Minireview Article
Energy-Mix Diversification and Renewable Energy Development in Nigeria and South Africa

ABSTRACT

The increasing global demand for energy access and security is a critical issue that has significant implications for sustainable development, economic growth, and environmental sustainability worldwide. Perhaps more specifically, this development has continued to be a major source of concerns for the energy sector development in both Nigeria and South Africa. Renewable energy plays a crucial role in addressing the problem of greenhouse gas emissions by offering clean and sustainable alternatives to fossil fuel-based electricity generation. The adoption of renewable energy alternatives in both countries to provide clean and reliable power supply to their citizens is a major step at attempting to alleviate the effects of greenhouse emissions. In the quest for sustainable energy systems and reduced reliance on fossil fuels, countries around the world are increasingly turning towards energy mix diversification and the development of renewable alternatives. This paper focuses on the efforts of Nigeria and South Africa in diversifying their energy mixes and promoting the development of renewable energy sources to meet their growing energy needs while addressing environmental concerns and fostering sustainable development. Finally, it presents recommendations on the steps that can further drive the integration of renewable energy technologies into the present energy mix of both countries.

Keywords - energy mix, energy security, sustainable growth, climate change, renewable sources

1 INTRODUCTION

In the quest for sustainable energy security and reduced reliance on fossil fuels, countries around the world are increasingly turning towards energy mix diversification and the development of renewable alternatives [1]. The idea of an energy mix refers to the combination of different energy sources used for power generation and consumption, particularly within a country. This is because a well-balanced energy mix is expected to enhance energy security, affordability, environmental sustainability, and energy system resilience [2].

Without doubt, energy mix development is a complex and dynamic process that involves balancing various considerations to achieve a sustainable energy security. However, by embracing innovation, collaboration, and strategic planning countries can successfully transition towards a diversified energy mix that meets their needs for sustainable socio-economic growth [1] [36]. Additionally, diversifying the energy mix will reduce dependence on a single energy source, mitigating risks of supply disruptions or price fluctuations. Energy mix with a higher share of renewable sources will help reduce carbon emissions and combat climate change; enhance energy affordability, promote innovation, and create new job opportunities in the energy sector; as well as improve grid stability and resilience to fluctuations in supply and demand [32]. As the world transitions towards a clean energy future, the expansion of renewable energy sources plays a critical role in mitigating climate change, promoting energy access, and building a more resilient and sustainable energy mix for future generations [26][27].

1.1 Global Demand for Energy Access and Security

The increasing global demand for energy access and security is a critical issue that has significant implications for sustainable development, economic growth, and environmental sustainability worldwide [34]. This is because expanding energy access is crucial for improving living standards, healthcare, education, and economic opportunities. Additionally, the United Nations has set a target to ensure universal access to affordable, reliable, and modern energy services by 2030 [23][27]. However, a significant portion of the global population, especially in rural areas of developing countries, such as Nigeria and South Africa still lack access to reliable and affordable electricity. Other issues include the dire need for diversification of energy sources to address the challenges of overdependence on fossil fuels as energy source, as well as the need to develop a resilient energy infrastructure that can withstand disruptions in supply.

Transition to renewable energy involves a shift from conventional energy sources to renewable energy sources like solar, wind, hydro, and geothermal power and it is crucial for enhancing energy security and reducing greenhouse gas emissions. Other issues in the front burner of global discourse include: decentralized energy systems to improve energy access in remote areas and enhance energy security by reducing dependence on centralized grids as well as smart technologies for grid modernization to enhance efficiency, reliability, and resilience. Therefore, comparing Nigeria and South Africa in terms of renewable energy development offers valuable insights into the diverse approaches, challenges, and opportunities that these two major African economies face in transitioning towards a sustainable energy future. Therefore, this paper is aimed at conducting a review of Nigeria's and South Africa's energy mix diversification process and renewable energy development. This is with the view of examining the trends in the development of the energy sector of the two countries.

2 TRENDS IN NIGERIA'S ENERGY MIX DIVERSIFICATION

As the most populous nation in Africa with over 200 million citizens, Nigeria is rich in various energy resources, but has yet to fully harness the potential of these resources for sustainable socio-economic development [2] [28]. Put differently, in spite of the abundance of renewable energy sources such as solar, wind, hydro, and biomass in Nigeria, their utilization remains low and the nation has traditionally relied heavily on fossil fuel for power generation. This overdependence on fossil fuel has posed challenges such as power supply disruptions due to irregular fuel supply, environmental degradation as a result of greenhouse gas emission, and energy price volatility due to ineffective policy implementation [1] [3] [4] [5] [6].

Renewable energy development has considerable potential for socioeconomic growth in Nigeria, and could bridge the major energy gaps in rural areas. Recent studies credibly put concentrated solar thermal power potential in Nigeria at over 427,000MW [5][6]. Present available power generation capacity of around 5000MW meet only a fraction of demand, and renewable energy could play an escalating role. Large-scale renewable power generation will definitely transform the nation's economy [4].

The International Renewable Energy Agency (IRENA) noted that Nigeria is endowed with abundant renewable energy resources – namely solar, wind, hydro and biomass - that can be harnessed to scale up its energy supply and achieve universal energy access, energy security and the reduction of greenhouse gas emissions for climate change mitigation [8]. Energy consumption in the country is expected to continue to increase due to a rising population and increase in the socio-economic activities of the people. It further noted that Nigeria is at a key juncture in time; with a growing population and a range of socio□economic challenges, it requires sustainable energy sources to meet the growing needs for all the sectors of its economy and achieve universal access to modern energy services [1].

Nigeria's electricity supply system can be grouped into two: centralised (grid-connected) and decentralised (off-grid) systems [8]. The centralised system consists of the large-scale generation of electricity at centralised facilities such as large hydro and thermal plants. The decentralized electricity supply system consists of a few kilowatts to megawatt capacities such as captive diesel and gasoline generator sets as well as renewable energy technologies such as solar home systems, streetlights and mini-grids. Available data as at 2024 indicated that the total installed capacity of grid-based systems in Nigeria is between 13 GW to 13.5 GW. However, the available on-grid peak generation is around 4.0 GW to 4.5 GW [3][4] [8]. Nigeria's on-grid generation is dominated by natural gas power stations (86%) and large hydropower plants (14%) [12]. However, unavailability of gas, machine breakdowns, seasonal water shortages and limited grid capacity have severely limited the operational performance of these power plants. This situation has led to acute shortages of electricity supply across the country [9]. Efforts are underway to accelerate the transition to an adequate electricity generation capacity that can meet the current and future demand of Nigerian citizens and their businesses [11].

2.1 International Cooperation for Energy Development in Nigeria

In 2023, the World Bank approved for Nigeria, the Distributed Access through Renewable Energy Scale-up (DARES) project. This was designed to be financed by an International Development Association (IDA) credit of $750 million [26]. Additionally, the project will leverage over $1 billion of private capital and significant parallel financing from development partners, including $100 million from the Global Energy Alliance for People and Planet and $200 million from Japan International Cooperation Agency [27]. Other development partners collaborating on the program include the United States Agency for International Development (USAID), the German Development Agency (GIZ), Sustainable Energy for All (SEforAll) and the African Development Bank (AfDB). The DARES project aims to provide over 17.5 million Nigerians with new or improved access to electricity through distributed renewable energy solutions. The DARES project is expected to adopt innovative financing solutions to scale up private sector led clean electricity provision in Nigeria [26].

The Sustainable Energy for All (SEforAll) is a global initiative that aims to ensure universal access to modern energy services, doubling the global rate of improvement in energy efficiency, and doubling the share of renewable energy in the global energy mix by 2030. This initiative was launched by the United Nations in 2011 with the goal of addressing energy challenges, such as energy poverty, climate change, and sustainable development. Through partnerships with governments, businesses, civil society organizations, and international institutions, the SEforAll initiative works to mobilize resources, share best practices, and drive action towards achieving its objectives. Perhaps most significantly, under the SEforAll initiative, Nigeria targets electricity generation of 30GW by 2030 with 30% renewable energy integration [3] [26].

Various energy policy initiatives have been proposed and implemented in Nigeria to address the country's energy challenges and diversify the energy mix for sustainable development. These energy policy initiatives include: National Renewable Energy and Energy Efficiency Policy (NREEEP), Rural Electrification Strategy and Implementation Plan (RESIP), Electric Power Sector Reform Act (EPSRA), National Renewable Energy Master Plan (REMP), Off-Grid Electrification Strategy (OGES). The NREEEP was designed to increase the share of renewable energy in Nigeria's energy mix, and improve energy efficiency through regulatory frameworks [53]. RESIP was established to focus on expanding access to electricity in rural and underserved areas through off-grid and mini-grid solutions, leveraging renewable energy sources [52]. EPSRA established the legal framework for the privatization and reform of Nigeria's electricity sector, aiming to attract private investment and enhance competition. The REMP provided a roadmap for the development of renewable energy resources in Nigeria, setting targets for renewable energy deployment, identifying investment opportunities, and guiding policy interventions to support renewable energy growth [54]. OGES focuses on promoting off-grid solutions, including solar home systems and mini-grids, to provide electricity to communities without access to the main grid and improving energy access in underserved areas [51]. These energy policy initiatives in

Nigeria underscored the government's commitment to addressing energy challenges, promoting sustainable energy development and driving economic growth.

The development and implementation of a comprehensive national policy on renewable energy and energy efficiency are crucial for Nigeria to achieve sustained best practices in the energy sector beyond 2030 [10] [33]. Challenges currently facing the diversification of energy mix in Nigeria include: inadequate grid infrastructure, financing and investment barriers, policy and regulatory uncertainties, as well as lack of adequate energy expertise [13][26][27]. Nigeria's electricity grid has significant limitations in terms of capacity and reliability, which hinders the integration of renewable energy sources. Securing adequate financing for renewable energy projects remains a challenge due to the perceived higher risks compared to traditional fossil fuel projects [29][30][39]. Inconsistent policies and regulatory changes have created an uncertain environment for renewable energy investors and developers. Additionally, there is a shortage of technical expertise and skilled workforce to support the growth of the renewable energy industry in Nigeria [1][6][5].

2.2 Diversification of energy-mix through domestic production in Nigeria

Nigeria has a tropical climate and hence well-suited for solar energy projects. Average temperatures range from 25°C to 35°C (77°F to 95°F) depending on the region and season. The temperature in the northern regions is generally higher than the southern coastal areas [45]. Sunlight is abundant due to Nigeria's location near the equator. Average annual sunshine hours of 2877.5 hours for Maiduguri, 2435.4 hours for Minna and 1474.2 hours for Port Harcourt were reported [45]. Annual rainfall varies across the country, with the southern regions receiving more rainfall than the arid northern regions. Annual rainfall is above 2,000 mm, indicating a high precipitation rate. In specific areas like the Niger Delta, annual rainfall amounts can exceed 4,000 mm (World Bank, 2024). In addition, sunlight is abundant due to its location near the equator. Average annual sunshine hours of 2877.5 hours for Maiduguri, 2435.4 hours for Minna and 1474.2 hours for Port Harcourt were reported [45].

Diversifying the energy mix through domestic production in Nigeria refers to the strategic approach of broadening the sources from which the country generates its energy within its own borders [33]. This strategy involves reducing dependence on a single energy source, typically fossil fuels, by incorporating a variety of energy resources that are produced locally [32]. Nigeria has been making efforts to diversify its energy mix through domestic production by focusing on various initiatives and strategies. These efforts collectively aim to diversify Nigeria's energy mix through increased domestic production of renewable energy, reduce carbon emissions, enhance energy security, and promote sustainable development in the country [29].

As shown in Table 1 there is a steady increase in coal production at the domestic level from 7,791 TJ to 65,531 TJ between 2000 and 2015 but declined to 64,656 TJ in 2021. This indicated that the use of coal is gradually being replace by renewable energy from solar as this increased from 89 TJ to 175 TJ from 2015 to 2021. Furthermore, crude oil tops the list of domestic energy production as increased from 4,923,513 TJ in 2000 to 5,499,316 TJ in 2005 but steadily decreased from 5,407,965 TJ to 2,944,359 TJ from 2010 to 2021. This development represented a decline in the production of crude in Nigeria. The local production of natural gas increased from 426,132 TJ in 2000 to 1,494,117 TJ in 2015, however, it decreased slightly in 2021. Hydro energy production increased from 20,260 TJ to 28,594 TJ between 2005 and 2021 [11].

Table 1: Diversification of energy-mix through domestic production in Nigeria [11]

Domestic Energy Production (TJ) in Nigeria	2000	2005	2010	2015	2021
Coal	7,791	8,436	31,192	65,531	64,656
Crude Oil	4,923,513	5,499,316	5,407,965	4,535,371	2,944,359
Natural gas	426,132	828,009	1,112,884	1,494,117	1,476,355
Hydro	20,260	27,964	22,946	23,122	28,594
Wind, solar, etc.	-	-	-	89	175
Biofuels and waste	2,925,235	3,444,506	4,121,469	4,661,530	5,143,941

2.3 Diversification of electricity generation sources in Nigeria

South Africa has a varied climate due to its diverse topography. Average annual rainfall in South Africa is about 464 mm and average temperatures range from 15℃ to 36℃ in the summer and -2℃ to 26℃ in the winter [47][48]. The western regions, such as the Western Cape, experience winter rainfall, while the eastern regions have summer rainfall [49]. South Africa receives ample sunlight, especially in the northern and central regions. There is an average of 2,343 h of sunlight per year with an average of 6.4 h of sunlight per day [50]. This makes the country well-suited for solar energy projects.

Efforts targeted at diversifying electricity generation sources in Nigeria are crucial for improving energy

security, sustainability, and access to reliable electricity across the country. Nigeria has been focusing on increasing solar power generation capacity through large-scale solar projects and off-grid solar solutions to tap into the country's abundant solar resources. Additionally, initiatives have been launched to develop wind power projects, particularly in regions with high wind potential, to diversify the electricity generation mix. The nation’s hydropower capacity is undergoing expansion through the development of new hydroelectric dams and upgrading of existing facilities. As presented in the report of the International Energy Agency (IEA) in Table 2, natural gas represented the highest energy source for electricity generation in Nigeria with a value of 28,045 TJ in 2021. This is followed by hydro energy with a value of 7,942 TJ. The transition into solar energy started in 2015 with a value of 25 TJ and increased to 48 TJ in 2021 [11]. This showed that despite the demonstrated benefits of renewable sources, the adoption of renewable energy technologies in Nigeria’s energy mix is still growing at a slow pace compared with what is obtainable in other countries like South Africa.

Table 2: IEA data for electricity generation sources in Nigeria [11]

Electricity Generation (GWh) in Nigeria	2000	2005	2010	2015	2021
Natural gas	9,099	15,771	19,747	26,697	28,045
Hydro	5,628	7,768	6,374	6,423	7,942
Solar PV	-	-	-	25	48

Overall, Nigeria has made some progress in diversifying its energy mix and increasing the share of renewable energy, but significant challenges remain to achieve its ambitious renewable energy targets. Continued policy support, infrastructure investments, and capacity-building efforts will be crucial to accelerate the deployment of renewable energy solutions in the country.

3 TRENDS IN SOUTH AFRICA’S ENERGY MIX DIVERSIFICATION

South Africa's energy landscape presents a unique situation where the country possesses significant potential for renewable energy sources like biomass, wind, and solar energy, yet relies heavily on coal as its primary fuel source. This mix of abundant renewable resources alongside a strong dependence on coal poses both challenges and opportunities for the country's energy transition [14][15][16]. South Africa's state-owned utility, Eskom, has historically been one of the largest and most established power providers in Africa [36]. It dominates domestic electricity production with a significant total installed capacity of about 49 GW [17] to serve an estimated population of 64 million citizens [27]. Grid constraint, climate change challenges and increasing demand for electricity in South Africa created a need to up-scale generation capacity from alternative sources [18].

In view of the foregoing, the strategic environmental assessment (SEA) was designed to enable proactive spatial planning for wind and solar PV energy developments in South Africa. The SEA takes a strategic and integrated approach to identifying geographical areas in which large scale wind and solar PV development would be most appropriate, taking into consideration environmental, social and economic factors [20]. In South Africa, 18 Strategic Integrated Projects (SIPs) have been developed to fast-track development and growth of social and economic infrastructure across all nine provinces. Among the 18 SIPs, SIP 8 targets the development of green energy in support of the South African economy and SIP 10 targets the provision of electricity transmission and distribution for all [24].

The Integrated Resource Plan (IRP) in South Africa is a crucial long-term planning document that outlines the country's strategy for new electricity generation capacity. The IRP serves as a roadmap for the development of the energy sector, guiding decisions on the mix of energy sources to meet present and future electricity demand sustainably and reliably. The IRP envisages adding 14,400MW of wind and 6,400MW of solar PV, including some additional 4,000MW of embedded generation and 2,000MW of storage by 2030 [21]. South Africa's energy mix was heavily reliant on coal, with coal-fired power plants playing a significant role in electricity generation, providing 80% of the total system load [22]. This makes

South Africa one of the world's top 15 greenhouse gas (GHG) emitters. The energy sector contributes nearly 80% of the country's GHG emissions [22][23]. In December 2009, South Africa committed to a reduction in greenhouse gas emissions from its emissions growth trajectory by 34% in 2020, and by 42% in 2025 in line with the agreements of the United Nations Framework Convention on Climate Change (UNFCCC) [23].

3.1 Diversification of energy-mix through domestic production in South Africa

In South Africa, the power utility agency, Eskom, has faced significant financial and operational difficulties, which have impacted the country's electricity supply and hindered the integration of renewable energy. The country's aging and insufficient grid infrastructure has posed challenges in transmitting and distributing renewable energy generated from remote locations [14]. In spite of these challenges South Africa's combination of integrated policymaking, strong regulation, well-designed incentives for low carbon investment including private investment and greater efficiency give it enviable strength for the task [38].

As shown in Table 3, coal production at the domestic level has continued to dominate energy production in South Africa with a value between 5 million TJ and 6 million TJ from year 2000 to 2021. This is followed by biofuel and waste production which has declined from 454,276 TJ to 244,678 TJ from year 2000 to 2021. As at 2021, nuclear energy production came third in terms of domestic production with a value of 134,781 TJ, followed by wind and solar energy with a value of 71,482 TJ. Hydo, crude oil and natural gas came last in terms of domestic production in the country [23].

Table 3: Diversification of energy-mix through domestic production in South Africa [23]

Domestic Energy Production (TJ) in South Africa	2000	2005	2010	2015	2021
Coal	5,314,150	5,793,067	6,032,381	6,065,922	5,416,351
Crude Oil	39,501	35,713	20,695	16,615	1,910
Natural gas	58,521	74,678	52,776	40,344	1,312
Nuclear	141,927	123,196	131,989	133,494	134,781
Hydro	3,963	4,795	7,610	2,916	7,347
Wind, solar, etc.	-	787	2,890	22,654	71,482
Biofuels and waste	454,276	344,120	315,451	242,601	244,678

Additionally, Table 4 presents energy mix for electricity generation in South Africa. It is shown that coal is the dominating fuel source for electricity generation, followed by nuclear, wind and solar sources [36]. This shows that South Africa has made significant progress in the transition to renewable energy ahead of Nigeria.

Table 4: IEA data for electricity generation source in South Africa [23]

Electricity Generation (GWh) in South Africa	2000	2005	2010	2015	2021
Coal	193,419	229,073	242,001	228,572	209,557
Crude Oil	-	78	197	183	327
Nuclear	13,010	11,293	12,099	12,237	12,355
Hydro	3,934	4,199	5,067	3,729	6,784
Biofuels	307	267	203	298	350
Wind		12	34	2,500	8,356
Solar PV	-	-	-	1,946	5,001
Solar thermal	-	-	-	190	1652

In view of the above, when compared to Nigeria, South Africa has indeed made significant progress in the transition to renewable energy, particularly in the power sector. Nigeria has been slower in its transition to renewable energy despite having vast renewable energy potential, including solar, wind, and hydro resources.

Challenges such as policy inconsistencies, regulatory barriers, funding constraints, and reliance on oil and gas have hindered Nigeria's progress in renewable energy development [37]. However, Nigeria has also been taking steps to promote renewable energy, such as launching solar power projects, exploring off-grid solutions, and setting renewable energy targets. With continued efforts and investments, Nigeria has the potential to accelerate its transition to renewable energy [31] and catch up with countries like South Africa in the transition to renewable energy.

Perhaps equally important is the increasing recognition of hydrogen fuel cells (HFC) as an emerging energy source that can play a significant role in diversifying the energy mix of countries around the world. The development of HFC industry is an important aspect of the transition towards cleaner and more sustainable energy systems. As noted by Azni and Khalid [41], the formulation of enabling policies, and action plans by government plays a crucial role in encouraging the private sector to invest in the HFC industry. In the case of Nigeria, transitioning to a hydrogen energy economy represents a significant long-term goal rather than an immediate reality. Many nations globally have conducted impact assessment studies to evaluate the feasibility and suitability of integrating hydrogen energy systems into their economies [44]. In South Africa, however, the Hydrogen South Africa (HySA) was initiated to focus on the research, development, and commercialization of hydrogen and fuel cell technologies. The program was aimed at leveraging the country's abundant renewable energy resources, such as wind and solar power, to produce green hydrogen as a clean and sustainable energy carrier. The implementation of HySA involved three phases to ensure the successful development, deployment, and commercialization of hydrogen and fuel cell technologies. The first phase of the HySA program from 2008 to 2013 was focused on establishing robust Research and Development capabilities in the field of hydrogen and fuel cell technologies. This phase aimed to lay the foundation for future innovation, collaboration, and technological advancements within the program. The second phase spanned 2013 to 2018 and was focused the demonstration and validation of hydrogen fuel cell (HFC) technologies in South Africa. The third which centered on HFC technologies commercialization in South Africa [42].

4 CONCLUSION AND RECOMMENDATIONS

In summary, South Africa's energy mix, on the one hand, has historically been dominated by coal, with on-going efforts targeted at diversifying and incorporating more renewable energy sources. South Africa has abundant renewable resources, offering significant opportunities for renewable energy development [40]. Challenges facing energy mix diversification in South Africa include dominance of coal in its energy mix, regulatory hurdles, grid constraints, etc. In this regard, South Africa has made significant strides in renewable energy deployment, particularly through the Renewable Energy Independent Power Producer Procurement Program (REIPPPP), which has facilitated the integration of renewable energy into the grid. Still there is need for the south African government to continue to support the growth of renewable energy through policy incentives and regulatory frameworks. By so doing, South Africa can accelerate the transition to a more sustainable and diversified energy mix for sustainable economic growth, leverage its renewable energy potential, and contribute to the protection of the environment in the country.

On the other hand, Nigeria's energy mix is heavily reliant on fossil fuels, with limited utilization of renewable energy sources despite the country's abundant renewable alternative sources which include: solar, wind, hydro, and biomass, presenting diversified energy mix opportunities for sustainable development. The challenges militating against energy mix diversification in Nigeria include inadequate infrastructure, high upfront costs, technical barriers, and limited and inconsistent policy implementation. For Nigeria to catch up with South Africa in the renewable energy transition and accelerate the adoption of clean energy sources integration in its energy mix, it is recommended as follows:

i) Nigeria should establish clear and consistent renewable energy policies, targets, and regulatory frameworks to provide a stable and conducive environment for investments in the sector.

ii) Domestic and foreign investments in renewable energy projects should be encouraged through mechanisms such as feed-in tariffs, power purchase agreements, tax incentives, and financing options to attract private sector participation.

iii) Procurement with competitive bidding processes like tenders for renewable energy projects should be implemented to drive down costs, prevent corruption, increase transparency, and attract experiencedenergy developers.

iv) Renewable energy infrastructure, including grid expansion, modernization, and energy storage systems should be invested in to integrate variable renewable energy sources into the grid effectively.

v) Access to electricity in rural and underserved areas should be expanded through off-grid and mini-grid solutions powered by renewable energy sources, promoting energy access and decentralization.

vi) Training programs and capacity building should be promoted to develop local expertise in renewable energy technologies, project development, operation, and maintenance.

vii) Research and development initiatives should be supported to drive innovation in renewable energy technologies, increase efficiency, and reduce costs of renewable energy systems.

viii) Collaborations between the public and private sectors should be fostered to leverage expertise, resources, and funding for the development of renewable energy projects and initiatives.

ix) Energy efficiency programs across sectors should be promoted to reduce energy demand, optimize energy use, and complement renewable energy deployment for a more sustainable energy transition.

x) Collaboration with international organizations, development partners, and financial institutions should be pursued to access technical expertise, funding, and best practices in renewable energy development.

xi) Awareness among stakeholders, including policymakers, businesses, communities, and the public should be created about the benefits of renewable energy and the importance of transitioning to clean and sustainable energy sources.

xii) Efficient waste management scheme should be provided especially in rural areas, so more household wastes and agricultural residues can be efficiently collected and utilized for biomass production.

By implementing the above recommendations, Nigeria can accelerate its transition to renewable alternative sources in its pursuit of diversified energy mix, increase energy access and security, reduce carbon emissions, and catch up with South Africa in the energy transition process. It will require a concerted effort from the government, private sector, and other stakeholders to effectively drive the diversification of energy mix and sustainable development of the renewable energy sector for improved electricity supply in Nigeria.

Disclaimer (Artificial intelligence)

Author hereby declares that NO generative AI and text-to-image generators have been used during the writing or editing of this manuscript.

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