SCIENTIFIC Publishing Limited

New Energy Exploitation and Application

https://ojs.ukscip.com/index.php/neea

Review

Economic and Environmental Benefits of Renewable Energy Transition in Nigeria

Justice Obomejero [1], Ikioukenigha Michael [2,*], Godspower Oke Omokaro [1], Ogheneochuko Shadrack Efeni [1], Opelopejesu Israel Adeyanju [1] and Efe Akpotu [3]

[1] Institute of Environmental Engineering, Peoples' Friendship University of Russia, Moscow 117198, Russia

[2] Department of Geography and Regional Planning, Igbinedion University, Okada 302110, Nigeria

[3] Academy of Engineering, Peoples' Friendship University of Russia, Moscow 117198, Russia

[*] Correspondence: francaikious@gmail.com

Received: 13 August 2025; **Revised:** 22 September 2025; **Accepted:** 25 September 2025; **Published:** 14 October 2025

Abstract: Nigeria faces an urgent energy challenge marked by chronic electricity shortages, dependence on fossil fuels, and worsening environmental degradation. This study examines the economic and environmental benefits of transitioning to renewable energy in Nigeria, adopting a mixed-methods approach that combines a systematic literature review, policy analysis, and synthesis of empirical case studies. Findings reveal that Nigeria possesses vast potential for solar, wind, biomass, and hydropower, capable of transforming its energy landscape. Economically, the adoption of renewable energy can generate employment, stimulate industrial growth, expand rural electrification, attract investment, and stabilize public finances by reducing vulnerability to global oil price shocks. Environmentally, it can reduce greenhouse gas emissions, improve air quality, conserve biodiversity, promote sustainable waste management, and enhance resilience to climate variability. Case studies demonstrate the effectiveness of decentralized solar mini-grids, biomass utilization, and hybrid systems in meeting local energy needs; however, persistent barriers, including weak policy enforcement, financing gaps, and infrastructural limitations remain. The study concludes that a comprehensive framework is required, built on policy alignment, financing innovation, institutional strengthening, infrastructure development, and social inclusion. Renewable energy transition thus represents not only a climate responsibility but also a strategic pathway for Nigeria's sustainable economic and environmental future.

Keywords: Renewable Energy; Economic Benefits; Environmental Sustainability; Nigeria; Energy Transition

1. Introduction

Nigeria occupies a critical position in Africa's energy and climate discourse as both a major crude oil exporter and a country with persistent electricity shortages. Heavy dependence on fossil fuels has made the economy highly vulnerable to global oil price fluctuations, fiscal instability, and environmental degradation [1–3]. Petroleum provides over 90 percent of export earnings and more than 60 percent of government revenue, yet over 80 million Nigerians lack reliable electricity access due to chronic underinvestment in infrastructure [4,5]. This paradox of energy wealth and energy poverty reflects deep policy inconsistencies and sector inefficiencies [6–8]. The environmental consequences of fossil fuel dependence are severe. Oil spills, gas flaring, and deforestation have degraded ecosystems and undermined the livelihoods of the people in the Niger Delta [9,10]. Nigeria is also highly vulnerable to climate change,

with rising temperatures, erratic rainfall, flooding, and desertification, threatening food security and exacerbating inequality [11,12]. Transitioning to renewable energy is therefore both an environmental necessity and a development opportunity, aligned with Nigeria's Energy Transition Plan and Paris Agreement obligations [13,14].

Nigeria's renewable resources are substantial. An average solar irradiation of 4–6 kWh/m^2/day is sufficient for both off-grid and grid-scale projects [15,16]. Wind speeds of 3–5 m/s have been recorded in Maiduguri, Oyo, and Jos Plateau [17–19]. Biomass potential exceeds 144 million tonnes annually from agricultural residues and waste streams [20–22]. Hydropower contributes about 17 percent of current electricity but remains underutilized [23]. These endowments position Nigeria as one of Sub-Saharan Africa's most promising renewable energy frontiers [24,25]. The economic benefits of renewable adoption are equally significant. Global and regional evidence shows strong correlations between renewables, growth, and poverty reduction [26–28]. In Nigeria, renewable expansion could create jobs, stimulate rural electrification, attract foreign investment, and reduce macroeconomic vulnerability to oil price shocks [29–32]. Environmentally, renewables reduce carbon emissions, improve air quality, and lower health burdens from diesel generators and biomass burning [33–36].

Despite vast potential, structural barriers persist. Weak enforcement of policies such as the Renewable Energy Master Plan, financing gaps, and inadequate grid infrastructure constrain large-scale adoption [23,31,32,37]. Yet innovations in decentralized microgrids, hybrid systems, and public–private partnerships are emerging pathways [38, 39]. Nigeria's energy transition must therefore integrate economic growth, social inclusion, and environmental sustainability within national development frameworks, such as Vision 2030 and the Sustainable Development Goals [11,12,40]. In this context, the purpose of this paper is to analyze the economic and environmental benefits of Nigeria's renewable energy transition and to identify strategic interventions that can accelerate its implementation, as displayed in **Figure 1**. The paper synthesizes evidence from empirical studies, evaluates case studies of renewable integration, and proposes a framework for sustainable energy transition. The ultimate objective is to highlight how renewable energy can serve as both a catalyst for development and an environmental safeguard in Nigeria's pursuit of sustainable growth.

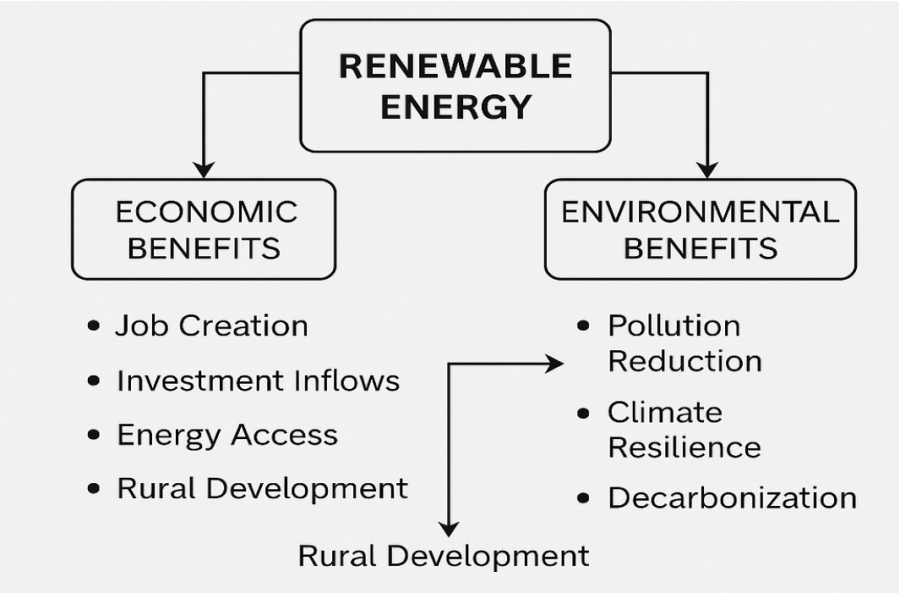

Figure 1. Framework linking economic and environmental benefits of renewable energy.

2. Methodology

This study employed a scoping review approach to systematically map existing literature and evidence on the economic and environmental benefits of transitioning to renewable energy in Nigeria. The methodological framework was adapted from Arksey and O'Malley's [41] original scoping review model, further refined by Levac et al. [42], and aligned with best practice recommendations outlined by Tricco et al. [43]. In addition, guidance from Popay et al. [44] on narrative synthesis on literature review methodology informed the analytical process and

the integration of findings.

The review process followed five structured stages:

1. Identifying the research question: The central question guiding this review was, *"What are the documented economic and environmental benefits of renewable energy adoption in Nigeria, and what policy and practical pathways exist for effective implementation?"*
2. Identifying relevant studies: A comprehensive search was conducted across major academic databases, including Scopus, ScienceDirect, JSTOR, SpringerLink, and Google Scholar.
3. Study selection: A set of inclusion and exclusion criteria was applied to filter relevant studies.
4. Charting the data: Data were systematically extracted and organized for synthesis.
5. Collating, summarizing, and reporting the results: Findings were thematically analyzed and narratively synthesized.

The search strategy used Boolean operators with keywords such as *"renewable energy," "economic benefits," "environmental benefits," "Nigeria," "solar energy," "biomass," "wind energy,"* and *"climate change mitigation."* Eligible materials included peer-reviewed journal articles, systematic reviews, government reports, policy briefs, and high-quality grey literature published between 1989 and 2025. Preference was given to recent empirical research in order to capture contemporary evidence and trends in Nigeria's renewable energy sector.

The inclusion criteria required that studies explicitly address either the economic or environmental outcomes of renewable energy in Nigeria, or propose policy and implementation strategies. A total of 79 publications were initially identified. After title, abstract, and full-text screening, 58 documents met the inclusion criteria. These comprised case studies, comparative policy analyses, and sector-specific evaluations of solar, wind, biomass, and biogas technologies.

Data charting involved extracting key information, such as the type of renewable energy technology, application context, economic indicators (e.g., job creation, cost savings, productivity gains), environmental indicators (e.g., emission reduction, land use impact), and policy instruments. Extracted data were then categorized thematically, which allowed for a structured narrative synthesis following Popay et al.'s [44] guidance. The synthesis emphasized identifying cross-cutting patterns, emerging themes, and evidence gaps to provide a comprehensive understanding of how renewable energy contributes to Nigeria's sustainable development. This methodological design ensured broad coverage of the literature while maintaining analytical depth. By combining scoping review principles with narrative synthesis, the study integrated both qualitative and quantitative evidence, providing a basis for empirically grounded policy recommendations.

3. Result

3.1. Renewable Energy Potential and the Nigerian Energy Landscape

Solar, wind, biomass, and hydropower can be developed through a mix of centralized plants, decentralized off-grid systems, and hybrid technologies, enabling the country to reduce its dependence on fossil fuels while enhancing energy security, economic diversification, and environmental sustainability. Nigeria's energy landscape reflects a paradox of abundance and deficiency. The country is endowed with diverse renewable resources, including solar, wind, biomass, hydro, and geothermal, that could generate more than 427 GW of electricity annually; yet, its citizens experience some of the lowest electricity access rates in Sub-Saharan Africa [7,23,45]. Despite the abundance of renewable resources, Nigeria's energy landscape remains dominated by fossil fuels, which account for more than 70 percent of the country's generation capacity [4,34]. Structural barriers, including inconsistent policy frameworks, lack of financing, weak transmission infrastructure, and limited local technical expertise, have slowed the pace of renewable integration [13,31,37].

3.1.1. Solar and Wind Energy Potential

Solar radiation in Nigeria averages between 4 and 6 kWh/m^2/day, with high levels across the northern regions and year-round availability nationwide [15,16]. This potential is sufficient to power both decentralized home systems and utility-scale photovoltaic (PV) plants. For instance, Okoye et al. [15] estimated that strategically located solar PV systems in cities such as Kano, Sokoto, and Maiduguri could generate electricity more cost-effectively than

diesel generators, which remain prevalent despite their high costs and environmental impacts. Studies emphasize that solar energy could meet most rural electrification needs while also supporting urban demand through grid-connected PV plants [29,33]. On the other hand, wind energy assessments in Nigeria highlight promising but regionally uneven potential. Early studies identified viable wind speeds of 3–5 m/s in coastal and northern regions, including Maiduguri and Sokoto [17,46]. Subsequent field measurements confirmed that states such as Oyo, Jos Plateau, and parts of Borno possess wind speeds adequate for commercial electricity production [18,19,47]. Ohunakin [48] further demonstrated the suitability of high-altitude locations, where wind speeds are stronger and more consistent. Although Nigeria lacks large-scale wind farms, decentralized wind projects could play a critical role in hybrid systems for rural electrification, particularly when integrated with solar PV [48].

3.1.2. Biomass, Biogas, and Hydropower Resources

Biomass constitutes one of Nigeria's most accessible and underexploited renewable resources. Agricultural residues, forest products, municipal waste, and animal dung provide a sustainable feedstock base. Estimates suggest that Nigeria produces over 144 million tonnes of biomass annually, much of which is unused or burned inefficiently [20,21]. Sawdust, in particular, has been investigated as a low-cost adsorbent for environmental applications and as a fuel source for bioenergy conversion [21]. Biogas derived from livestock and municipal waste is another promising option. Akinbami et al. [22] documented the country's significant potential for biogas production, while Nwankwo et al. [36] highlighted its role in displacing firewood use and reducing deforestation. If harnessed systematically, biomass could provide rural industries with a reliable source of energy while addressing environmental concerns related to waste disposal. Hydropower remains an important but underutilized component of Nigeria's energy mix. Large dams such as Kainji, Shiroro, and Jebba supply approximately 17 percent of the nation's electricity, yet the overall hydropower potential exceeds 10,000 MW, much of which remains untapped [23,49]. Small hydro projects offer further potential for decentralized supply to rural communities, particularly in areas unsuitable for solar or wind generation. However, climate change-induced variability in rainfall patterns presents challenges to hydropower reliability, necessitating diversification into complementary renewables [11,38].

3.1.3. Decentralized and Hybrid Energy Systems

One of the defining characteristics of Nigeria's renewable energy landscape is the importance of decentralized and hybrid systems. Given the weak and unreliable national grid, decentralized solutions are often more viable than centralized plants [35,50]. Hybrid systems that combine solar PV, wind, and biomass have been identified as effective pathways for a stable power supply in rural and peri-urban areas. Comparative studies, such as Coban et al. [51] in Somalia, demonstrate the cost-effectiveness and technical feasibility of decentralized hybrid renewable systems in regions with similar socio-economic conditions to Nigeria. Their findings suggest that adopting hybrid systems can enhance energy security, reduce reliance on costly diesel imports, and strengthen climate resilience. However, policy reforms, international climate finance, and advances in off-grid technologies provide opportunities for significant progress. The Renewable Energy Master Plan and the Energy Transition Plan both underscore the government's recognition of renewable energy as a driver of sustainable development, although effective implementation remains the critical challenge [29,30].

3.2. Economic Benefits of Transitioning to Renewable Energy in Nigeria

The economic case for renewable energy transition in Nigeria is compelling, particularly given the country's heavy dependence on oil exports, its volatile revenue streams, and its urgent need for industrial diversification. Renewable energy offers multiple pathways for strengthening the national economy, reducing poverty, and stabilizing public finances, as explained in **Table 1**. Scholars agree that renewable energy is not merely an environmental necessity, but a developmental catalyst that can transform Nigeria's socio-economic trajectory [7,26,29]. One of the most important benefits of adopting renewable energy is the potential for job creation. The deployment of solar, wind, biomass, and hydropower systems creates employment opportunities along the value chain, ranging from research, manufacturing, and installation to maintenance and distribution. Empirical studies show that solar PV systems, in particular, generate more jobs per unit of electricity produced compared to fossil fuel plants [15,16]. In Nigeria, where youth unemployment exceeds 30 percent, the renewable energy sector could absorb a significant portion of the labor force if adequately supported by policy and financing mechanisms [29,49]. Rural electrification

projects powered by solar mini-grids and biomass also create jobs in construction and local management, strengthening community-level economies [20,35].

Table 1. Renewable energy technologies and their economic benefits in Nigeria.

Renewable Energy Technology	Key Applications	Economic Benefits	References
Solar PV and Solar Mini-grids	Off-grid electrification, urban and rural power supply	Job creation in installation and maintenance; reduced household energy costs; support for small businesses; attraction of foreign investment	Okoye et al. [15], Shaaban & Petinrin [16], Fagbenle & Karayiannis [19]
Wind Energy	Grid-connected and hybrid systems in Oyo, Maiduguri, Jos Plateau	Expansion of electricity supply; diversification of energy mix; potential export to neighboring countries; industrial manufacturing opportunities	Ajayi [17], Adaramola & Oyewola [18], Fagbenle & Karayiannis [19]
Biomass and Biogas	Household cooking, rural electrification, agro-industry	Reduction of fuelwood use; stimulation of rural industries (agricultural processing); improved waste management; income generation through bio-product markets	Jekayinga et al. [20], Adegoke et al. [21], Akinbami et al. [22], Nwankwo et al. [36]
Hydropower (Large and Small)	National grid supply, small hydro for rural communities	Provision of stable electricity; stimulation of irrigation and local industries; reduced reliance on expensive diesel; contribution to regional electricity trade	Mohammed et al. [23], Akorede et al. [49]
Hybrid Systems (Solar–Wind–Biomass)	Off-grid electrification, rural mini-grids	Reliable and continuous supply; reduction in generator fuel imports; lower operating costs; investment opportunities in decentralized energy	Thango & Obokoh [38], Coban et al. [51]

In addition to employment, renewable energy can stimulate industrial development. Local manufacturing of solar panels, wind turbines, batteries, and biomass digesters has the potential to establish new industries and reduce dependence on costly imports. Akuru and Okoro [31] observed that the Renewable Energy Master Plan could provide a blueprint for building a domestic renewable energy industry that enhances Nigeria's competitiveness in the African market. International case studies suggest that renewable energy industries can stimulate the growth of allied sectors such as steel, electronics, and transportation, which could be replicated in Nigeria if enabling policies are introduced [32,51]. Moreover, small hydro and biogas projects in rural areas have been shown to support agricultural processing industries, improving productivity and creating local value chains [22,36]. Energy access and poverty reduction form another critical dimension of the economic benefits of renewable energy. Millions of Nigerians, particularly in rural communities, continue to rely on kerosene, firewood, and diesel generators to meet their energy needs [8,52]. These sources are not only expensive but also inefficient and environmentally harmful. Renewable energy offers a cost-effective alternative that improves household welfare and reduces energy poverty. Studies have shown that decentralized solar and wind systems increase agricultural productivity by powering irrigation, cold storage, and small-scale processing, thereby enhancing rural incomes [5,16]. Biogas adoption reduces expenditure on firewood and kerosene, while improving indoor air quality, which in turn enhances productivity by reducing health-related work absences [21,22]. Thus, the adoption of renewable energy directly contributes to poverty alleviation and economic inclusion.

Investment, Macroeconomic Stability, and Regional Competitiveness

A further economic advantage of renewable energy lies in its capacity to attract foreign direct investment and diversify Nigeria's revenue base. The global transition toward clean energy has created vast opportunities for climate finance, green bonds, and concessional loans, which Nigeria can leverage by demonstrating commitment to renewable energy integration [13,53]. International development banks, private investors, and multinational corporations increasingly prioritize renewable energy projects due to their long-term stability and alignment with global decarbonization goals [24,32]. Akorede et al. [45] argued that distributed energy resources in Nigeria can attract significant foreign interest if policies are transparent and investment risks are minimized. By expanding renewable energy capacity, Nigeria also positions itself to benefit from technology transfer, international partnerships, and regional energy trade [24,29].

Renewable energy transition also enhances macroeconomic stability. Nigeria's fiscal system is heavily dependent on oil revenues [1], which are highly volatile due to fluctuating global prices and geopolitical disruptions. This volatility often results in budget deficits, currency instability, and reduced capacity to finance development. By diversifying its energy supply through renewables, Nigeria can reduce its exposure to global oil price shocks and stabilize its foreign reserves [2, 54, 55]. Renewable energy also reduces the foreign exchange burden created by diesel and petrol imports, allowing resources to be redirected toward productive investment [4, 34]. Empirical

evidence from cross-country studies demonstrates that renewable energy consumption contributes to economic growth and reduces vulnerability to fluctuations in fossil fuel markets [26,27]. Nigeria's integration of renewables could therefore serve as a buffer against global energy market disruptions while strengthening long-term fiscal resilience. Furthermore, the adoption of renewable energy has the potential to enhance Nigeria's global competitiveness and position the country as a leader in Africa's energy transition. Aliyu et al. [24] emphasized that Nigeria, South Africa, and Egypt are key to shaping renewable energy development on the continent due to their resource endowments and market sizes. By actively investing in renewable energy, Nigeria could not only meet its domestic needs but also export clean electricity to neighboring countries under regional energy frameworks such as the West African Power Pool. This would generate new revenue streams while reinforcing Nigeria's geopolitical influence in West Africa [23,49].

4. Environmental Benefits of Transitioning to Renewable Energy in Nigeria

The environmental benefits of renewable energy adoption in Nigeria are profound, extending beyond the reduction of greenhouse gas emissions to include improvements in air quality, conservation of ecosystems, biodiversity protection, and the strengthening of climate resilience. Given the extent of environmental degradation caused by decades of fossil fuel dependence, particularly in the Niger Delta, a transition toward renewable sources represents an opportunity to mitigate past damage while preventing future ecological and health crises [9,10]. One of the most immediate environmental benefits of renewable energy is the reduction of carbon dioxide and other greenhouse gas emissions. Nigeria is Africa's largest oil producer and one of the continent's leading countries in terms of gas flaring, emitting millions of tonnes of carbon annually [1,7]. The combustion of fossil fuels for electricity generation, transportation, and industry contributes significantly to national emissions, which, although modest compared to those of developed countries, are rising rapidly due to population and economic growth [12,33]. Transitioning to renewables such as solar, wind, biomass, and hydropower would drastically reduce the carbon intensity of Nigeria's energy sector. Empirical studies confirm that renewable energy consumption is associated with long-term reductions in CO_2 emissions, thereby supporting climate change mitigation goals [26,27,56].

Closely linked to emission reduction is the improvement of air quality. Fossil fuel-based electricity generation and widespread reliance on diesel and petrol generators release sulfur oxides, nitrogen oxides, carbon monoxide, and particulate matter, which have severe health implications [8,34]. Indoor air pollution is a major concern in rural areas, where households depend on firewood and kerosene for cooking and lighting [16,52]. Renewable energy technologies, such as solar home systems, mini-grids, and biogas digesters, provide cleaner alternatives that eliminate harmful emissions and reduce the incidence of respiratory diseases. By substituting kerosene lamps and diesel generators with solar-powered solutions, households experience improved health outcomes and reduced exposure to toxic pollutants [21,22]. Renewable energy transition also plays a significant role in biodiversity conservation and land protection. The environmental cost of fossil fuel extraction in Nigeria is most evident in the Niger Delta, where oil spills have contaminated soil and water resources, devastated fisheries, and destroyed agricultural lands [3,9]. Gas flaring has further contributed to acid rain, deforestation, and declining soil fertility. By shifting toward renewable energy, Nigeria could reduce dependence on oil extraction and lessen the ecological footprint of its energy sector. Biomass and biogas technologies, when sustainably managed, help reduce deforestation by substituting fuelwood and charcoal with cleaner energy sources [10,36]. This not only protects forests but also safeguards habitats critical for biodiversity as outlined in **Table 2**.

A further environmental benefit of renewable energy lies in the potential for sustainable waste management. Nigeria generates large quantities of agricultural residues, municipal waste, and sawdust, much of which is either burned or left to decompose, releasing methane and other greenhouse gases [20,21]. Converting these wastes into energy through biomass and biogas technologies reduces methane emissions while providing a renewable energy supply. This dual function of waste reduction and energy generation exemplifies the circular economy model, which is increasingly being recognized as vital for sustainable development [53]. Renewables also enhance Nigeria's climate resilience. Climate change is expected to intensify energy insecurity through disruptions to hydropower generation caused by irregular rainfall, desertification in the north, and flooding in the south [11,40]. Renewable energy diversification, especially through decentralized solar and wind systems, provides a buffer against these risks by reducing reliance on single energy sources that are vulnerable to climate variability [23,38]. Hybrid renewable systems that combine solar, wind, and biomass further strengthen resilience by ensuring a continuous supply even

when one resource is unavailable, as demonstrated in comparative studies from similar African contexts [51]. Importantly, the adoption of renewable energy supports Nigeria's alignment with global sustainability commitments. The transition addresses several Sustainable Development Goals, including SDG 7 on affordable and clean energy, SDG 13 on climate action, and SDG 15 on life on land [12]. By reducing its reliance on fossil fuels, Nigeria not only fulfills its Paris Agreement commitments but also contributes to the global green transition, which emphasizes low-carbon growth and environmental stewardship [11,54].

Table 2. Environmental impacts of renewable energy compared to fossil fuel use.

Energy Source	Major Environmental Impacts	Net Environmental Outcome in Nigeria	References
Fossil Fuels (Oil, Gas, Diesel)	High CO_2 and methane emissions; gas flaring; oil spills; deforestation; acid rain; soil and water pollution; air pollution and respiratory diseases	Severe ecological degradation in the Niger Delta; climate vulnerability; negative health impacts	Omokaro et al. [9], Wajim [10], Oyedepo [34]
Solar PV	Minimal emissions during use; lifecycle impacts limited to manufacturing and disposal	Reduction of kerosene and diesel use; improved indoor and outdoor air quality; mitigation of greenhouse gas emissions	Okoye et al. [15], Shaaban & Petinrin [16]
Wind Energy	Low emissions, some noise, and land use impacts	Clean electricity generation with negligible pollution; preservation of ecosystems compared to fossil fuels	Ajayi [17], Adaramola & Oyewola [18]
Biomass and Biogas	Risk of overharvesting if unmanaged; methane release if poorly controlled	Reduction in deforestation from firewood demand; sustainable waste management; contribution to the circular economy	Fagbenle & Karayiannis [19], Adegoke et al. [21], Oyedepo [36]
Hydropower	Ecosystem disruption in dam sites; climate-related variability in rainfall	Significant reduction in fossil fuel dependence; potential support for biodiversity through reduced deforestation pressures	Omokaro [11], Akinbami et al. [23]
Hybrid Systems	Environmental footprint depends on system design	Optimized balance of resources with reduced reliance on diesel; resilience against climate-related energy disruptions	Thango & Obokoh [38], Coban et al. [51]

5. Case Studies and Empirical Illustrations of Renewable Energy Integration in Nigeria

One of the most significant examples of renewable energy integration in Nigeria is the deployment of solar mini-grids in rural communities. Projects supported by international donors and private investors have provided thousands of households in underserved areas with access to electricity, reducing their dependence on kerosene lamps and diesel generators. Shaaban and Petinrin [16] documented the success of decentralized solar systems in meeting rural energy needs, noting improvements in education, healthcare delivery, and small-scale businesses. Similarly, Mohammed et al. [5] emphasized the role of solar energy in distributed power generation, arguing that it represents the most feasible pathway for addressing energy poverty in rural Nigeria. The growth of these mini-grids underscores the value of decentralized systems in contexts where grid expansion is slow and costly. Wind energy projects also provide empirical evidence of Nigeria's renewable potential. Early assessments by Ajayi [17] and Adaramola and Oyewola [18] evaluated wind speeds in Oyo State, confirming their viability for electricity generation. Ngala et al. [46] examined the feasibility of wind energy in Maiduguri, while Fagbenle et al. [19] assessed wind resources in northeastern Nigeria. These studies collectively established the technical potential of wind energy in specific regions, though large-scale projects have yet to materialize. Ohunakin [48] further explored wind resource evaluation in high-altitude locations, demonstrating the potential for hybrid wind–solar systems in electricity generation. These findings suggest that wind energy could play an important role in Nigeria's energy mix, particularly in combination with other renewables for stable hybrid systems [48].

Biomass and biogas projects represent another set of important case studies. Akinbami et al. [22] documented early initiatives to promote biogas energy in Nigeria, emphasizing its potential to displace firewood and charcoal in rural households. More recently, Jekayinfa et al. [20] assessed biomass resources and concluded that Nigeria produces sufficient agricultural residues to sustain widespread bioenergy development. Adegoke et al. [21] explored the use of sawdust-based biomass for pollutant sequestration and energy applications, highlighting its dual role in environmental management and renewable energy production. Nwankwo et al. [36] examined biogas technology penetration in Nigeria, stressing that adoption could reduce deforestation and improve rural livelihoods if supported by targeted policies. These studies confirm that biomass and biogas offer a sustainable pathway for rural energy supply, while addressing waste management challenges. Hydropower integration provides further empirical illustration of renewable energy use in Nigeria. Large dams such as Kainji, Jebba, and Shiroro have historically contributed to the grid, supplying approximately 17 percent of the country's electricity [23]. However, small-scale

hydropower remains underdeveloped despite its potential to provide reliable electricity to remote areas. Akorede et al. [49] argued that small hydro projects could serve as an effective complement to solar and wind in decentralized energy systems. Yet, the reliability of hydropower is increasingly challenged by climate-induced variability in rainfall, reinforcing the need for diversification and hybridization of energy sources [11,38].

From another perspective, some studies also illustrate the policy and institutional dimensions of renewable energy integration. Akuru and Okoro [31] reviewed Nigeria's Renewable Energy Master Plan, observing that while it provided a framework for investment, implementation has been inconsistent. Emodi and Ebele [37] highlighted the gaps in policy enforcement, which hindered the scaling up of renewable technologies. Nevertheless, some progress has been recorded through public–private partnerships. For instance, Eberhard et al. [32] documented the role of independent power projects across Sub-Saharan Africa, including Nigeria, which have mobilized private capital for renewable and hybrid systems. These projects underscore the importance of aligning policy frameworks with investor confidence and long-term sustainability goals. In recent years, empirical studies have examined hybrid renewable systems as a solution to Nigeria's energy challenges. Thango and Obokoh [38] conducted a techno-economic analysis of hybrid systems and concluded that they are effective in reducing the frequency and impact of power interruptions. Coban et al. [51], though focusing on Somalia, provided useful comparative insights into the advantages of decentralized hybrid systems in contexts similar to Nigeria. Their findings reinforce the argument that integrating multiple renewable sources can reduce costs, improve supply reliability, and enhance climate resilience. These lessons are directly applicable to Nigeria, where hybrid solar–wind–biomass systems are increasingly being piloted.

6. Strategic Policy Interventions and Implementation Pathways

The successful transition to renewable energy in Nigeria requires more than resource availability and technological feasibility. It demands coherent policy frameworks, innovative financing models, robust institutions, and strong community engagement. Although Nigeria has adopted several policy instruments, including the Renewable Energy Master Plan (REMP), the National Energy Policy, and the Energy Transition Plan, their effectiveness has been undermined by inconsistent implementation, weak regulatory oversight, and insufficient funding [13,31,37]. Strengthening these frameworks and aligning them with international best practices is critical for accelerating the country's renewable energy transition. One key intervention pathway lies in regulatory reform. Nigeria's energy sector has long been characterized by policy inconsistency and overlapping institutional mandates that discourage investment [7,30]. Regulatory clarity, particularly in licensing, tariffs, and grid access, is essential for encouraging private sector participation. The unbundling of the Nigerian power sector, although intended to stimulate competition and efficiency, has been plagued by weak regulation and limited incentives for renewable integration [50]. Lessons from other African and global contexts suggest that establishing a strong, independent regulatory authority with clear mandates can enhance investor confidence and ensure effective policy enforcement [32,51].

Financing renewable energy remains a critical bottleneck. Most renewable projects require significant upfront investment, which is often difficult to secure given Nigeria's macroeconomic risks and policy uncertainties [54]. Expanding financing mechanisms such as green bonds, concessional loans, and climate funds is therefore essential. Nigeria has already issued green bonds to support low-carbon projects, but these instruments need to be scaled up and directed toward renewable energy infrastructure [13]. Public–private partnerships (PPPs) also offer a pathway for mobilizing capital and sharing risks between the government and private investors. International climate finance mechanisms, such as the Green Climate Fund, can further support Nigeria if the government demonstrates clear commitments to climate action and renewable integration [53]. Infrastructure development is another priority area. Nigeria's national grid is outdated, fragile, and unable to absorb large-scale renewable inputs without significant upgrades [23,50]. Investments in transmission and distribution systems are therefore essential to integrate renewable energy efficiently. Equally important is the promotion of decentralized, off-grid, and mini-grid solutions, particularly in rural communities where grid expansion is economically unviable [16,35]. Hybrid renewable systems that combine solar, wind, and biomass have been shown to enhance reliability while lowering costs, making them a practical solution for Nigeria's energy access challenges [38,51].

Capacity building and human resource development are indispensable for sustaining renewable energy growth. Nigeria currently suffers from a shortage of skilled engineers, technicians, and researchers in renewable technologies, which limits the pace of adoption [29, 49]. Training programs in universities, polytechnics, and vocational

centers should be expanded to produce a workforce capable of designing, installing, and maintaining renewable energy systems. International collaborations can also provide knowledge transfer and capacity enhancement, particularly through partnerships with countries that have achieved rapid renewable integration [24]. Community participation represents another strategic pathway. Renewable energy projects are more likely to succeed when they are designed with community involvement, ensuring local ownership and sustainability [35,36]. Cooperative models, where communities collectively invest in and manage renewable projects, have proven effective in many parts of the world and can be adapted to Nigeria's rural contexts. Awareness campaigns are also essential to promote behavioral change, reduce resistance to new technologies, and highlight the economic and environmental benefits of renewables [10,21].

Thus, aligning renewable energy policy with broader development goals is necessary for coherence and effectiveness. Nigeria's Vision 2030, the National Climate Change Policy, and its Sustainable Development Goal commitments all emphasize the importance of sustainable energy; however, coordination among these frameworks remains weak [12,29]. Integrating renewable energy into agricultural policy, industrial development, and urban planning would ensure that its benefits are maximized across multiple sectors. Furthermore, policies should anticipate future challenges, such as stranded assets in the oil sector, and design just transition strategies to support workers and communities dependent on fossil fuel industries [3,54].

7. Toward a Comprehensive Framework for Renewable Energy Transition in Nigeria

Nigeria's renewable energy transition cannot be achieved through fragmented initiatives or isolated projects. It requires a comprehensive framework that integrates economic development, environmental sustainability, policy coherence, and social inclusion into a single strategic vision. A central component of this framework is the alignment of renewable energy policy with national development priorities. Nigeria's Energy Transition Plan, Vision 2030, and National Climate Change Policy all underscore the importance of clean energy, yet these documents often operate in silos, limiting their collective impact [12,37]. A unified framework should ensure that renewable energy is integrated into economic planning, agricultural development, industrial policy, and climate strategies. This would enable renewable projects to deliver cross-sectoral benefits such as improved food security, industrial growth, and reduced greenhouse gas emissions [11,29]. Financing is another critical pillar of the framework. Nigeria must diversify funding sources beyond government allocations to include green bonds, concessional loans, and international climate funds [13]. Public–private partnerships can mobilize capital while reducing risk, particularly for large-scale solar, wind, and biomass projects [32,54]. Innovative financial instruments such as feed-in tariffs, renewable energy credits, and community cooperatives could further encourage investment and participation at multiple levels.

Institutional strengthening is equally important. Weak enforcement of existing policies has hindered renewable adoption in Nigeria, despite the availability of frameworks such as the Renewable Energy Master Plan [30,31]. Establishing a strong, independent regulatory body to oversee renewable energy development would enhance investor confidence, ensure compliance, and prevent policy reversals. Coordination among federal, state, and local governments is also essential to avoid duplication and ensure coherent action [7]. The framework must also emphasize infrastructure and technological innovation. Grid upgrades are necessary to accommodate large-scale renewable inputs, while decentralized mini-grids and hybrid systems should be promoted in rural areas where grid extension is uneconomical [16,23]. Hybrid renewable systems that combine solar, wind, and biomass have already been demonstrated as cost-effective and reliable in similar contexts [38,51]. Encouraging research and development in universities and research centers will further support local innovation, reduce technology costs, and foster domestic manufacturing capacity [29].

Capacity building and human development are also critical for sustaining the adoption of renewable energy. Training programs in renewable technologies should be expanded at universities, polytechnics, and vocational centers to ensure a steady pipeline of skilled professionals [24,49]. International collaborations and knowledge exchange can enhance Nigeria's technical expertise and accelerate the adoption of advanced renewable systems. Community-level training is equally important to promote acceptance, ensure local ownership, and maintain installed systems [36]. More so, the framework must prioritize social inclusion and just transition principles. Millions of Nigerians depend directly or indirectly on the fossil fuel economy, and a sudden shift could create social and economic dislocations. Policies should therefore include measures to retrain workers, support communities affected

by oil sector divestments, and promote equitable access to renewable energy technologies [3,54]. Gender inclusion should also be emphasized, as women often bear the burden of energy poverty and stand to benefit significantly from improved access to clean and affordable energy [10].

8. Discussion

The evidence presented in this study confirms that renewable energy has the capacity to transform Nigeria's economy and environment. The benefits identified in earlier sections demonstrate that renewable energy is not just a technical solution to electricity shortages but also a developmental driver. Economic gains include job creation, rural electrification, and macroeconomic stability through reduced reliance on volatile oil markets [29,54]. These benefits are reinforced by environmental outcomes, including lower greenhouse gas emissions, improved air quality, biodiversity conservation, and enhanced resilience to climate variability [11,56]. Case studies highlight the success of decentralized systems, such as solar mini-grids, biomass projects, and hybrid renewable configurations, which have proven effective in expanding access to electricity in underserved communities [5, 16, 20]. Nevertheless, challenges remain. Weak enforcement of policies such as the Renewable Energy Master Plan, financing gaps, limited technical expertise, and fragile transmission infrastructure continue to constrain progress [13,31,37]. The findings suggest that Nigeria's pathway forward lies in building a coherent framework that integrates renewable energy into broader development planning, supported by robust institutions, innovative financing, and local participation. Lessons from comparative studies in similar African contexts confirm that decentralized hybrid systems and climate financing mechanisms can provide workable solutions to persistent barriers [51].

9. Conclusions

The renewable energy transition in Nigeria offers a unique opportunity to achieve economic diversification, environmental protection, and inclusive growth. The analysis shows that solar, wind, biomass, and hydropower resources can deliver reliable and affordable energy while reducing dependence on fossil fuels. The economic benefits include employment creation, industrial development, poverty reduction, and fiscal stability. The environmental benefits include reduced emissions, cleaner air, improved waste management, and enhanced climate resilience. Case studies confirm that renewable integration is technically feasible and socially beneficial, particularly through decentralized and hybrid systems that bring electricity to rural populations. However, persistent barriers in policy implementation, financing, and infrastructure highlight the need for comprehensive reforms. A successful transition requires a framework built on policy alignment, institutional strengthening, financing innovation, infrastructure development, and social inclusion. Nigeria's renewable energy transition is therefore both a climate imperative and a development necessity. By harnessing its vast renewable resources through coherent strategies, Nigeria can redefine its energy future and set an example for other resource-rich but energy-poor nations.

Author Contributions

Conceptualization, J.O., and I.M.; methodology, I.M., G.O.O., and J.O.; validation, J.O., O.S.E., and E.A.; formal analysis, J.O., I.M., G.O.O., and O.S.E.; investigation, J.O., I.M., O.S.E., O.I.A., and E.A.; writing—original draft preparation, J.O., I.M., O.S.E., and O.I.A.; writing—review and editing, J.O., I.M., G.O.O., O.S.E., O.I.A., and E.A.; supervision, G.O.O. All authors have read and agreed to the published version of the manuscript.

Funding

This work received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

All data used are contained in the manuscript.

Conflicts of Interest

The authors declare that there is no conflict of interest.

References

1. Omokaro, G.O. Oil Extraction and the Environment in Nigeria's Niger Delta: A Political-Industrial Ecology (PIE) Perspective. *Asian J. Adv. Res. Rep.* **2024**, *18*, 161–169. [CrossRef]
2. Adams, U. Climate Change and the Future of Nigeria's Oil-Dependent Economy. *Glob. J. Manag. Bus. Res.* **2024**, *24*, 1–10.
3. Emetumah, F.C.; Emetumah, F.I. Nigerian Oil and Gas Industry in an Era of Energy Transition: Analysis of TotalEnergies' Activities in Nigeria. *Am. J. Environ. Econ.* **2025**, *4*, 104–112. [CrossRef]
4. Ibitoye, F.; Adenikinju, A. Future Demand for Electricity in Nigeria. *Appl. Energy* **2007**, *84*, 492–504. [CrossRef]
5. Mohammed, Y.S.; Mustafa, M.W.; Bashir, N.; et al. Renewable Energy Resources for Distributed Power Generation in Nigeria: A Review of the Potential. *Renew. Sustain. Energy Rev.* **2013**, *22*, 257–268. [CrossRef]
6. Shao, Y.; Yang, Z.; Yan, Y.; et al. Navigating Nigeria's Path to Sustainable Energy: Challenges, Opportunities, and Global Insight. *Energy Strateg. Rev.* **2025**, *59*, 101707. [CrossRef]
7. Aliyu, A.S.; Dada, J.O.; Adam, I.K. Current Status and Future Prospects of Renewable Energy in Nigeria. *Renew. Sustain. Energy Rev.* **2015**, *48*, 336–346. [CrossRef]
8. Oseni, M.O. Improving Households' Access to Electricity and Energy Consumption Pattern in Nigeria: Renewable Energy Alternative. *Renew. Sustain. Energy Rev.* **2012**, *16*, 3967–3974. [CrossRef]
9. Omokaro, G.O.; Efeni, O.S.; Adeyanju, O.I.; et al. Oil Spillage in the Niger Delta: Impacts, Institutional Failures, and Policy Reforms. *Acad. Environ. Sci. Sustain.* **2025**, *2*, 1–14. [CrossRef]
10. Wajim, J. Impacts of Deforestation on Socio-Economic Development and Environment in Nigeria. *Int. J. Soc. Sci. Humanit. Invent.* **2020**, *7*, 5852–5863.
11. Omokaro, G.O. Multi-Impacts of Climate Change and Mitigation Strategies in Nigeria: Agricultural Production and Food Security. *Sci. One Health* **2025**, *4*, 100113. [CrossRef]
12. Okafor, C.C.; Madu, C.N.; Nwoye, A.V.; et al. Research on Climate Change Initiatives in Nigeria: Identifying Trends, Themes and Future Directions. *Sustainability* **2025**, *17*, 3995. [CrossRef]
13. Olujobi, O.J.; Okorie, U.E.; Olarinde, E.S.; et al. Legal Responses to Energy Security and Sustainability in Nigeria's Power Sector Amidst Fossil Fuel Disruptions and Low Carbon Energy Transition. *Heliyon* **2023**, *9*, e17912. [CrossRef]
14. Ajia, A.T. Renewable Energy Policy and Sustainable Development in Nigeria: A Systematic Scoping Review. *J. Energy Res. Rev.* **2025**, *17*, 1–16. [CrossRef]
15. Okoye, C.O.; Taylan, O.; Baker, D.K. Solar Energy Potentials in Strategically Located Cities in Nigeria: Review, Resource Assessment and PV System Design. *Renew. Sustain. Energy Rev.* **2016**, *55*, 550–560. [CrossRef]
16. Shaaban, M.; Petinrin, J.O. Renewable Energy Potentials in Nigeria: Meeting Rural Energy Needs. *Renew. Sustain. Energy Rev.* **2014**, *29*, 72–84. [CrossRef]
17. Ajayi, O.O. Assessment of Utilization of Wind Energy Resources in Nigeria. *Energy Policy* **2009**, *37*, 750–753. [CrossRef]
18. Adaramola, M.S.; Oyewola, O.M. On Wind Speed Pattern and Energy Potential in Nigeria. *Energy Policy* **2011**, *39*, 2501–2506. [CrossRef]
19. Fagbenle, R.L.; Karayiannis, T.G. On the Wind Energy Resource of Nigeria. *Int. J. Energy Res.* **1994**, *18*, 493–508. [CrossRef]
20. Jekayinfa, S.O.; Orisaleye, J.I.; Pecenka, R. An Assessment of Potential Resources for Biomass Energy in Nigeria. *Resources* **2020**, *9*, 92. [CrossRef]
21. Adegoke, K.A.; Adesina, O.O.; Okon-Akan, O.A.; et al. Sawdust-Biomass Based Materials for Sequestration of Organic and Inorganic Pollutants and Potential for Engineering Applications. *Curr. Res. Green Sustain. Chem.* **2022**, *5*, 100274. [CrossRef]
22. Akinbami, J.F.K.; Ilori, M.O.; Oyebisi, T.O.; et al. Biogas Energy Use in Nigeria: Current Status, Future Prospects and Policy Implications. *Renew. Sustain. Energy Rev.* **2001**, *5*, 97–112. [CrossRef]

23. Mohammed, Y.S.; Mustafa, M.W.; Bashir, N.; et al. Existing and Recommended Renewable and Sustainable Energy Development in Nigeria Based on Autonomous Energy and Microgrid Technologies. *Renew. Sustain. Energy Rev.* **2017**, *75*, 820–838. [CrossRef]
24. Aliyu, A.K.; Modu, B.; Tan, C.W. A Review of Renewable Energy Development in Africa: A Focus in South Africa, Egypt and Nigeria. *Renew. Sustain. Energy Rev.* **2017**, *81*, 2502–2518. [CrossRef]
25. Nkalo, U.K. Nigeria's Renewable Energy Sector: Analysis of the Present and Future Prospects. *Sol. Compass* **2025**, *14*, 100123. [CrossRef]
26. Apergis, N.; Payne, J.E. Renewable Energy Consumption and Economic Growth: Evidence from a Panel of OECD Countries. *Energy Policy* **2010**, *38*, 656–660. [CrossRef]
27. Apergis, N.; Payne, J.E. Renewable Energy, Output, CO_2 Emissions, and Fossil Fuel Prices in Central America: Evidence from a Nonlinear Panel Smooth Transition Vector Error Correction Model. *Energy Econ.* **2014**, *42*, 226–232. [CrossRef]
28. Ighodaro, C.A.U. Co-Integration and Causality Relationship Between Energy Consumption and Economic Growth: Further Empirical Evidence for Nigeria. *J. Bus. Econ. Manag.* **2010**, *11*, 97–111. [CrossRef]
29. Adeshina, M.A.; Ogunleye, A.M.; Suleiman, H.O.; et al. From Potential to Power: Advancing Nigeria's Energy Sector Through Renewable Integration and Policy Reform. *Sustainability* **2024**, *16*, 8803. [CrossRef]
30. Emodi, N.V.; Boo, K.J. Sustainable Energy Development in Nigeria: Current Status and Policy Options. *Renew. Sustain. Energy Rev.* **2015**, *51*, 356–381. [CrossRef]
31. Akuru, U.B.; Okoro, O.I. Renewable Energy Investment in Nigeria: A Review of the Renewable Energy Master Plan. In *Proceedings of the 2010 IEEE International Energy Conference*, Manama, Bahrain, 18–22 December 2010. [CrossRef]
32. Eberhard, A.; Gratwick, K.; Morella, E.; et al. Independent Power Projects in Sub-Saharan Africa: Investment Trends and Policy Lessons. *Energy Policy* **2016**, *108*, 11. [CrossRef]
33. Adeyemi-Kayode, T.M.; Misra, S.; Damaševičius, R. Impact Analysis of Renewable Energy Based Generation in West Africa—A Case Study of Nigeria. *Probl. Ekorozwoju* **2021**, *16*, 67–78. [CrossRef]
34. Oyedepo, S.O. Energy and Sustainable Development in Nigeria: The Way Forward. *Energy Sustain. Soc.* **2012**, *2*, 15. [CrossRef]
35. Elusakin, E.J.; Ajide, O.O.; Chuks, D.J. Challenges of Sustaining Off-Grid Power Generation in Nigeria Rural Communities. *Afr. J. Eng. Res.* **2014**, *2*, 52–56.
36. Nwankwo, N.C.; Madougou, S.; Inoussa, M.M.; et al. Review of Nigeria's Renewable Energy Policies with Focus on Biogas Technology Penetration and Adoption. *Discov. Energy* **2024**, *4*, 14. [CrossRef]
37. Ugwu, J.; Odo, K.C.; Oluka, L.O.; et al. A Systematic Review on the Renewable Energy Development, Policies and Challenges in Nigeria with an International Perspective and Public Opinions. *Int. J. Renew. Energy Dev.* 2022, *11*, 287–308. [CrossRef]
38. Thango, B.A.; Obokoh, L. Techno-Economic Analysis of Hybrid Renewable Energy Systems for Power Interruptions: A Systematic Review. *Eng.* **2024**, *5*, 2108–2156. [CrossRef]
39. Unegbu, H.C.O.; Yawas, D.S.; Dan-Asabe, B.; et al. Assessing the Environmental and Economic Benefits of Integrating Solar Energy in Nigerian Construction. *Discov. Civ. Eng.* **2025**, *2*, 114. [CrossRef]
40. Arogundade, S.; Hassan, A.S.; Mduduzi, B. Is Climate Change Hindering the Economic Progress of Nigerian Economy? Insights from Dynamic Models. *Heliyon* **2024**, *10*, e39288. [CrossRef]
41. Arksey, H.; O'Malley, L. Scoping Studies: Towards a Methodological Framework. *Int. J. Soc. Res. Methodol.* **2005**, *8*, 19–32. [CrossRef]
42. Levac, D.; Colquhoun, H.; O'Brien, K.K. Scoping Studies: Advancing the Methodology. *Implement Sci.* **2010**, *5*, 69. [CrossRef]
43. Tricco, A.C.; Lillie, E.; Zarin, W.; et al. A Scoping Review on the Conduct and Reporting of Scoping Reviews. *BMC Med. Res. Methodol.* **2016**, *16*, 15. [CrossRef]
44. Popay, J.; Roberts, H.; Sowden, A.; et al. *Guidance on the Conduct of Narrative Synthesis in Systematic Reviews: A Product from the ESRC Methods Programme*. University of Lancaster: Lancaster, UK, 2006; pp.1–92. [CrossRef]
45. Akorede, M.F.; Hizam, H.; Pouresmaeil, E. Distributed Energy Resources and Benefits to the Environment. *Renew. Sustain. Energy Rev.* **2010**, *14*, 724–734. [CrossRef]
46. Ngala, G.M.; Alkali, B.; Aji, M.A. Viability of Wind Energy as a Power Generation Source in Maiduguri, Borno State, Nigeria. *Renew. Energy* **2007**, *32*, 2242–2246. [CrossRef]
47. Attabo, A.A.; Ajayi, O.O.; Oyedepo, S.O. Wind Energy Generation from Nigeria Continental Shelf: A Review. In Proceedings of the International Conference on Energy and Sustainable Environment, Covenant University, Nigeria, 18–20 June 2019. [CrossRef]

48. Ohunakin, O.S.; Ojolo, S.J.; Ogunshina, S.B.; et al. Analysis of Cost Estimation and Wind Energy Evaluation Using Wind Energy Conversion Systems (WECS) for Electricity Generation in Six Selected High Altitude Locations in Nigeria. *Energy Policy* **2012**, *48*, 594–600. [CrossRef]
49. Akorede, M.F.; Ibrahim, O.; Amuda, S.A.; et al. Current Status and Outlook of Renewable Energy Development in Nigeria. *Niger. J. Technol.* **2017**, *36*, 196–212. [CrossRef]
50. Alao, O.; Awodele, K. An Overview of the Nigerian Power Sector, the Challenges of Its National Grid and Off-Grid Development as a Proposed Solution. In Proceedings of the 2018 IEEE PES/IAS PowerAfrica, Cape Town, South Africa, 28–29 June 2018. [CrossRef]
51. Coban, H.H.; Rehman, A.; Mohamed, A. Technical and Economical Investigation of a Centralized and Decentralized Hybrid Renewable Energy System in Cadaado, Somalia. *Processes* **2022**, *10*, 667. [CrossRef]
52. Onyebuchi, E.I. Alternate Energy Strategies for the Developing World's Domestic Use: A Case Study of Nigerian Households' Fuel Use Patterns and Preferences. *Energy J.* **1989**, *10*, 121–138. [CrossRef]
53. Adanma, U.M.; Ogunbiyi, E.O. Assessing the Economic and Environmental Impacts of Renewable Energy Adoption across Different Global Regions. *Eng. Sci. Technol. J.* **2024**, *5*, 1767–1793.
54. Abolarin, S.K.; Fevrier, K.; Abdulsamad, A. Navigating the Energy Transition: International Oil Company Divestments and the Stranded Asset Dilemma in Africa. *Extr. Ind. Soc.* **2025**, *24*, 101737. [CrossRef]
55. Omokaro, G.O.; Nafula, Z.S.; Iloabuchi, N.E.; et al. Energy Sanctions in the Global Economy: Geopolitical Disruptions, Market Fragmentation, Innovation and Green Transition. *Int. J. Innov. Stud.* **2025**, *9*, 246–261. [CrossRef]
56. Obada, D.O.; Muhammad, M.; Tajiri, S.B.; et al. A Review of Renewable Energy Resources in Nigeria for Climate Change Mitigation. *Case Stud. Chem. Environ. Eng.* **2024**, *9*, 100669. [CrossRef]