Innovations

Biomass Energy in Nigeria: Prospects, Challenges and Solutions

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Abstract: *Nigeria's energy landscape, characterized by a burgeoning population and a rapidly growing economy, is confronted with a pressing need for sustainable and diversified energy sources to meet the requisite energy demands of industries and the society. This study presents a critical review that analyzes the potentials, challenges and solutions involved in the use of biomass energy as an alternative energy resource for the country. The nation has a wide array of resources with the potential to produce 7.5 million m^3 of bioethanol per annum, of which 62% (4.7 million m^3) are obtainable from agricultural residues, with more than 71% of the generated municipal solid waste (MSW) being combustible with high energy potentials. Amidst these prospects, biomass energy in Nigeria is faced with challenges ranging from financial constraints and infrastructural deficiencies to inefficient resource utilization, poor policies and the lack of government support. Despite these challenges, the prospects of biomass in Nigeria section illuminates a promising path forward with multifaceted opportunities, including renewable energy generation, rural electrification, sustainable waste management, job creation, climate change mitigation, and improved indoor air quality. These prospects resonate with Nigeria's aspiration for sustainable development and align with global trends in renewable energy adoption. By navigating the challenges and capitalizing on the prospects of biomass energy, Nigeria can chart a course toward a resilient, diverse, and environmentally conscious energy future through international partnerships, public acceptance campaigns, development of logical databases for biomass resources, establishing the proper framework and infrastructure for biomass implementation as well a robust support from the government to inculcate biomass into the existing energy grid of the country. This transition holds the potential to reshape the nation's energy landscape while fostering innovation, economic growth, and sustainable progress.*

Keywords: *Energy, Biomass energy, bioenergy, energy source, prospects, challenges, solutions*

1.0 Introduction

Energy is an important ingredient and driver required for the growth and sustainability of any economy, it is by far considered the life wire and bedrock on which industrialization and economic development is sustained to increase gross domestic product and national income. Furthermore, the qualitative energy generated and adequately used in any country's economy is the most significant measurement of the growth/development of that nation, in fact the importance of energy in the development and growth of a nation cannot be overemphasized (Jekayinfa*et al.,* 2020). Globally the demand for energy continues to increase because of the ever increasing population so therefore alternative energy resources must be explored to meet this demand without losing a positive drive on the economy as is reported by Sokan-Adeoga and Ana (2015), the global energy demand is expected to grow to about 50% by 2025, with the major part of this increase coming from rapidly emerging countries. Nigeria, often referred to as the "Giant of Africa," boasts of a diverse array of energy resources that play a crucial role in driving its economic growth and development and in all hemispheres/aspects, Nigeria is indeed endowed with both renewable and non-renewable energy sources and is considered the continent's largest economy while only 60% of the population had access to electricity in 2018 (EIA, 2020).With a population exceeding 200 million people and a rapidly expanding economy, the country's energy demands are substantial and ever-evolving. Nigeria is endowed with a wealth of energy resources, both conventional and renewable, which form the backbone of its energy sector.

Nigeria's oil and gas industry stands as a cornerstone of its economy, contributing significantly to government revenue, export earnings, and overall energy supply. With extensive oil reserves and a history deeply intertwined with the global energy market, the sector plays a pivotal role in shaping Nigeria's socioeconomic landscape. Oil production has historically been the primary driver of Nigeria's energy sector, accounting for a significant portion of the country's GDP and export earnings. Nigeria's oil production peaked at around 2.5 million barrels per day (bpd) in the early 2000s but has since fluctuated due to factors such as geopolitical tensions, security challenges, and fluctuations in global oil prices. Natural gas production has gained prominence, particularly in the context of liquefied natural gas (LNG) exports. The country's LNG facilities have placed Nigeria among the world's top LNG exporters, contributing to a more diversified energy portfolio. Despite its potential, the oil and gas sector in Nigeria faces an array of challenges that impact its sustainable development. The Niger Delta region, where much of the oil production occurs, has experienced security issues and unrest due to demands for more equitable distribution of oil wealth and environmental concerns, oil exploration and production have led to environmental degradation in the Niger Delta, impacting local communities, ecosystems, and water sources. Oil spills and gas flaring have been persistent

issues, insufficient infrastructure, including pipelines, refineries, and storage facilities, has hindered efficient oil and gas operations. This has led to a reliance on imports of refined petroleum products amidst the abundance of crude oil deposits.

Table 1.0: Production Capacities per Energy Source

Energy Source	Total in Nigeria	Percentage in Nigeria	per capita in Nigeria
Fossil fuels	79.98 bn kWh	78,1 %	365.99 kWh
Nuclear power	0.00 kWh	0,0 %	0.00 kWh
Solar energy	204.83 m kWh	0,2 %	0.94 kWh
Wind power	0.00 kWh	0,0 %	0.00 kWh
Water power	22.22 bn kWh	21,7 %	101.69 kWh
Tidal Power Plants	0.00 kWh	0,0 %	0.00 kWh
Geothermics	0.00 kWh	0,0 %	0.00 kWh
Biomass	102.41 m kWh	0,1 %	0.47 kWh

Source: Adapted from www.worlddata.info

Table 1.0 shows a definitive look at the production capacity per energy source in Nigeria, referring to the maximum amount of energy that can be generated or produced from a specific type of energy source. It provides insights into a Nigeria ability to generate power using different energy sources. Figure 1.0 shows the total energy supply for various energy sources (coal. Wind, solar, natural gas oil and biofuel) and the graph reveals that biofuels have a steady and progress growth as the years go by thus indicating a rich energy supply source.

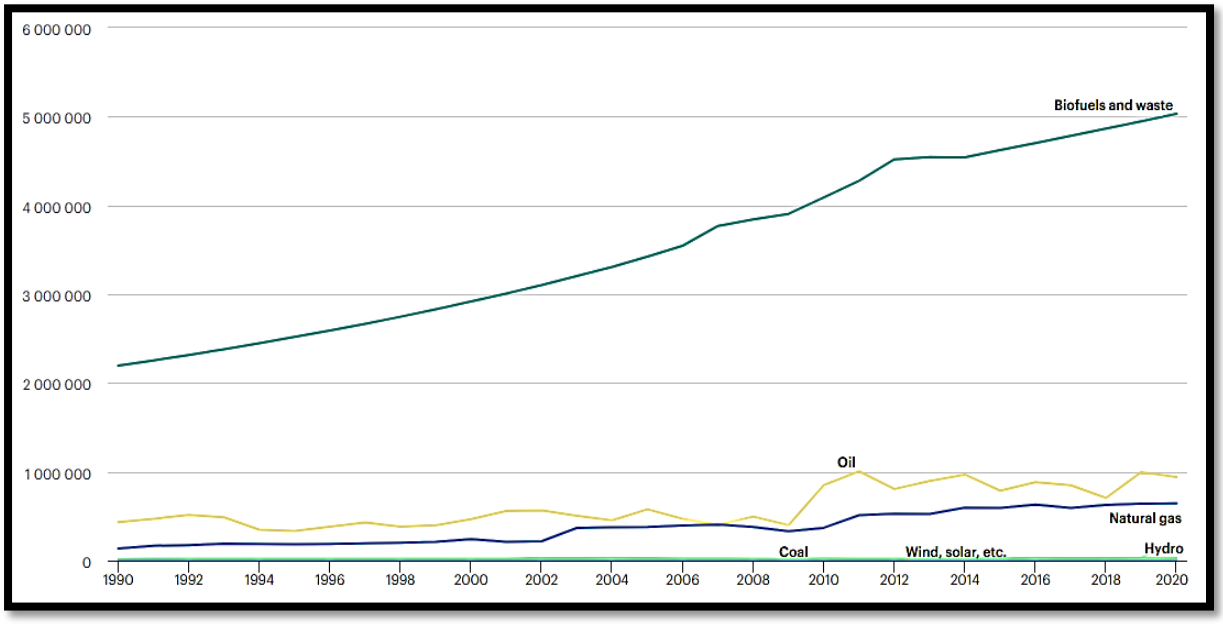

Fig 1.0: Total energy supply (TES) by source, Nigeria 1990-2020

Note: Adapted from: www.iea.org.

2.0 Biomass in Nigeria

The utilization of biomass as an energy source presents both promising opportunities and complex challenges for Nigeria. Nigeria has a total of 1160 constituted forest reserves, covering a total area of 10,752,702 ha, representing about 10% of the total land area (Sokan-Adeoga and Ana 2015), In 2005, research revealed that bioenergy reserves/potential of Nigeria stood at: fuel wood 13,071,464 ha; animal waste, 61 million tons per year; crop residues, 83 million tons (Agba *et al.,* 2010). According to Shaaban and Petinrin (2014), Nigeria has substantial biomass potential of about 144 tons per year, Oyedepo (2012) estimated that the overall biomass and bioenergy potentials in Nigeria to be about 200 billion kg/year and 2.58 billion GJ (61.67 Mtoe) respectively, representing about 51% of total energy, consumption in the country in the country in 2015. Biomass encompasses a wide array of materials derived from plants and animals, serving as versatile resources that can be harnessed for generating valuable energy in multiple forms and for a range of applications (Sambo, 2005). It has been estimated that Nigeria produces about 227,500 tons of fresh animal waste daily which when estimated with 1kg of fresh animal waste producing 0.03m^3 biogas, which points to the fact that Nigeria can potentially produce about 6.8 million m^3 of biogas every day from animal waste only (Ezugwu, 2015). This diverse range of biomass materials can be categorized based on their end-use, including fuel biomass, feed biomass, fiber biomass, organic fertilizer biomass, and chemical biomass.Biomass energy stands as a renewable and enduring energy source, harnessed from organic substances, capable of producing electricity and various other types of power. Ordinary resources suitable for crafting biomass fuel encompass materials like manure, forest detritus, discarded timber, mulch, sewage, specific crops, and select varieties of residual waste (Demirbas*et al*., 2009).It possesses the capacity for conversion into energy through an array of technological procedures, each tailored to distinct scales and applications as elucidated by Montes, Cuchietti, and Galimberti (2015). Among these, thermal conversion approaches, encompassing combustion, gasification, and pyrolysis, entail the application of heat to biomass, thereby engendering the generation of thermal energy, electrical power, or biofuels. Anaerobic digestion, operating in the absence of oxygen, enzymatically disintegrates organic matter, yielding biogas suitable for deployment in both heating and electricity production. Furthermore, biochemical mechanisms, typified by fermentation, facilitate the conversion of biomass into biofuel commodities such as ethanol and biodiesel. These versatile and adaptive conversion technologies thus furnish the means for leveraging biomass across an extensive spectrum of domains, ranging from residential heating to industrial-scale power generation. Biomass energy presents a plethora of environmental benefits, rendering it an alluring proposition for the pursuit of sustainable energy generation (Purohit and Michaelowa 2007). Foremost among these merits, the

combustion of biomass is widely acknowledged to maintain a carbon-neutral status, given that the carbon dioxide emissions resulting from combustion approximate the carbon intake during the biomass's growth phase. This stands in stark contrast to the utilization of fossil fuels, which liberate carbon compounds sequestered over geological epochs. Furthermore, biomass energy systems exhibit potential in ameliorating waste management quandaries by repurposing residues originating from agricultural and forestry activities, thereby mitigating the onus on landfill facilities.

Nigeria's rich agricultural and forestry sectors contribute significantly to its abundant biomass resources, in fact the estimated theoretical energy potential for agricultural wastes/residues and animal wastes is 5.81EJ (Jekanyifa, 2020). Various biomass sources include agricultural residues (crop stalks, husks, and shells), forest residues, animal waste (manure), and organic municipal waste. These sources are readily available, making biomass a valuable energy option for both rural and urban areas. Nigeria's overreliance on fossil fuels has not only rendered the nation susceptible to global market fluctuations but has also cast shadows on environmental sustainability and energy security. Amidst this backdrop, the significance of biomass emerges as a beacon of hope, offering an indigenous, sustainable, and decentralized solution to the country's energy conundrum. Nigeria's treasure trove of biomass resources resides within its agricultural, forestry, and waste sectors. The fertile soils of the nation bear a bounty of agricultural residues, encompassing the remnants of crop harvests, the husks of grains, and the shells of nuts. In the realm of forests and woodlands, nature's castoffs - twigs, leaves, and branches - become valuable biomass feedstock. Even in urban landscapes, organic municipal waste presents an opportunity for transformative energy generation.

Table 2.0: Biomass Energy Resource Potentials of Nigeria

Biomass Resource	**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 Waste	4.51	21.36
Animal Waste	17.69	106.39
Human Waste	2.87	28.83
Overall Total	200.18	2,582.26 (61.67 Mtoe)

Source: Francis et al., (2019)

The synopsis of Nigeria's anticipated biomass and bioenergy potentials is presented in Table 2.0 The study suggests that Nigeria could potentially generate around 200 billion kg/year of biomass and approximately 2.58 billion GJ

(equivalent to 61.67 Mtoe) of bioenergy. This assessment accounts for 51% of the nation's total energy consumption in the year 2015 (Francis *et al.,2019).*

3.0 Challenges of Biomass in Nigeria

The widespread adoption and efficient utilization of biomass for energy production in the country face several challenges that hinder its development and application, some of such key challenges to biomass/bioenergy usage in Nigeria include:

- High initial cost of installment: According to Ezealigo*et al*., 2021, currently the cost of production of biofuels is higher than the present cost of fossil fuels, this alone makes it very discouraging for the country to embark on the generation/production of biofuels. High initial cost poses a challenge when compared with other conventional energy sources in Nigeria (Olanipekun and Adelakun, 2020). Setting up a biomass/bioenergy center presently may require extra costs since it has not been established before, and it is this high initial cost that prevents the implementation and support of bioenergy policies.

- Poor regulatory framework: Just as a platform exists for the generation, collection and transmission of electricity from hydropower and thermal sources, resulting in tariffs that regulates power consumption/usage and the resultant payments, there exists none of such platforms to regulate and monitor generation, collection and transmission of power that is produced from biomass resources. This absence is a major setback to investment because these frameworks produce the estimated usage and intended profits.

- Inadequate Data and uncoordinated Research: According to Ezealigo*et al*., 2020 one of the strategies for developing biofuel plants includes assessing potential feedstock, data acquisition and establishing a database on feedstock for biofuel production (its availability, feasibility and sustainability assessment). The availability of data still remains one major setback because although by population Nigeria is the most populous nation in Africa and generates a lot of municipal and solid wastes there is still no dependable database that states in direct and measurable terms the appropriate quantities of feedstock that can sustain biomass/biofuel plants to meet the energy demands of the country's population.

- Financial Constraint: The need for adequate funding for biomass energy projects is another major challenge facing the development of biomass energy in Nigeria. Most biomass energy projects require significant financial investment, which is often difficult to obtain due to Nigeria's high

capital cost. The lack of access to funding has made it difficult for many biomass energy projects to get off the ground. Having the cost of biofuel to be significantly greater than that of fossil fuels like diesel and gasoline, financial constraint has been a leading factor (Saidu*et al.,* 2017).

- Absence of Infrastructures: In Nigeria, even though Nigeria has electricity generation potential of about 26744 GWh/yr from municipal solid waste (MSW), poor collection means/structures reflect availability capacity of only 3800 GWh/yr (Okafor *et al*., 2022). The challenge of biomass extends to the deficiency in infrastructure for the collection, characterization, generation, production and distribution of biomass energy. The essential framework required to facilitate the generation and dissemination of biomass energy, encompassing tasks like biomass collection, processing, transportation, and storage, is frequently inadequate or absent in numerous regions of the country. According to Idris et al. (2022), generation and storage of biogas and efficient use of wastes from animal parts to replace conventional firewood is plagued with the challenge of lack of equipment and infrastructure. One of the major restrictions of bioenergy commercialization in Nigeria has been the unavailability of indigenous technologies (Igbokwe *et al*., 2022).This inadequacy poses a significant obstacle to the wide scale production and distribution of biomass energy. Furthermore, there is a notable absence of both equipment and infrastructure designed for the storage of biogas intended for cooking purposes and its subsequent conversion into electricity. This situation is particularly pronounced in rural areas where there exists a pressing necessity for a dependable energy source for cooking, aiming to curtail the prevalent use of fuelwood (Nwofe, 2014).

- Inefficient Use of Biomass Resources: Another challenge facing the development of biomass energy in Nigeria is the inefficient use of biomass resources. Many households and businesses in Nigeria use inefficient stoves and ovens for cooking and heating, which leads to the wastage of biomass resources. The inefficient use of biomass resources not only reduces the availability of these resources but also contributes to environmental degradation through the generation of greenhouse gases that tend to trigger environmental/climatic issues.

- Absence of Government Policies for Support: Insufficient governmental backing represents a significant hurdle impeding the advancement of biomass energy within Nigeria. Regrettably, the government's provision of support for biomass energy initiatives has fallen short, marked by the absence of policies aimed at fostering the adoption of biomass energy.

This dearth of official support has created a challenging environment for private investors seeking to engage in biomass energy projects/investment.To catalyze progress, it is imperative for the government to establish a comprehensive and consistent policy framework. Such a policy would serve as a robust foundation, inviting collaboration from diverse stakeholders including industries, non-governmental organizations (NGOs), research institutes, and private investors (Bassey, 2010). According to Adepoju*et al*., 2018, inconsistency of policies overtime has hampered the gradual incorporation of bioenergy as many policies designed to solve energy crisis never made it into bill/law. Also, Aliyu *et al*., 2017, points out that poor policy formulation and implementation could be critical factors hindering biomass-energy (biofuel) wide-scale adoption in Nigeria. If such policies are incorporated, the envisioned policy should encompass a spectrum of sectors including funding mechanisms, subsidization strategies, extension of informational resources, tax incentives, investment facilitation, and the endorsement of standardized biofuel blends.By enacting this overarching policy, the government can effectively invigorate the biofuel industry. It would provide the necessary impetus for collective efforts from various sectors, propelling the nation towards sustainable and innovative biomass energy solutions.

- Public Acceptance: As the world shifts towards sustainable and renewable energy sources, biomass has emerged as a promising avenue for reducing carbon emissions and meeting energy demands. However, the successful integration of biomass into the energy landscape hinges not only on technological and economic factors but also on garnering public acceptance and support. In Nigeria, like in many countries, public acceptance presents a significant challenge that must be addressed to fully leverage the potential of biomass energy. While biomass energy offers undeniable environmental benefits and the potential to bolster energy security, several factors contribute to the resistance and hesitancy observed within Nigerian society such as: cultural perception, economic consideration, land use competition, sabotage and environmental impact. In overcoming these barriers, a multifaceted approach is required, which could include education and awareness campaigns, community engagement, policy support, and technology demonstration.
- Competition from Oil Industries: Presently, the country is dependent on fossil fuel plants to generate energy and these are supported by existing oil companies/industries. This already established arrangement poses a challenge since the adoption of biomass/bioenergy and other renewable energy sources will arbitrarily take such companies/industries out of business thereby increasing the chances of corrupt practices in the forms

of bribes to prevent the acceptance of biomass and its policies. A critical barrier to adoption of renewables and biomass utilization is the competition from oil industry, competitive oil prices and the initial high investment cost of renewables (Adepoju*et al*., 2018).

4.0 Prospects of Biomass in Nigeria

According to Igbinovia (2014) an estimated 200 million tons of dry biomass is obtainable from forage grasses and shrubs, producing a total of 2.28 x 10^6 MJ of energy. More than 71% of the generated municipal solid waste (MSW) in Nigeria are combustible and have energy potentials (Ibikunle*et al*., 2019); Nigeria has the potential to produce 7.5 million m^3 of bioethanol per annum 62% (4.7 million m^3) obtainable from agricultural residues (Awoyale and Lokhat, 2019).This implies that biomass utilization holds significant prospects for sustainable energy production and environmental benefits in Nigeria due to the large expanse of land which is covered by luxuriant growing trees and shrubs which can also be converted to biomass/bioenergy resources. The country's abundant biomass resources, coupled with increasing energy demand and environmental concerns, present opportunities for harnessing biomass for various applications.Theareas of which key prospects are associated with biomass use in Nigeria is outlined as follows.

- Renewable Energy Generation:Biomass has the potential to contribute significantly to Nigeria's renewable energy mix. As a country with rich agricultural and forestry sectors, biomass feedstock such as crop residues, wood waste, and animal manure can be efficiently converted into bioenergy through processes like combustion, gasification, and anaerobic digestion. This could alleviate the strain on fossil fuel-based electricity generation, reduce greenhouse gas emissions, and enhance energy security (Diji, 2013).
- Rural Electrification:Biomass energy systems, such as biogas digesters and biomass-powered mini-grids, offer a promising avenue for providing electricity to rural and underserved communities. These systems can improve energy access, support local economic activities, and enhance the overall quality of life in rural areas where grid connection is challenging as well as non-existent (Ogunwo, 2022).
- Agricultural and Waste Management: The popular statement of ‘‘waste to wealth’’ which is heard everywhere is one that encourages biomass energy. Biomass utilization can help address agricultural waste management challenges in Nigeria because resultant waste materials through proper characterization can serve as feedstock for energy generation, organic manure or even bio char for soil amendment. Crop residues and other organic waste can be processed into biofuels, bio fertilizers, and biogas, reducing the environmental impact of waste

accumulation and promoting sustainable agricultural practices (Koul*et al.,* 2022).

- Job Creation and Economic Growth:The development of biomass value chains, including collection, processing, and distribution, has the potential to create employment opportunities along the biomass supply chain. From farmers growing biomass feedstock to technicians maintaining bioenergy systems, biomass utilization could contribute to local economic growth and rural development. The report by Kartha and Leach (2001) emphasizes the potential of modern bioenergy to reduce rural poverty, aligning with the opportunities presented by biomass utilization, considering village-scale biomass energy as a means of providing modern energy services to the billions who lack them, thus helping to reduce poverty making it affordable and sustainable.
- Climate Change Mitigation:By substituting fossil fuels with biomass, Nigeria can make strides in mitigating climate change because fossil fuels generate greenhouse gasses which cause degrading environmental issues associated with global warming and ozone layer depletion.Nigeria has set a goal of achieving a reduction of 50% over pre-industrial levels in global greenhouse gas emissions by 2030. To achieve this, Nigeria needs to take significant steps towards mitigating the impacts of climate change, including investing in renewable energy, improving energy efficiency, encouraging sustainable transportation, adopting sustainable agricultural practices, reducing deforestation, encouraging waste management, and collaborating with the international community.(Oyedepo, 2012)
- Improved Indoor Air Quality:Transitioning from traditional biomass cooking methods to cleaner and more efficient cookstoves or biogas systems can have significant health benefits.Improved indoor air quality from reduced smoke and pollutants can lead to a decrease in respiratory diseases, can reduce respiratory illnesses, lower respiratory infections, and other health issues associated with indoor air pollution, particularly affecting women and children in households(Saad and Bugaje, 2016).

Conclusion

Nigeria's energy landscape stands at a pivotal juncture, marked by the intricate interplay of diverse resources, challenges, and prospects. The exploration of biomass as an alternative energy source reveals both the potential for transformative change and the hurdles that must be overcome to realize this potential.Despite the challenges and prospects of biomass in Nigeria, there is a path towards sustainable energy development, as biomass offers avenues for renewable energy generation, rural electrification, agricultural and waste management improvements, job creation, climate change mitigation, and enhanced indoor air quality. These prospects align with Nigeria's aspiration for a resilient and environmentally responsible energy future. The following are

suggested ways in which biomass can be considered as a solution to the energy demands of the country and these include;

- Inculcation of biomass energy into the existing energy grid of the nation at a ratio to substitute already overloaded areas.
- Public awareness through widespread seminars and workshops on the prospects of biomass energy so as to instill public acceptance.
- Establishment of a detailed database on the available biomass energy feedstock(s) through in-depth research so as to ascertain sustainability and accessibility.
- Provision of sustainable platform/frameworks for biomass through policy implementation for biofuel generation that attracts investors within and outside the country (Awodumi and Adewuyi, 2020).
- Development, enactment and implementation of biomass/bioenergy policies that will allow the use of biomass as an alternative source of power and as well encourage investment into the sector.
- Provision of regulatory bodies and firms to provide adequate regulations on the use, collection and consumption of biomass energy,
- Installment/construction of waste recycling plants that are able to convert raw biomass resources into forms that can ensure sustainable and environmentally friendly usage.
- Government assistance in providing recent technologies that encourage the application of biomass/bioenergy resources.
- Establishment of dependable partnerships either with international or local investors to encourage the use of biomass/bioneregy.

The review underscores the importance of integrated approaches involving public and private stakeholders, policymakers, researchers, and communities. The comprehensive consideration of biomass energy within Nigeria's energy mix has the potential to alleviate fossil fuel dependency, bolster energy security, mitigate climate change, and enhance the well-being of its citizens.

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