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Sustainable biomass electricity generation in Nigeria: Prospects, issues and ways forward

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Abstract

Energy is an essential ingredient for socio-economic and technological development of any nation. The electric power supply in the country, Nigeria is grossly inadequate, unreliable and inefficient. This has indeed retarded her socio-economic and industrial growths. The problems persist as a result of overdependence on fossil-fuels for power generation and the lack of diversity in the nation's energy mix. Integrating the abundant biomass resources (that is available almost everywhere in the country) into the national energy mix will enhance the country to improve its electric power generation and reduce the GHG emission gradually. This work explored the different sources of biomass, identified the prospects, challenges of electricity production from biomass and made some recommendations towards improving electric power generation and GHG emission reduction. The available biomass resources in the country, if properly harnessed will reduce the persistent global energy pressure substantially. The work recommended policy implementation, marketing promotion, funding and supports as some of the ways of improving electricity generation through biomass.

Keywords: Biomass; Electricity; Sustainability; Conversion Techniques; Energy Mix

1. Introduction

Energy is an essential ingredient for socio-economic and technological development of any nation. Efficient energy system is a necessary tool in keeping pace with the global trends. Access to efficient and reliable electric power supply is vital for economic development, effective health care system, environmental sustainability, poverty reduction and quality standard of living [Adebanji,2019].

Electric power supply in the country, is grossly inadequate, inefficient and unreliable. This has indeed retarded her socio-economic and industrial growths. The problems persist as a result of over dependence on fossil-fuels for power generation and the lack of diversity in the nation's energy mix. The country continues to experience perennial power outages as a result of insufficient and unreliable power supply system, to meet the estimated power demand of about 35,000 MW for her population [Akuru *et al*, 2017]. The total installed capacity of all the generating stations in the country is 12,522 MW with average available generation fluctuating between 3500 and 4500 MW. About 85 million people (representing 42.5% of the population) have no electric power supply [Adebanji,2019].

This challenge can be overcome by harnessing renewable energy sources (RES) like biomass, solar, wind and Small hydro power which are available in large number in almost everywhere in the country. RES is clean, abundant and sustainable. Renewable energy can be said to be a clean energy because it does not constitute environmental hazards and is also renewable. Despite the abundant RES available almost everywhere in the country, the country is yet to make

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any remarkable progress towards RES adoption/utilization. It is imperative to increase RES shares in global energy's balance in order to ensure sustainability [Barz,2008].

RES like sun and wind however, are stochastic in nature since they depend on weather. This also makes them not to be totally reliable unless a hybrid system of energy is employed. Biomass resources unlike other RES, is dependable and reliable. Hence, the interest in the use of biomass for power generation. Integrating the abundant biomass resources into the country's energy mix will enhance the country to increase its power generation through RES by about 45% before 2030 and also achieve a reduced low GHG emission of 2% [Onwumelu,2023]. The traditional usage of biomass for heating, firing and cooking is totally unsustainable. Almost about 85% of biomass resources usage in the country is majorly being used for heating, fuel wood and domestic purposes [Ugwu *et al,* 2022]. This may lead to serious environmental issues like deforestation, erosion and desertification. The major factors that influence the choice of biomass' usage in Nigeria are culture, poverty and availability.

Several authors have worked on biomass resources, conversion technologies, utilization and challenges [Barz, 2008; Oguo *et al*, 2012; Sa'ad and Bugaje,2016; Sobamowo and Ojola 2018; Lewis, 2021; Adebanji *et al*,2023; Aduba and Shimada, 2023]. Barz, 2008 reviewed different technologies available for biomass conversion to electricity generation. The study specifically highlighted electricity generation through biomass using a particular community, Friedland as a case study. Some of the technologies discussed were classified as solid biofuels (steam turbines, steam engine, steam scraw engine, sterling engine etc.) and liquid/gaseous biofuels (Gas turbines, micro gas turbine, gas engine, fuel cell).

Ogwo *et al* (2012) did a comprehensive overview on different types of biomass resources based on the conversion techniques required with major focus on the issues and its implication on the society. Sa'ad and Bugaje (2016) expressed the importance of biomass energy usage /demand analysis for efficient and sustainable usage of these resources. The authors showed that even though, biomass resources are no more popular with so many people, yet people who are using the resources continue to increase. This is basically caused by high level of poverty, cultural and inaccessibility to other alternative energy sources. There is a strong correlation between biomass usage and poverty level. The authors stressed the need for effective and deliberate policies to promote /enhance an efficient and sustainable biomass energy utilization in Nigeria. Hence, the need to make clean energy more available and at a cheaper cost.

Sobamowo and Ojola (2018) worked on the possibility of meeting Nigeria's electric power demand using biomass gasification technique. A techno-economic analysis of biomass energy utilization was carried out and some peculiar merits/prospects of biomass energy resources were discussed. The authors carried out a techno-economic analysis of biomass energy utilization in Nigeria and stated some of the peculiar advantages/prospects of biomass energy resources. The paper advocated for a reduction in capital cost, fuel cost, operation and maintenance cost through biomass technology by using local materials and introduction of financial incentives by the government and other stakeholders in the power sector.

Lewis (2021) expressed the need to harness the rich biomass resources for production of electricity and chemicals for industrial and domestic uses. The author opined that effective biomass utilization in the country will prevent the negative environmental practice of burning agricultural products. Ezekiago *et al* (2021) investigated the potentials of the available biomass resources using data collected for municipal liquids and solid wastes and agricultural residues from 2008-2018. The research used analytical and computational techniques for moderate assumptions. The research concluded that there are so many biomass resources in Nigeria that is enough to meet the electricity needs of the country.

Adebanji *et al* (2023) also reviewed the status of biomass resources for electric power production in Nigeria's rural areas with a case study of Agbonikeji, Nigeria. The analysis was carried out using RET Screen software. The work established that the project was not viable especially for remote, scattered/sparse populated areas unless government and other power stakeholders introduce some incentives (like tax holidays) in attracting would-be-inventors.The feasibility and viability of biomass resources for electricity production in Nigeria was assessed by Aduba and Shimada (2023). The work carried out the feasibility of using rice husks for electricity generation by employing two sampling techniques in resolving the lack of millers' data and lack of wastes generation from biomass will improve /increase energy generation mix and reduces potential emissions.

Biomass resources for electricity generation is clean, viable, affordable and sustainable. Hence, the need to aggressively pursue green energy sources with little or no negative environmental effect to complement the existing too much dependence on fossil fuel plants. This work explored the different sources of biomass, identified the prospects, challenges of electricity production from biomass and made some recommendations towards improving electric power

generation and GHG emission reduction. The available biomass resources in the country, if properly harnessed will reduce the persistent global energy pressure substantially.

2. Energy Potentials of Biomass Resources in Nigeria

Biomass can be described as an organic matter derived from either plant/animal for generation of electric power/heat for some industrial purposes [Simoyan and Fasina, 2013]. Typical examples include aquatic plants, animal wastes, municipal and industrial wastes, wood, forest residues, trees and plants, agricultural crops, animal wastes. Agric crop residues accounted for about 76% of the biomass resources produced annually in Nigeria with about 153.76 million tonnes (Olanrewaju *et al*, 2019).

Nigeria is abundantly blessed with biomass resources. It produces about 144 million tons of biomass on a yearly basis [Ben-Iwo *et al*, 2016]. About 70% of her population use biomass daily for cooking, heating and other purposes [Chanchangi *et a*l, 2022]. The estimated total biomass potential is about 5.5 EJ as at the year, 2020 and it has the potential to increase to 29.8 EJ by 2050 [Ojolo *et al*, 2012]. The types of Biomass resources and distribution in the country depends on the prevailing climatic conditions in each region. It is discovered that large number of timbers/woody biomass are commonly found in the south while crop residues are more prevalent in the north. The major types of biomass resources found in Nigeria are animal dungs, agricultural residues, fuel wood, energy crops, aquatic biomass [Simoyan and Fasina,2013]

The available biomass resources in the country can be broadly classified as agricultural biomass, forest residues, municipal solid wastes and agricultural residues as shown in Figure 1 [Ojolo *et al*, 2012]. They can be liquid, gaseous and solid forms. The most common in Nigeria are agricultural biomass and residues [Ojolo *et al*, 2012]. The individual contribution of biomass resources are as shown in Figure 2. The total estimated energy potential from biomass in Nigeria is as in Table 1.

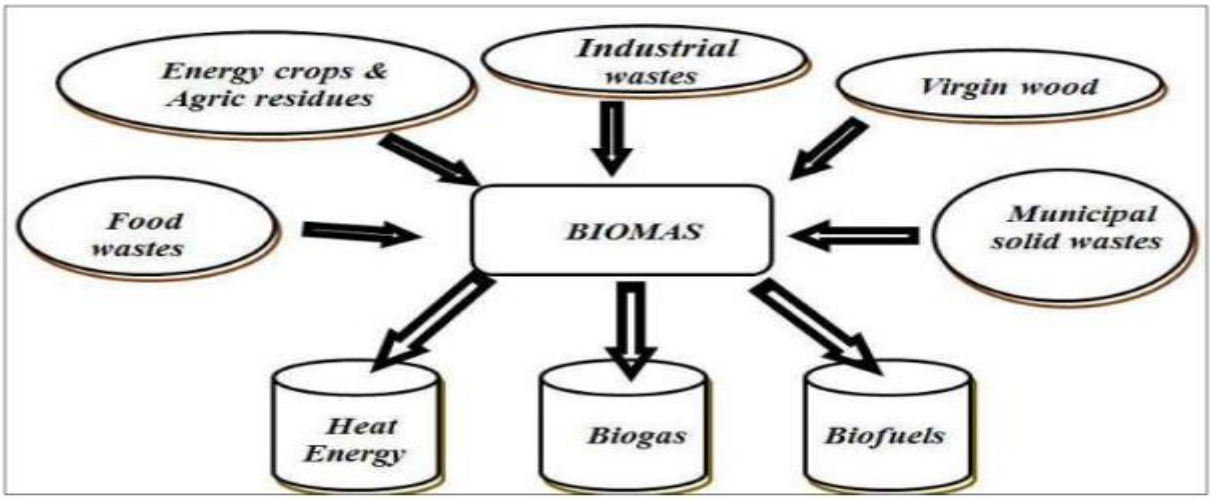

Figure 1 Sources and products from biomass [Akorede *et al*, 2017; Ibrahim *et al*, 2022].

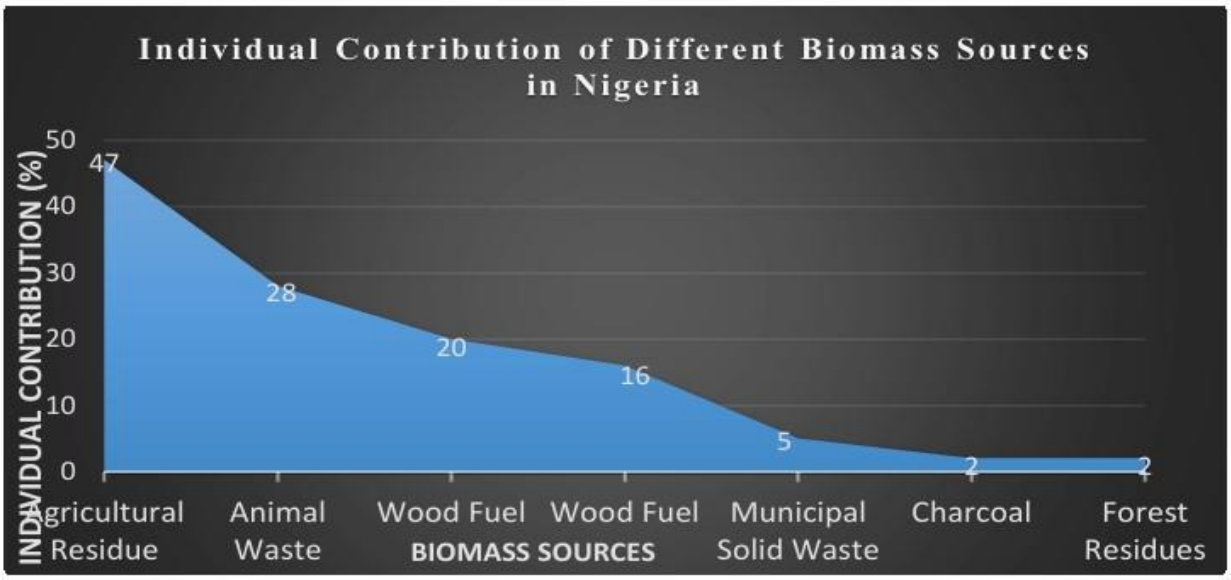

Figure 2 Individual contribution of different Biomass resources [Jekayinfa *et al*, 2020]

Table 1 Estimated energy potentials of Biomass resources in Nigeria [Olanrenwaju,2019]

Biomass Resources	Quantity (billion kg/year)	Estimated Energy potential (PJ/year)
Crop residues	153.76	2,033.85
Perennial crop residues	2.35	28.88
Forest residues	19	362.95
Municipal solid wastes	4.51	21.36
Animal wastes	17.69	106.39
Human wastes	2.87	28.83
Total	**200.18**	**2,582.26 (61.67 Mtoe)**

3. Biomass to Electricity Conversion Techniques

The two major ways of converting biomass to energy, products and fuels are viz: thermochemical and biochemical conversion techniques. The appropriate conversion process to be taken depends on the type and quantity of biomass feedstock, the specific factors of the project and the desired form of energy. Its conversion efficiency depends on reactor types, the size and shape of the particles, the type of use and gas flow. The choice of conversion technology should be geared towards achieving optimum results (Simoyan and Fasina, 2013). The conversion process (as shown in Figure 3) are discussed in the subsequent sub sections

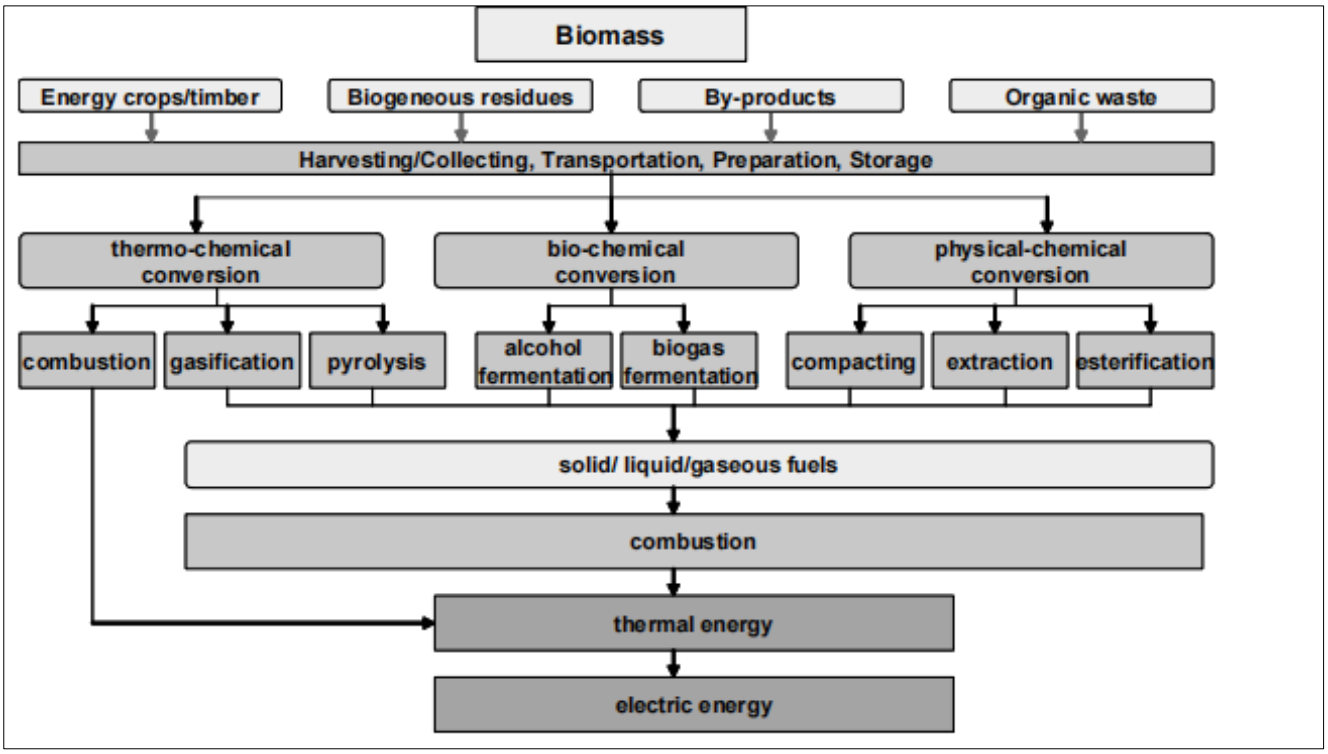

Figure 3 Biomass-electricity conversion routes (Barz,2008)

3.1. Thermochemical conversion

This refers to conversion techniques like direct combustion, gasification, pyrolysis e.t.c.

3.1.1. Direct Combustion

This is the conversion of chemical energy in biomass to generate heat, transform to mechanical power/electric power as in stoves. It goes along with biomass oxidation in the presence of excess air in producing hot gases to generate steam in the exchanger section in the boiler, this is then used in turning of the turbine that is connected to the electric power generator to produce electricity. Most electric power production through biomass are by direct combustion technique. This is as shown in Figure 4. This technique is most common in rural and remote areas for energy generation, cooking and heating purposes. It has low efficiency as it results to energy wastage [Jekayinfa *et al,*2020].

3.1.2. Gasification

Gasification (for power production) can be described as a thermochemical conversion process that include devolatization and biomass resources conversion process (in the presence of steam and or air) in producing a low or medium caloric value (producer gas) for power generation [Ugwu et al,2022). The three major variables that affect gasification are gasifier operating pressure, gasification medium and the type of reactor. The Battelie gasification process is shown in shown in Figure 5.

3.1.3. Pyrolysis

Pyrolysis can be described as a thermal conversion technique that involves biomass resources materials decomposition (under pressure without oxygen at a temperature range of between 350^0 C to 550^0 C [Ben-Iwo *et al*,2016; Simoyan and Fasina,2013]. The three major fractions that are produced out of this process are solid fraction (in ash form), liquid fraction (in bio-oil form) and gaseous fractions. Pyrolysis has a very wide application. It is economical and viable.

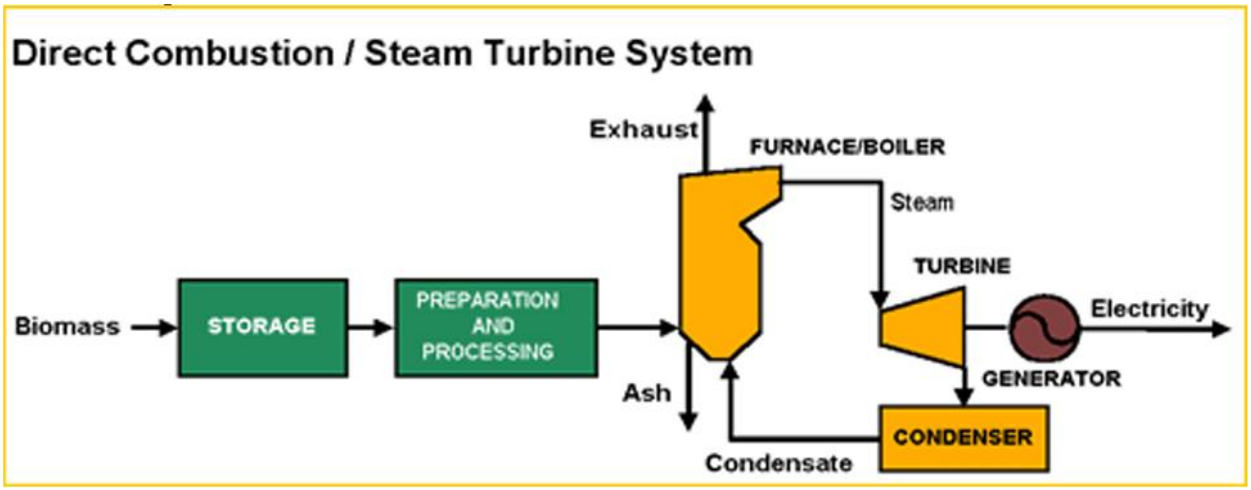

Figure 4 Direct combustion [Diji,2013]

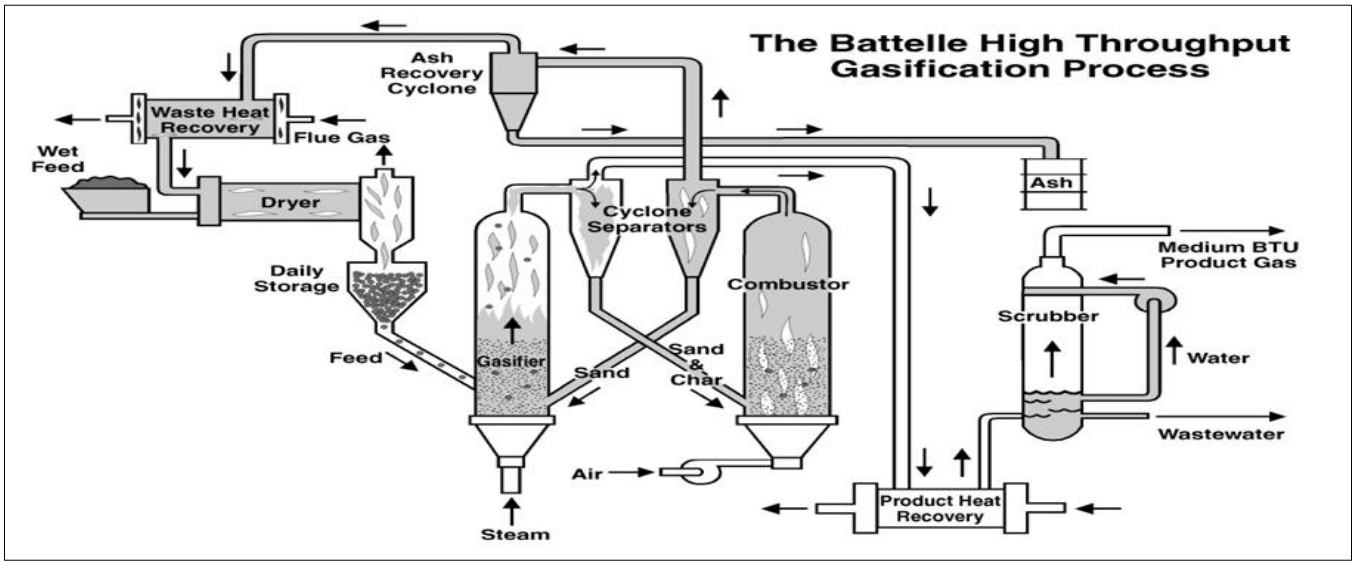

Figure 5 Battelle Biomass Gasification [Diji,2013]

3.1.4. Anaerobic Digestion

This is a biochemical process that involves biogas production to generate electricity or and for other usage by digesting animal or food wastes in the absence of oxygen as shown in Figure 6. This process can take place in any air tight medium consisting of bacteria mixture in animal wastes. The complex chemicals (like fat and protein) will then be broken down into simpler molecules gradually by the different types of bacteria present in sequential manner. The final product-biogas (containing carbon dioxide and methane) can be used for electricity generation or heating purposes in a modified internal combustion engine [Diji,2013].

The process is in three stages characterized by different types of micro-organisms in each of the stages. Biomass having high-moisture content of the range 85-90% is very ideal for this process. This activates the microorganism available in the system to be very active. Biogas that is produced through anaerobic digestion is between 20% and 40% of the lower heating value of the feedback.

3.1.5. Fermentation

Fermentation is a biochemical process of converting carbohydrates (like sugar and starch) into ethanol. The process utilizes enzymes or microorganisms in converting fermentable substrates into recoverable products using alcohols/organic acids. Fermentation process involves two major stages, viz: the pre-treatment and hydrolysis stages. In the pre-treatment stage, the biomass material surface area is increased, cellulose crystallinity is decreased,

hemicellulose is eliminated and finally the lignin breaks. In hydrolysis stage, the cellulose component is converted into glucose by the enzymes and the hemicellulose is converted into hexoses and pentose and finally, the microorganism selected ferment the glucose into ethanol (Ugwu et al. 2021).

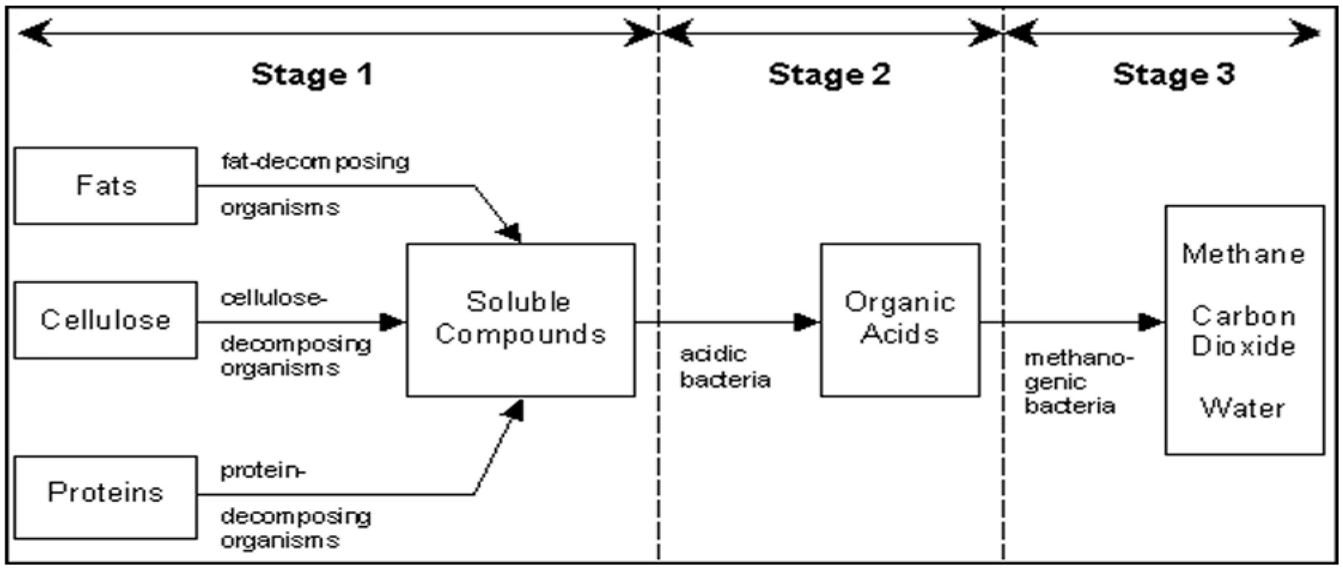

Figure 6 Anaerobic Digestion [Diji,2013]

3.2. Physicochemical Conversion

This involves application of both physical and chemical process in converting or synthesis of products at a very close ambient temperature and pressures. The primary/major feedstock usually used for this process include grease, animal fats, fresh and used vegetables and fallow. Physicochemical conversion process can also be described as extraction of oil process from oil crops (like rapeseed, jatropha, soya bean e.t.c.) and followed by transesterification technique. Bio diesel and vegetable oil are the liquid fuels that are usually produced by this process.

4. Prospects and Challenges of Electricity Production from Biomass in Nigeria

4.1. Prospects

Prospects of biomass exploitation as an alternative energy source to fossil fuels (due to its negative environmental effects and rising global oil price) are enormous. The country is well positioned for effective bioenergy production due to availability of so many hydro resources, available large fertile land and good climatic conditions. Biomass energy growth will enhance quick/rapid rural energy access and create more job opportunities. Biomass is sustainable and can create more direct and indirect jobs for the teeming unemployed youths.

The by-products of biomass like urban and industrial wastes (which ordinarily could have constituted an environmental issue) can be effectively be converted to electric power production for socio-economic growth. This will indeed help in reducing the negative environmental effects. Some other benefits of biomass resources utilization in the country are poverty reduction, clean and sustainable RES, rural development e.t.c. The search for more innovations about biofuels as an alternative source of energy to fossil fuels will lead to reduced carbon footprints, reduced greenhouse gas emission and conformity with global climate change campaigns (Ogwo *et al*, 2012).

4.2. Challenges

Even though, the country has a high potential in bioenergy production from Biomass. The level of production is at a very low level. This can be attributed to various challenges hindering bioenergy growth. Some of the identified challenges are defective policy formulation, technical constraints, inaccurate data of feedstocks, ineffective R &D scheme, lack of effective regulatory framework and unfriendly investment environment.

One of the major challenges of biomass generation of electricity is the scarcity of land to site biomass electric power generation plant. If a larger part of land is used, it will reduce the available plots of land for agricultural purposes. This

may pose serious danger to food security in the country. Hence, the need to improve the quality and yield of agricultural products without necessarily compromising that quality. Governments (at all levels) are also encouraged to facilitate infrastructural provisions such as good roads and water especially for the rural areas. Some other major challenges of biomass resources conversion are the high investment costs, inadequate data/information of the biomass resources available, subsistence farming, defective waste management system, insufficient government support, technical limitations [Onwumelu, 2023).

5. Overcoming the Challenges- Ways Forward

Some of the ways of promoting effective biomass conversion to electric power are in an policy implementation and formulation, research and training, fundings and supports and making promotion. There is need to formulate an efficient policy to protect the interest the interest of small-scale farmers along the location of biomass plant. Proper planning and evaluation at the initial stage should be done in order to avoid compromising the sustaining capacity level. In order to solve the problem of high transportation costs, conversion facility should be sited very close to the bioenergy plants

6. Conclusion

This work explored the different sources of biomass, identified the prospects and challenges of electricity production from biomass, and made some recommendations towards improving electric power generation and GHG emission reduction. The work revealed the need to focus more on production of electricity from biomass. The available biomass resources in the country, if properly harnessed can go a long way in reducing the global energy pressures. The work recommended policy implementation, marketing promotion, funding and supports as some of the ways of improving electricity generation through biomass.

In order for the country to experience improved electricity generation and achieve its clean energy goals, it is imperative to integrate RES like biomass into her national energy mix. Incorporating biomass into the national energy mix will improve social and economic life of the people. It will create job opportunities for our youths and helps in achieving SDG goals.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Adebanji, B. (2019), "Development of a hybrid power system model for rural electrification," an unpublished Ph.D thesis submitted to the Department of Electronic and Electrical Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

[2] Adebanji B., Osalade A.J., Fasina E.T. (2023), Harnessing Biomass Energy Resources for Electricity Generation in the Rural Areas of Nigeria: A Case Study, ABUAD Journal of Engineering and Applied Sciences (AJEANS), Vol.1, no.1, pp. 1-7.

[3] Aduba J.J. and Shimada K. (2023), Assessing the Viability of a Sustainable Biomass Electricity Generation in Nigeria: A Feasibility Study, Chemical Engineering Transactions, Vol.10, pp.206-210.

[4] Akuru, V.B.,Onubwube, I.E., Okoro, O.F. and Obe, E.S.(2017), Renewable and Sustainable Energy Reviews, 71, pp.943-953.

[5] Akorede, M.F., Ibrahim, O., Amuda, S.A., Otuoze, A.O., and Olufeagba, B.J. Current Status and Outlook of Renewable Energy Development in Nigeria. Nigerian Journal of Technology (NIJOTECH). 2017; 36(1): 196-212. ISSN: 0331 8443, eISSN: 2467-8821. Doi: 10.4314/njt.v36i1

[6] Barz M. (2008), Biomass Technology for Electricity Generation in Community, International Journal of Renewable Energy, Vol.3,no.1,pp. 1-10.

[7] Ben-Iwo J., Manovic V. and Longhurst P. (2016), Biomass resources and biofuels potential for the production of transportation fuels in Nigeria. Renewable and Sustainable Energy Reviews, 63,pp.172-192.

[8] Chanchangi Y.N., Adu F., Ghosh A., Sundaram S. and Mallic T.K. (2022), Nigeria's Energy review: Focussing on Solar energy potential and penetration. Environment, Development and Sustainability (Springer), 25:5753-5796.

[9] Diji C.J. (2013), Electricity Production from Biomass in Nigeria: Options, prospects and challenges, International Journal of Engineering and Applied Sciences, Vol.3,no.4, pp.84-98.

[10] Ezealigo U.S.,Otoijamum I.,Onwualu A.P. (2021), Electricity and Biofuel Production from Biomass in Nigeria: Prospects, challenges and Way Forward, IOP Conf. Series: Earth and Environmental Science, 730,pp.1-9.

[11] Ibrahim, A., Burari, F.W., and Olasoji, O.W. A Review Assessment of the Energy Potential of Biomass around Maiduguri Metropolitan, Nigeria. International Journal of Advances in Engineering and Management. 2022; 4(2): 825-830. ISSN: 2395-5252.

[12] Jekayinfa, S. O., Orisaleye, J. I. and Pecenka, R., An Assessment of Potential Resources for Biomass Energy in Nigeria. Resources, vol. 9, no. 92, 2020. doi:10.3390/resources9080092

[13] Lewis A.C. (2021), Biomass resources and Bioenergy potentials in Nigeria: A review, International Journal of Pure and Applied Science, Vol.23, no.9,pp.159-164.

[14] Ogwo J.N.,Dike O.C., Mathew S.O. and Akabuogu E.O. (2012), Ovwerview of Biomass Energy Production in Nigeria: Implications and Challenges, Asian Journal of Natural and Applied Sciences, Vol.1, No.4,pp.46-51.

[15] Olanrewaju, F.O, Andrews, G.E., Li, H and Phylaktoum, H.N. (2019), Bioenergy potential in Nigeria, Chemical Engineering Transactions, 74, 61-66.

[16] Ojolo S.J.Orisaleye J.I., Ismail S.O. and Abolarin S.M. (2012), Technical Potential of Biomass Energy in Nigeria, Ife Journal of Technology,Vol.2 (2), 60-65.

[17] Onwumelu D.C. (2023), Biomass-to-power: Opportunities and challenges for Nigeria, World Journal of Advanced Research and Reviews, Vol. 20 (2), pp. 1-23.

[18] Sa'ad S. and Bugaje I. (2016), Biomass Consumption in Nigeria: Trends and Policy Issues, Journal of Agriculture and Sustainability, Vol.9 (2), pp.127-137.

[19] Simoyan K.J. and Fasina O. (2013), Biomass resources and bioenergy potentials in Nigeria, African Journal of Agricultural Research, Vol.8 (40), pp. 4975-4989.

[20] Sobamowo G.M. and Ojolo S.J.(2018), Techno- Economic Analysis of Utilization through Gasification Technolgy for Sustainable Energy pRODUCTION and Economic Development in Nigeria, Journal of Energy, Vol., 2018,pp1-17.

[21] Ugwu C.O.,Ozor P.A., Ozoegwu C.G.,Ndukwe A. and Mbohwa C.(2022), Biomass Resources in Nigeria and the Conversion Pathways, Proceedings of the International Conference on Industrial Engineering and Operations Management, Nsukka, Nigeria, 5-7, April, 2022, pp. 1-11.