment of renewable energy readiness in Africa: Case study of Nigeria and Cameroon.*" Renewable and Sustainable Energy Reviews, 2015. 51: p. 775-784.
6. A. Johari, B.B. Nyakuma, S.H. Mohd Nor, R. Mat, H. Hashim, A. Ahmad, Z. Yamani Zakaria, and T.A. Tuan Abdullah, "*The challenges and prospects of palm oil based biodiesel in Malaysia.*" Energy, 2015. 81: p. 255-261.
7. R. Cervigni, J.A. Rogers, and M. Henrion, *Low-Carbon Development: Opportunities for Nigeria*. 2013, Washington DC: World Bank Publications.
8. O.E. Ilevbare, M. Sanni, F.M. Ilevbare, and G.A. Ali, "*Transition to Low-Carbon Future in Nigeria: The Role of Pro-Environmental Behaviors.*" Handbook of Climate Change Adaptation, 2015: p. 2119-2142.
9. E.O. Eleri, O. Ugwu, and P. Onuvae, *Low-carbon Africa: Nigeria*. 2011, International Center for Energy, Environment & Development ICEED: Abuja Nigeria.
10. M. Shaaban and J. Petinrin, "*Renewable energy potentials in Nigeria: meeting rural energy needs.*" Renewable and Sustainable Energy Reviews, 2014. 29: p. 72-84.
11. Y.S. Mohammed, M.W. Mustafa, N. Bashir, and A.S. Mokhtar, "*Renewable energy resources for distributed power generation in Nigeria: A review of the potential.*" Renewable and Sustainable Energy Reviews, 2013. 22: p. 257-268.
12. Y.S. Mohammed, M.W. Mustafa, N. Bashir, M.A. Ogundola, and U. Umar, "*Sustainable potential of bioenergy resources for distributed power generation development in Nigeria.*" Renewable and Sustainable Energy Reviews, 2014. 34: p. 361-370.
13. N. Abila, "*Econometric estimation of the petroleum products consumption in Nigeria: Assessing the premise for biofuels adoption.*" Renewable Energy, 2015. 74: p. 884-892.
14. E.O. Eleri, O. Ugwu, and P. Onuvae. "*Expanding access to pro-poor energy services in Nigeria*." 2012; Available from: http://iceednigeria.org/ic/iceed-launches-report-on-expanding-access-to-pro-poor-energy-services-in-nigeria/.
15. A.S. Sambo, "*Strategic developments in renewable energy in Nigeria.*" International Association for Energy Economics, 2009. 16(3): p. 15-19.
16. A.A. Sokan-Adeaga and G.R. Ana, "*A comprehensive review of biomass resources and biofuel production in Nigeria: potential and prospects.*" Reviews on Environmental Health, 2015. 30(3): p. 143-162.
17. B.B. Nyakuma, A. Johari, and A. Ahmad, "*Analysis of the pyrolytic fuel properties of empty fruit bunch briquettes.*" Journal of Applied Sciences, 2012. 12(24): p. 2527-2533.
18. P. McKendry, "*Energy production from biomass (part 1): overview of biomass.*" Bioresource Technology, 2002. 83(1): p. 37-46.
19. P. McKendry, "*Energy production from biomass (part 2): conversion technologies.*" Bioresource technology, 2002. 83(1): p. 47-54.
20. B.B. Nyakuma, A. Johari, A. Ahmad, and T.A.T. Abdullah, "*Comparative analysis of the calorific fuel properties of Empty Fruit Bunch Fiber and Briquette.*" Energy Procedia, 2014. 52: p. 466-473.
21. E.I. Ohimain, "*Can the Nigerian biofuel policy and incentives (2007) transform Nigeria into a biofuel economy?*" Energy Policy, 2013. 54: p. 352-359.
22. S.O. Oyedepo, "*On energy for sustainable development in Nigeria.*" Renewable and Sustainable Energy Reviews, 2012. 16(5): p. 2583-2598.
23. B.B. Nyakuma, O.A. Oladokun, A. Johari, A. Ahmad, and T.A.T. Abdullah, "*A Simplified Model for Gasification of Oil Palm Empty Fruit Bunch Briquettes.*" Jurnal Teknologi, 2014. 69(2).
24. D. Tilman, J. Hill, and C. Lehman, "*Carbon-negative biofuels from low-input high-diversity grassland biomass.*" Science, 2006. 314(5805): p. 1598-1600.

25. P. Basu, *Biomass gasification, pyrolysis and torrefaction: practical design and theory*. 2013: Academic Press.

26. I. Ogbonna, N. Moheimani, and J. Ogbonna, "*Potentials of Microalgae Biodiesel Production in Nigeria."* Nigerian Journal of Biotechnology, 2015. 29(1): p. 44–55.

27. FAO. "*Agrciultural Database*." 2013 [cited 15.08.2015; Available from: http://faostat3.fao.org/home/E.

28. N.S. Bentsen, C. Felby, and B.J. Thorsen, "*Agricultural residue production and potentials for energy and materials services."* Progress in Energy and Combustion Science, 2014. 40: p. 59-73.

29. A. Koopmans and J. Koppejan, "*Agricultural and forest residues-generation, utilization and availability."* Paper presented at the regional consultation on modern applications of biomass energy, 1997. 6: p. 10.

30. L.S. Esteban, P. Ciria, and J.E. Carrasco, "*An assessment of relevant methodological elements and criteria for surveying sustainable agricultural and forestry biomass by-products for energy purposes."* BioResources, 2008. 3(3): p. 910-928.

31. S.V. Vassilev, D. Baxter, L.K. Andersen, and C.G. Vassileva, "*An overview of the chemical composition of biomass."* Fuel, 2010. 89(5): p. 913-933.

32. O. Oladokun, A. Ahmad, M.F.A. Kamaroddin, T.A.T. Abdullah, and B.B. Nyakuma, "*A Quasi Steady State Model For Flash Pyrolysis of Biomass in a Transported Bed Reactor."* Jurnal Teknologi, 2015. 75(6).

33. S.O. Jekayinfa and V. Scholz, "*Potential Availability of Energetically Usable Crop Residues in Nigeria."* Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 2009. 31(8): p. 687-697.

34. P. Breeze, "*Power from Waste."* 2014: p. 335-352.

35. P. Basu, *Biomass gasification and pyrolysis: practical design and theory*. 2010: Academic press.

36. Y. Uemura, W. Omar, N.A. Othman, S. Yusup, and T. Tsutsui, "*Torrefaction of oil palm EFB in the presence of oxygen."* Fuel, 2013. 103: p. 156-160.

37. Y. Uemura, W.N. Omar, T. Tsutsui, and S.B. Yusup, "*Torrefaction of oil palm wastes."* Fuel, 2011. 90(8): p. 2585-2591.

38. B.B. Nyakuma, A. Ahmad, A. Johari, T.A.T. Abdullah, and O. Oladokun, "*Torrefaction of Pelletized Oil Palm Empty Fruit Bunches."* arXiv preprint arXiv:1505.05469, 2015.

39. M.A. Islam, M. Asif, and B. Hameed, "*Pyrolysis kinetics of raw and hydrothermally carbonized Karanj (Pongamia pinnata) fruit hulls via thermogravimetric analysis."* Bioresource Technology, 2015. 179: p. 227-233.

40. M. Jatzwauck and A. Schumpe, "*Kinetics of hydrothermal carbonization (HTC) of soft rush."* Biomass and Bioenergy, 2015. 75: p. 94-100.