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Clean energy for a better Nigeria: Strategies for promoting renewable energy and reducing air pollution

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Abstract:

The growing threat of climate change poses major challenges to global energy infrastructures. In order to mitigate these consequences, Nigeria's fossil fuel-dominated energy industry needs to undergo a profound transition. This study investigates green energy integration as a means of achieving long-term decarbonisations. A thorough examination of existing green energy options indicates progress and gaps in the transition to a net-zero carbon environment. The study identifies major impediments to energy sector decarbonisation, such as low adoption of energy-efficient technologies and insufficient policy frameworks. To overcome these problems, the report proposes for a comprehensive approach to green energy integration, with the goal of meeting 60% of Nigeria's energy demand from green sources by 2050. This can be accomplished through energy-efficient technology, public-private collaborations, regulatory changes, and a transition away from fossil fuel dominance and toward a green energy economy. The paper utilizes secondary data to form its recommendations, which are in line with global decarbonisations targets for 2060. The findings are useful for energy stakeholders and investors, as they identify prospects for the spread of sustainable energy technology in Nigeria. A shift to a low-carbon economy can increase energy security, lower greenhouse gas emissions, and boost economic growth. Nigeria can reduce the effects of climate change and assure a sustainable future by switching to a green energy economy. This report provides a path for Nigeria's energy sector transformation, with a focus on sustainable development and climate resilience.

Keywords: *Renewable Energy, Sustainable Development, Climate Change, Energy Transition*

1. Introduction

Renewable Energy is pivotal for Nigeria's socio-economic growth, catalysing industrial development and economic activation. Africa faces pronounced challenges in fostering socio-economic progress and poverty alleviation, largely due to limited access to clean, modern energy services (Shao, *et al.,* 2025). Globally, the energy sector accounts for approximately 75% of CO_2 emissions (Saleh, *et al.,* 2021), driving climate change impacts like rising temperatures, sea level increases, ecosystem disruption, and extreme weather events. Nigeria, heavily reliant on fossil fuels (oil, natural gas, coal), is acutely vulnerable to climate change consequences. Fossil fuel utilisation precipitates significant CO_2 emissions, contributing to adverse outcomes including heightened temperatures, altered precipitation patterns, and ecological degradation. Climate change is projected to cause circa 250,000 annual deaths from related diseases between 2030 and 2050 (Ravanipour, *et al.*, 2024). Transitioning from fossil fuel dominance is thus imperative. Nigeria pledged at COP Glasgow to attain a net-zero carbon economy by 2060 (IEA, 2023), necessitating holistic policy shifts and greenhouse gas mitigation strategies aligned with the 2015

Paris Agreement goal of limiting warming below 2°C. Realising this requires engineering-driven solutions: applying technologies and innovations to decarbonise the energy sector, fostering a sustainable, low-carbon economy (Okwonko, *et al.,* 2021).

Carbon-neutral renewable energy sources such as hydroelectric, biomass, solar, and wind power offer a transformative pathway for Nigeria's sustainable energy expansion (Saleh, *et al.,* 2021). Adoption of RES technologies can catalyse economic growth, satisfy energy demand, generate employment opportunities, and bolster socioeconomic development. Projections indicate RES could fulfil approximately 60% of Nigeria's energy requirements by 2050 (Abe, *et al.,* 2024). Climate change's adverse impacts manifesting as droughts, sea level rise, and extreme heat pose pronounced sustainability challenges in Nigeria (Bello, 2024), a country highly vulnerable to such effects. The nation's greenhouse gas emissions originate predominantly from three sectors: energy (notably fossil fuel utilisation), agriculture, and waste management.

Several authors have explored integration of Renewable Energy Sources (RES) technologies into the grid, aiming for a sustainable future energy system (Abubakar, *et al.,* 2024; Adedoja, *et al.,* 2023; Erifeta, 2025; Omotoso, *et al.,* 2025; Asuni, *et al.,* 2025; Bello and Orosun, 2025).

Adeshina, *et al.* (2024) focused on energy sector development via renewable energy integration and policy reforms, assessing existing policies against universal electricity access goals for 2030. This also is in agreement with the studies conducted by Khang, *el al.* (2023) and Liza, *et al.* (2024).

Using a multilevel perspective, Ogbonna, *et al.* (2023) evaluated Nigeria's policy shift to low-carbon pathways, analysing data from literature, documents, and empirical sources. Findings revealed uncertainties and political barriers in current low-carbon transitions, recommending synergistic use of natural resources and management systems for carbon neutrality by 2060.

Tanko, *et al.* (2023) Delved into Nigeria's transition to net-zero emissions, spotlighting design aspects, emerging technologies, and sectors like agriculture, transportation, energy, and industry. It underscored sustainable practices, RES, energy efficiency for carbon reduction, and the importance of international cooperation, technical innovation, and governmental backing. Meanwhile, Okafor, *et al.* (2025) highlighted climate change impacts like droughts, sea level rise, and extreme heat posing pronounced sustainability challenges in Nigeria, a country highly vulnerable to such effects. Furthermore, as reported by Imarhiagbe, *et al.* (2025), there exist a significant cross-disciplinary link between air pollution, the climate crisis, and sustainable lifestyles, representing some of the most complex challenges of the 21st century. These interconnected issues require multifaceted approaches touching on environmental science, policy, technology, and human behaviour

This study evaluates sustainable decarbonisation of Nigeria's energy sector through green energy solutions, examining extant strategies and their implementation toward a net-zero carbon environments. The research highlights the imperative for holistic green energy technology integration, targeting circa 60% of Nigeria's energy demand via Renewable Energy Sources (RES) by 2050 (Chibueze, *et al.,* 2025).

2. Methodology

This study employed a qualitative research approach, incorporating expert interviews, case studies, and a comprehensive literature review on sustainable decarbonisation of Nigeria's energy sector. Insights were garnered from stakeholders in energy, transportation, environmental, and industrial sectors to discern effective strategies for transitioning from a fossil fuel-dominated economy to a green energy economy. Data were sourced from government reports, publications, and relevant stakeholders.

The research evaluated green energy solutions for Nigeria's energy sector decarbonisation, examining extant strategies and implementation levels toward a net-zero carbon environments. Crucial barriers and challenges impeding energy sector decarbonisation were identified. Emphasising holistic green energy technology integration, the study posits meeting circa 60% of Nigeria's energy demand via green sources by 2050. Secondary data analyses assessed availability, utilisation, and adoption levels of green energy technologies.

3. Result and discussion

Nigeria's CO_2 emission profile, depicted in Figure 1, indicates a rise from 121.0 million tonnes (Mt) CO_2 equivalent in 2016 to 130.0 Mt CO_2 equivalents in 2019, followed by a reduction to 128 Mt CO_2 equivalent in 2023 from 130 Mt CO_2 equivalent in 2022. Baseline projections estimate Nigeria's 2030 GHG emissions at 453 Mt CO_2-equivalent, representing a 31% increase from 2018 levels, or a 2.6% annual increment aligning with historical trends (Omotoso, *et al.,* 2025 and Umeh, *et al.,* 2024).

3.1 Nigeria's Net-Zero emissions pathways

Nigeria's energy sector sustainability is contingent upon implementing progressive and deliberate emission reduction strategies to effectively mitigate the far-reaching impacts of climate change, with the decarbonisation process necessitating a holistic and integrated approach that encompasses the widespread adoption of green energy solutions, the formulation and implementation of supportive policy and financial reforms, the deployment of cutting-edge technological innovations, and concerted efforts across key sectors, ultimately steering the nation towards a resilient, low-carbon energy future that aligns with global climate objectives and fosters sustainable development [9], with these critical elements explored in greater detail in the following sections.

3.1.1 Technical strategies for decarbonising Nigeria's energy sector

Nigeria's energy sector decarbonisation can be significantly advanced through the implementation of key technical strategies, elaborated as follows:

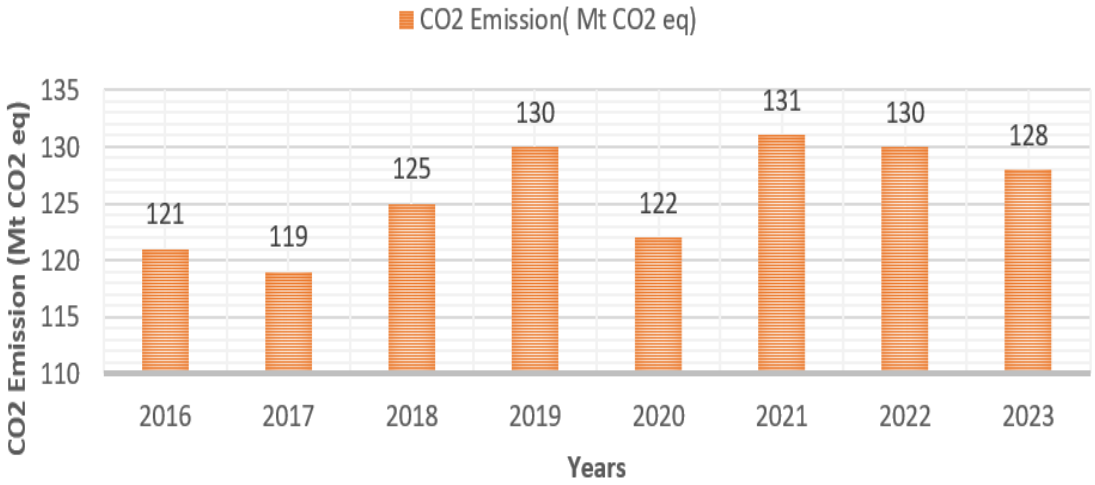

Figure 1: Nigeria's CO_2 Emission Profile (million metric tonnes CO_2 equivalent)

3.1.1.1 Transitioning to renewable energy technologies (RETs)

A pivotal approach involves the widespread deployment of Renewable Energy Sources (RES) such as solar, wind, and hydroelectric power, or the combination of such systems as hybrid aimed at reducing the nation's dependence on fossil fuels. The integration of RES technologies is instrumental in lowering carbon emissions, bolstering energy security, and fostering sustainable energy access. To align with ambitious net-zero carbon emission targets by 2050, Nigeria necessitates an accelerated push towards green energy technologies, with solar and wind energy playing prominent roles (Chibueze et al., 2025).

3.1.1.2 Enhancing Energy Efficiency

Implementing improved energy efficiency measures represents a critical strategy for reducing emissions across various sectors. This encompasses the adoption of technologies and best practices that optimise energy consumption patterns in key areas including transportation systems, industrial processes, and building infrastructure. Enhanced energy efficiency contributes substantively to overall decarbonisation efforts.

3.1.1.2 Carbon capture and storage (CCS) technologies

Carbon Capture and Storage (CCS) constitutes a vital technical solution for mitigating CO_2 emissions from industrial sources. CCS involves capturing carbon dioxide emissions generated by industries and securely storing them underground, thereby preventing their release into the atmosphere (Umeh et al., 2024). Notably, CCS technologies possess the capability to capture approximately 90% of CO_2 emissions in industrial applications, rendering them a significant option for addressing emissions from large-scale industries. In the context of Nigeria's oil and gas sector, CCS can play a pivotal role in striking a balance between pursuing economic growth and ensuring environmental sustainability.

3.1.1.3 Transforming Nigeria's transportation sector

Shifting towards Electric Vehicles (EVs) and Compressed Natural Gas (CNG) represents a significant strategy for reducing emissions in Nigeria's transportation sector. EVs adoption can substantially lower pollution; the International Energy Agency (IEA) projects that achieving net-zero targets by 2030 would require EV usage to escalate from 5% to approximately 60% globally for all automobiles (Dalkic-Melek et al., 2025). Implementing EVs in Nigeria necessitates considerable investment in incentives and charging infrastructure development. Interim alternatives like hydrogen and CNG offer viable pathways; CNG vehicles emit fewer emissions compared to petrol and diesel counterparts.

3.1.2 Policy and finance strategies for energy sector decarbonisation

Nigeria can leverage policy and financial approaches to curb energy sector carbonisation, as outlined below:

3.1.2.1 Policy frameworks, agreements, and regulations

Aligning with the Paris Agreement, Nigeria has committed to reducing emissions by 20% by 2030 (Offiong, et al., 2025). This commitment underpins national strategies for formulating effective policies promoting Renewable Energy Sources (RES), clean energy adoption, and energy efficiency across transportation, industry, and agriculture to mitigate climate change impacts. Tailored policies can drive decarbonisation.

3.1.2.2 Carbon pricing mechanism (CPM)

Introducing Carbon Pricing Mechanisms (CPM) like carbon taxes can disincentivise carbon emissions. CPM serves as an essential tool for driving emission reductions in industrial sectors, encouraging low-carbon transitions.

3.1.2.3 Circular economy practices (CEP)

Circular Economy Practices (CEP) offer significant emission reduction potential. CEP entails minimising waste

generation and promoting materials cycling, fostering closed-loop systems where reused materials diminish needs for new energy-intensive inputs. Implementing CEP can lower emissions through resource efficiency and waste reduction strategies.

3.1.3 Moral and societal strategies for energy sector decarbonisation

Moral and societal approaches can drive Nigeria's energy sector decarbonisation, as outlined below:

3.1.3.1 Enlightenment and awareness campaigns

Public awareness initiatives on carbon emissions impacts and sustainable practices' importance are crucial for behavioural shifts. Campaigns highlighting energy conservation benefits, sustainable energy growth, and waste reduction can encourage individuals and organisations to adopt lower-carbon habits.

3.1.3.2 Corporate social responsibility (CSR) partnerships

Encouraging companies to invest in sustainable practices via CSR can mitigate environmental impacts. CSR initiatives aid compliance with regulations and foster healthy competition aligned with global carbon reduction goals.

3.1.3.3 Sustainable agricultural practices and food waste reduction

Transitioning to sustainable agriculture like agroforestry, improved livestock management can significantly curb emissions. Reducing food waste is also vital as it contributes substantially to global emissions; minimising waste lowers associated production and disposal emissions.

3.2 Green energy solutions and implementation strategies

Green Energy encompasses clean energy sources including hydro, solar, wind, and biomass, characterised by lower environmental impacts relative to conventional fossil fuels. Key attributes of Green Energy include scalability, sustainability, minimal to zero carbon emissions, and substantial net environmental benefits, rendering it crucial for sustainable development. Nigeria boasts diverse Renewable Energy Sources (RES) which, if effectively harnessed, can significantly augment the country's energy mix and diminish fossil fuel dependency (Raihan, 2025). The status of major RES in Nigeria is summarised in Table 1. Prominent green energy technologies available in Nigeria are briefly elaborated below.

Table 1: Nigeria's renewable energy development status

Energy source	Level of Growth	Major Development	Challenges
Solar energy	Steady growth in off-grid solar technologies, street lighting, mini grids and rural electrification	Deployment reaching about 700 households	High installation costs, lack of local experts, low maintenance level and ineffective policies
Hydropower (large and small)	About 29% contribution to the grid	Significant contribution to the national grid	Lack of technical expertise, high installation cost, lack of maintenance
Biomass	Low level of growth	Insignificant development	Lack of technical experts, financial constraints and lack of awareness
Wind Energy	Insignificant or stagnant level of growth	Demonstration project centres	Low wind speeds in some parts of the country, lack of experts and lack effective policies

3.2.1 Solar energy in Nigeria

Nigeria's geographical position near the equator blesses it with abundant solar energy resources, relatively uniform across the country, rendering solar a viable option for urban and rural electrification. The country's average solar radiation of about (4.0-6.5 kWh/m²/day) holds potential to generate approximately 427,000 MW of electricity (Nelson et al., 2025). Solar energy can significantly contribute to carbon emission reduction, being clean, reliable, and eco-friendly (Zhang, et al., 2024).

3.2.2 Hydro energy in Nigeria

Nigeria is endowed with both Small Hydropower (SHP) and large hydropower resources. The country possesses capacity to generate about 86,400 GWh of electricity annually from large hydropower, with roughly 24 GW of exploitable potential (Umeh, *et al.,* 2024). Existing hydropower installed capacity is under 2400 MW, tapping merely about 16% of identified potential, underscoring vast untapped hydro resources. Key large hydropower plants include Kainji (760 MW), Jebba (570 MW), and Shiroro (600 MW). Nigeria also boasts abundant SHP resources dispersed across urban and rural areas; SHP technologies are reliable, cost-effective, scalable, and sustainable (Dinneya-Onuoha, 2025).

3.2.3 Biomass energy in Nigeria

Biomass resources including animal dung, wood, and agricultural wastes are abundantly available in Nigeria, holding significant energy production potential. Biomass utilisation promotes improved waste management and enhances energy access (Mashhadi et al., 2024). It can transform the energy sector by providing sustainable alternatives to fossil fuels, fostering green energy, and reducing dependence on imported energy.

3.2.4 Wind energy in Nigeria

Nigeria is endowed with considerable wind energy resources, with abundant wind energy potential (Akporhonor et al., 2024). This potential remains largely untapped due to investment and infrastructural challenges. Harnessing wind energy presents a vast opportunity for electricity production, contributing to Nigeria's energy diversification and renewable energy goals.

4. Challenges and opportunities of Nigeria's energy sector decarbonisation

Nigeria's energy sector decarbonisation faces multifaceted challenges and barriers. A major constraint is the high implementation costs of carbon reduction strategies, potentially impacting the economy (Xiao, 2025). Balancing economic growth reliant on fossil fuels with carbon emission reduction poses a significant dilemma. Emission reductions might lead to income generation declines, economic disruptions, and job losses, complicating achievement of emission goals without economic trade-offs.

4.1 High costs of renewable energy technologies

Relative high capital costs of Renewable Energy Sources (RES) technologies compared to conventional fossil fuels constitute a major technical barrier. This discourages adoption among low-income earners unable to afford installation costs. Additionally, a lack of local expertise in manufacturing and maintaining RES equipment exacerbates challenges, fostering dependence on costly imported technologies with maintenance difficulties.

4.2 Limited awareness and misconceptions

Limited awareness among Nigerians, particularly rural dwellers, about Renewable Energy Sources (RES) benefits hinders adoption. There's insufficient communication on how low-carbon technologies can lower electricity costs, enhance environmental sustainability, and improve energy security. Misconceptions about RES being costly, unreliable, and impractical persist. Additionally, cultural and traditional beliefs may lead to community resistance against transitioning to renewables and energy-efficient technologies.

4.3 Inadequate investment and financial support

Nigeria's decarbonisation efforts suffer from lack of substantial financial backing for low-carbon projects. Financial incentives are needed to attract local investors, especially amid current economic challenges.

4.4 Lack of political wills and inconsistent policy frameworks

Policy inconsistencies and lacking political will lead to weak environmental regulation enforcement and slow climate initiative progress. Formulated policies often see lax implementation. Absence of robust regulatory frameworks supporting renewable energy investments and energy efficiency complicates low-carbon technology adoption [25]. Political and social challenges critically impact Nigeria's carbon emission reduction difficulties.

5. Conclusion

This comprehensive evaluation underscores the imperative of sustainable decarbonisation of Nigeria's energy sector through the adoption of green energy solutions. The study assesses existing green energy strategies and their implementation status towards achieving a net-zero carbon environments. Key findings highlight the necessity of holistic green energy technology integration into the national grid, targeting approximately 60% of the country's energy needs by 2050.

Recommendation

We therefore recommend the following:

a. Widespread implementation of energy-efficient technologies across sectors to drive decarbonisation.
b. Collaboration between government and private sector to accelerate green energy investments and infrastructure development.
c. Formulation and stringent implementation of policies supporting green energy transition and discouraging fossil fuel dependency.
d. Drastic transition from a fossil fuel-dominated economy to a green energy-driven economy to meet global decarbonisation goals by 2060.
e. Diversifying energy generation through green sources and distributed energy systems for a sustainable, resilient national development.
f. Encouraging development of non-oil sectors like agriculture, manufacturing, and renewable energy to mitigate risks tied to declining fossil fuel revenues

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