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Advancing Renewable Energy Solutions for Sustainable Development in Nigeria: Challenges, Opportunities, and Policy Implication

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Abstract - This paper examines the critical role of renewable energy in fostering sustainable development in Nigeria, focusing on the challenges of implementing renewable energy policies and offering actionable policy recommendations. Despite Nigeria's vast renewable energy potential, issues such as inadequate infrastructure, policy inconsistencies, regulatory bottlenecks, and limited financial investments hinder the sector's growth. The study explores these challenges in detail, emphasizing their socio-economic and environmental impacts. Furthermore, it outlines innovative solutions, including strengthening institutional frameworks, fostering public-private partnerships, and enhancing access to finance for renewable energy projects. By advocating for a multi-stakeholder approach and improved policy coherence, the paper provides a roadmap for advancing renewable energy adoption in Nigeria. The findings contribute to the broader discourse on sustainable energy solutions and offer valuable insights for policymakers, researchers, and practitioners committed to addressing Africa's energy challenges.

Keywords: Renewable energy, sustainable development, Nigeria, energy policy, public-private partnerships, energy infrastructure, green economy, renewable energy financing, clean energy transition

1.0 INTRODUCTION

Nigeria's energy sector is characterized by significant challenges and opportunities stemming from its diverse mix of energy resources, such as oil, natural gas, hydropower, and renewable potential, alongside a rapidly growing electricity demand driven by population growth, urbanization and industrial expansion. According to Reuter (2024), the national energy grid, which serves as the fundamental infrastructure for power distribution, faces persistent variations, frequent blackouts, and system instability, adversely affecting numerous families and businesses. In the same vein, the World Bank's Power Sector Recovery Programme (PSRP) fact sheet revealed that Nigerian economy loses $29 billion a year due to its unstable power supply, which causes electricity blackouts across the country. The primary causes include aging infrastructure, insufficient investment, unexpected demand fluctuations, and repeated instances of vandalism. The current scenario has led to a broad dependence on self-generation utilizing traditional biomass and fossil fuels (Akinyele et al., 2017).

According to the World Bank (2021), approximately 85 million Nigerians representing 43% of the population lack access to grid electricity. This positions Nigeria among the countries with the largest energy access deficits globally. With a population exceeding 200 million, the nation has an average electricity demand of 31.2 GW, yet its installed capacity of 14.38 GW operates at only 40% efficiency, highlighting an urgent need for interventions to bridge the gap between energy demand and supply (Akuru et al., 2017). Although renewable energy sources, particularly solar, offer immense potential, their current contribution to Nigeria's national grid remains marginal, accounting for less than 2% of total generation capacity (Remteng et al., 2021). However, the International Energy Agency (IEA, 2021) reports an 89% decline in solar electricity costs from 2010 to 2020, making it the most affordable source of new electricity in many regions. For Nigeria, this presents a critical opportunity to expand electricity access, especially in rural areas, where over 40% of the population lacks reliable power. Investing in solar and other renewable technologies could significantly address the energy deficit while promoting sustainable development.

Therefore, it is imperative to strategically prioritize the adoption and integration of renewable energy. To comprehend Nigeria's energy situation, it is necessary to analyze the difficulties encountered in generating and distributing electricity, as well as the possible remedies provided by renewable energy technologies and laws.

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1.1 Overview of Energy Landscape in Nigeria

Nigeria faces substantial obstacles in the generation and distribution of electricity, as seen by the persistent variations in the national grid, frequent power outages, and overall system instability. According to Onohaebi & Eseosa (2014), homes now only have access to an average of five hours of energy per day from the national grid. This has had a significant negative impact on daily life and economic activity. Ajayi and Ajayi (2013) observe that the national grid's output is insufficient to fulfill the demand, resulting in extensive dependence on self-generation using conventional biomass and fossil fuels.

In the last twenty years, Nigeria has had significant challenges in providing energy, leading to a considerable disparity between the amount of electricity needed and the amount available, which is continuously increasing. Nigeria has a population of over 200 million people. According to Akuru et al. (2017), the estimated average demand for electricity is 31.2 GW. However, Nigeria's installed capacity is only 14.38 GW and the average supply capacity is 6 GW. This highlights the significant insufficiency of the electricity generation system, which is operating at only about 40% of its potential. According to the rule of thumb, Nigeria would need around 200 GW of power to fulfill the energy requirements of its population, based on a minimum of 1,000 MW per 1,000,000 people. Nevertheless, the World Bank statistics (2023) indicate that electricity generation from renewable sources, excluding hydroelectric power, now stands at 0%. The sharp difference between these two aspects emphasises the immediate requirement for revolutionary actions in Nigeria's energy sector.

However, recent advancements in the installation of solar energy systems demonstrate a transition towards the acceptance of renewable energy. This rapid and assertive progress represents a possible pivotal moment in Nigeria's energy industry, providing optimism for a future with a more environmentally friendly and dependable electricity provision. In 2020, the World Energy Council (WEC) highlighted several major uncertainties in Nigeria's energy sector, including energy poverty, electricity costs, energy subsidies, and energy efficiency. Additionally, it identified pressing challenges for the country's leaders, such as addressing indicators for energy access, promoting renewable energies, combating corruption, removing trade obstacles, and optimizing liquefied natural gas operations. Despite significant financial investments in the sector over the past two decades, the report lamented that only marginal improvements have been achieved.
The persistently insufficient and inconsistent power supply compels individuals to resort to the self-generation of energy through the utilization of conventional firewood and fossil fuels (Abdallah & Adeleke, 2023). According to Anumaka (2012), Nigeria's electricity grid generation has been dominated by gas and other oil, hydroelectric, and coal sources. In 2014, Nigeria produced around 30 TWh of electricity distributed in the following manner: This distribution is shown in Fig. 1. It reveals Nigeria's dependency on fossil fuels, particularly natural gas, while renewable energy sources, such as solar, remain largely untapped.

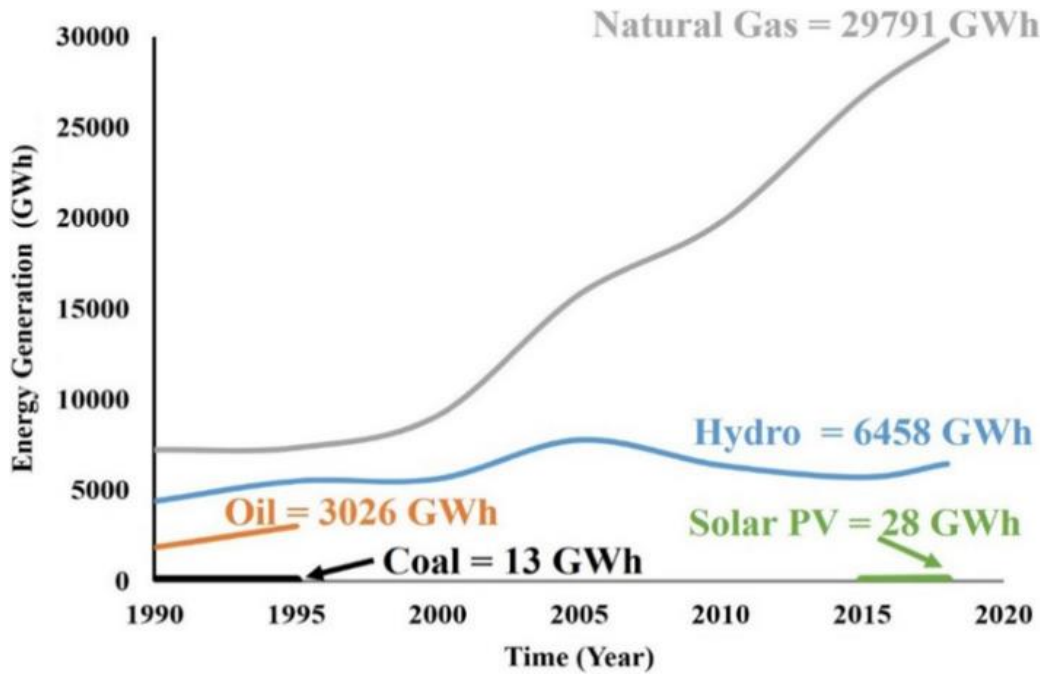

Figure 1: Variation of energy generation and its sources
Source: (IEA, 2021b)

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1.3 Sources of Energy in Nigeria

The table reveals information on various sources of energy in Nigeria, including their types and estimated reserves. These energy sources encompass a range of options, from traditional fossil fuels like crude oil and natural gas to renewable sources like biomass, hydro, solar, wind, wave, and tidal energy.

Energy type	Estimated reserves
Wave and tidal energy	150,000tj/(16.6 x 106 toe/year
Crude oil	36 billion barrels
Biomass	144 million tons/year
Hydro	14,750 MW
Natural gas	185 trillion cubic feet
Solar radiation	3.5-7.0 kmh/$m2$/day
Coal	2.75 billion metric tons
Wind energy	2.0-4.0 m/s

Source: IEA (2020)

2.0 RENEWABLE ENERGY POTENTIAL

Renewable energy (RE) is defined as energy resources that can be used for beneficial purposes, are continuously present in an environment, and naturally replenish over the course of a person's lifetime. Solar, wind, hydro, geothermal, and biomass resources are a few examples of RE systems. The rate at which these energy sources are consumed has little to no impact on their availability, and they are rapidly refilling (Okoye et al., 2016). By using a variety of conversion technologies, RE resources can be utilized to meet human energy needs by producing heat and power. For energy, countries currently mostly rely on fossil fuels like coal, oil, and natural gas, but this has a number of disadvantages. Fossil fuels have been identified as a major contributor to climate change and emit massive volumes of greenhouse gases when they are burned to generate electricity (Obada et al., 2024). With enormous resources in biomass, hydro, solar, and wind energy, Nigeria has a great deal of unrealized potential in renewable energy, according to scholarly literature. These are covered in the section below.

Biomass

Akuru et al. (2017) define biomass as non-fossil organic materials or living organisms derived from plants and animals, including their byproducts, capable of generating useful energy. Similarly, Aliyu et al. (2017) describe biomass as a chemical substance containing available energy, found in solid, liquid, or gaseous states. When biomass molecules break down, they release heat, producing both electrical and mechanical energy. Nigeria's biomass resources encompass fuelwood, charcoal, vegetation, sawdust, agricultural residues, animal waste, aquatic biomass, urban waste, and industrial byproducts (Akuru et al., 2017; Shaaban & Petinrin, 2014). These resources are categorized into animal waste, forestry resources, municipal solid waste, and agricultural residues (Akuru et al., 2017; Aliyu et al., 2017; Mas'ud et al., 2015; Shaaban & Petinrin, 2014). Firewood, or fuelwood, is widely used in Nigeria, particularly in Northern Nigerian households. Monyei et al. (2017) report that around 90% of homes in the north use firewood for cooking, with approximately 72% of the population relying on fuelwood daily. Emodi et al. (2017) support this data, indicating that about 70% of the population fits this pattern. Nigeria is estimated to have significant biomass resources, including 8× 10^2 MJ of biomass potential, 13 million hectares of wooded land, and 61 million tons of crop residue from animal waste annually (Shaaban & Petinrin, 2014).

The country's agricultural sector offers a diverse range of products such as cassava, sugarcane, cornstalk, rice husk, coconut, cashew nuts, peanuts, sesame, jatropha curcas, and castor oil, which have great potential for biofuel production. However, due to heavy reliance on traditional fossil fuels, there are relatively few biofuel companies in Nigeria. Nonetheless, Nigeria is predicted to have significant agricultural resource potential, estimated at 697.15 TJ (Giwa et al., 2017; Mohammed et al., 2013; Sambo, 2009). Regarding municipal solid waste, Nigeria has substantial potential due to its large population. Giwa et al. (2017) report that Nigeria generates approximately 2.04 million cubic meters of municipal solid waste daily, equivalent to around 74,428.85 tons. Various methods such as gasification, incineration, anaerobic digestion, and steam boilers can be used to convert this waste into bioenergy. However, currently, only a small fraction of public and private enterprises in the country are effectively harnessing energy from municipal solid waste to meet national energy demands.

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Hydro

Hydropower energy generation, as explained by Ikem et al. (2016), involves converting the kinetic energy of water into electricity using mechanical turbines, with energy output dependent on water volume and velocity. Nigeria is blessed with a handful of large rivers and a few waterfalls. Water resources in the country are divided into eleven water basins which encompass many small rivers and water ways with sufficient all year minimum level. There are currently about 200 dams in the country serving for power generation, irrigation and raw water supply with about 12 billion cubic meter (BCM)/year in capacity (Ogbonnaya, et al, 2019). It has been reported by Ref. [79] that about 286.6 (BCM)/year of water exist as in-country potential with about 375.1 BCM/year of surface water re- sources and 88 BCM/year (24 percent) inflows from neighbouring countries. A 2016 government assessment of water resources emphasize the possibility of generating electricity from River Niger, River Benue and tributaries in the Niger Delta. Only about 19 percent of the esti- mated 11,000 MW hydroelectricity potential is being exploited at the moment (Obada et al., 2024).

About 29% of the grid's power supply in Nigeria comes from hydropower, the only renewable energy source currently included in the national grid (Ogbonnaya et al., 2019). The nation's three primary hydroelectric plants—Kainji, Jebba, and Shiroro—provide roughly 1037 MW of electricity to the national system. The Mambila hydropower plant, Guarara II (360 MW), Kashim-bila (40 MW), Itisi (40 MW), and Guarara I (30 MW) are further power projects that were being built as of 2014 (Ogbonnaya et al., 2019). Despite these initiatives, the nation's hydropower potential remains mostly unrealized. Nigeria is expected to have a combined hydropower potential of more than 13 GW (Oyedepo, 2018). Hydroenergy is highly suitable for sustainable energy development due to its renewable nature and minimal environmental impact compared to fossil fuel-based energy sources. It contributes significantly to energy security, reduces greenhouse gas emissions, and promotes economic growth through job creation and infrastructure development, making it a key component of Nigeria's renewable energy strategy. To ensure a sustainable energy future and foster a well-developed energy stimulated economy, it is crucial to adopt and utilize hydropower as a renewable energy source

Wind

Wind energy is produced from the movement of air masses due to pressure differences and solar heating of the Earth's surface. Akuru et al. (2017) describe the conversion of wind's kinetic energy into electricity through turbine rotation. Wind speed is crucial for efficient wind energy generation, varying by location and season in Nigeria. Studies by Ohunakin (2010), Ikem et al. (2016), Sambo (2009), Vincent & Yusuf (2014), Mas'ud et al. (2015), and Shaaban & Petinrin (2014) provide insights into Nigeria's wind speeds, indicating higher speeds in the northern regions compared to the southern coastal areas.

According to the ECN data, Nigeria's wind energy potential varies across regions, with higher potentials observed in the northwest (Sokoto), north-central (Gas), and northeast (Yola) areas. Wind energy has significant potential for sustainable energy development in Nigeria due to its renewable nature and minimal environmental impact compared to fossil fuel-based energy sources. Harnessing wind energy can contribute to reducing greenhouse gas emissions, enhancing energy security, and promoting a more sustainable energy mix.

Utilizing wind energy for sustainable energy development in Nigeria offers several advantages. Firstly, wind power is a renewable energy source, meaning it does not deplete over time and can be continuously utilized without harming the environment. This aspect aligns well with global efforts to transition towards cleaner energy sources and reduce dependency on fossil fuels.

Secondly, wind energy has minimal environmental impact compared to traditional forms of energy generation, such as coal or oil-based power plants. Wind turbines produce no greenhouse gas emissions or air pollutants during operation, contributing to improved air quality and reduced carbon footprint.

Solar Energy

Solar energy is derived from nuclear fusion emitted by the sun's core, making it a renewable and abundant energy source. Nigeria, located in the equatorial region, receives intense solar radiation. Reports indicate that Nigeria benefits from significant sunshine, with an average of 6.25 hours of sunlight per day (Obada et al., 2024). This sunlight exposure varies across the country, with the far northern areas receiving up to 9 hours of sunlight and coastal regions experiencing around 3.5 hours. In terms of solar radiation, Nigeria receives an average of about 12.6 MJ/m²/day in the southern coastal latitudes and approximately 25.2 MJ/m²/day in the far northern part. This equates to an average solar power potential of 18.9 MJ/m²/day. The Global Solar Atlas (GSA) (2021) provides further details, indicating direct normal irradiation levels averaging about 724 kWh/m² in the far south and 1653 kWh/m² in the far north, translating to PV power potential of 1248 kWh/kWp in the south and 1756 kWh/kWp in the north. With Nigeria's total land area of 923,786 km², the country receives a substantial impact of solar radiation annually, estimated at 1500×10^9 MWh. This

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amount of solar energy received greatly exceeds the country's electricity generating capacity, emphasizing the vast potential of solar energy in Nigeria (Oyedepo et al., 2018).

Solar energy is highly suitable for sustainable development in Nigeria due to its renewable nature, abundant availability, minimal environmental impact, energy independence, economic opportunities, scalability, and ability to meet diverse energy needs, contributing to long-term energy security and environmental sustainability.

3.0 POLICY AND REGULATORY FRAMEWORK OF RENEWABLE ENERGY IN NIGERIA

The following are the existing policies and regulations related to renewable energy adoption in Nigeria:

3.1. National Energy Policy 2003 (NEP)

In 2003, the Federal Government of Nigeria approved renewable energy as part of its national energy policy to articulate sustainable exploitation and utilization of all viable energy resources (Dauda & Idehen, 2021). The objective of the Policy is among other things to ensure the development of the nation's energy resources with diversified energy resource options for the achievement of national energy security and an efficient energy delivery system with an optimal energy resource mix based on the principle of an energy economy in which modern renewable energy increases its share of energy consumed and provides affordable access to energy throughout Nigeria (Emodi & Ebele, 2017).

Some of the key elements addressed in the Policy are to develop, promote, and harness the renewable energy resources of the country and incorporate all the viable ones into the national energy mix, to promote a decentralized energy supply especially in rural areas, based on renewable energy resources, to de-emphasize and discourage the use of wood as fuel as it provides for de-emphasizing fuel wood and promotes the use of renewable energy and other environmentally friendly technologies that serve as alternatives like smokeless briquettes, to promote efficient methods in the use of biomass energy resource and to keep abreast with international developments in renewable energy technologies and applications (Dauda & Idehen, 2021).

The Policy looked at the various sources of energy and drew policies, objectives and strategies on how to drive the policies and strategies for the respective energy sources including renewable energy and rural electrification, and therefore constitutes a blueprint for all subsequent policies on the promotion of renewable energy (Giz,2015). These policy provisions have provided the impetus for the Federal Ministry of Power and Steel to embark on the development of the National Policy Guideline for Renewable Electricity and Renewable Electricity Action Programme. The Policy also created the platform upon which the rural electrification fund was later incorporated under the Rural Electrification Agency as well as constituting a blueprint for all subsequent policies on the promotion of renewable energy (Giz,2015).

In 2013, the National Energy Policy was reviewed to reflect recent developments in the energy sector with an emphasis on renewable energy and energy efficiency. In recognition of the importance of renewable energy, it has made provision for all forms of energy including renewable energy sources especially solar, wind, and biomass, and how they can be effectively utilized. It is reported that the Nigerian government has mandated electricity distribution companies in Nigeria to acquire a minimum percentage of electricity from renewable energy sources (Giz,2015). Though the Policy seeks to develop an energy strategy to address growing energy demand with affordable sustainable services that would enhance socio-economic development, the issue that arises is how these lofty objectives can be made possible, without enabling legislation to help propel the move towards renewable energy is one to be considered (Dauda & Idehen, 2021).

3.2. National Economic Empowerment and Development Strategy (NEEDS) 2004

The National Economic Empowerment and Development Strategy was drawn up by the National Planning Commission to meet the development challenges of Nigeria. The essence of NEEDS is finding ways and means to alleviate poverty by involving the use of human resources and the available natural resources to produce goods to satisfy the economic needs of the community (Yamusa and Ansari, 2015). Its other goals include among others consolidating the achievements of the previous legislative period to create a platform for further sustainable poverty reduction. NEEDS recognizes and provides for the promotion of the increase in the share of the utilization of the energy mix and stresses the need for a renewable energy agency to be created with its types of equipment put in place as well as making available provision for adequate funds for that purpose through the National Power Sector Reform Act. This recommendation has been commended as a milestone in respect of the adoption of renewable energy in the power sector (NEEDS, 2004)

3.3 Electric Power Sector Reform Act 2005 (EPSRA)

The Electric Power Sector Reform Act (EPSRA) marked the end of Nigeria Electricity Power Authority's monopoly and ushered in liberalization within the Nigerian Power Sector, allowing for independent and private participation in generation and distribution

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chains. The EPSRA, a product of the National Electric Power Policy 2001, established a new legal and regulatory framework for the energy sector. It provides guidelines for licensing, and regulation of all value chain segments (generation, transmission, distribution, and supply), and enforces performance standards, consumer rights, and obligations (Dauda & Idehen, 2021).

Moreover, the EPSRA promotes electricity generation from all energy sources, including renewables, by empowering the National Electricity Regulatory Commission to create a fair market and coordinate deregulated market activities (Ogunleye, 2017). The Act also established the Power Consumer Assistance Fund and Rural Electrification Fund, fostering liberalization, privatization, and unbundling of the power sector.

3.4. Renewable Electricity Policy Guidelines 2006

The federal government's general policy for all electricity produced from renewable energy sources is known as the Renewable Electricity Policy Guidelines on Renewable Electricity (REPG). It was produced by the Federal Ministry of Power and Steel and lays forth the goals, policies, and vision of the federal government. According to the Guidelines, by 2016, the federal government must take action to increase the market for renewable electricity to produce at least 5 TWh of electricity and five percent of all electricity generated. A summary of the state of the electricity sector is provided by the policy, which also acknowledges the benefits that renewable energy can offer the system, such as the ability to add more generating systems to already limited systems, improve electricity stability by reducing emissions, and lessen local supply disruptions (Onyi-Ogelle, 2016).

3.5. Renewable Electricity Action Programme (REAP) 2006

The Renewable Electricity Action Programme was launched by the Federal Ministry of Power in 2006 to aid in the implementation of the Renewable Energy Policy Guidelines (REPG). This project, which provides an overview of Nigeria's power sector and its relationship to the development of renewable energy, acts as a roadmap for implementing the Policy Guidelines. The program outlines the potentials, technology, and market prospects of renewable energy and provides information on government duties, risk assessments, development targets, strategies, funding options through the Renewable Electricity Fund, and monitoring structures (Giz, 2015).

The principal aim of the program is to utilize all forms of renewable energy for the production of electricity while taking into account any possible deficiencies, technical evaluations, economic consequences, and the advantages and constraints of Nigeria's renewable energy capacity (National Biofuel and Incentive, 2007). Nevertheless, the program seems to have been dropped as the Ministry of Power and Steel reorganized to become the Ministry of Power (Dauda & Idehen, 2021).

3.6. National Biofuel Policy and Incentives 2007

The goal of the policy is to create a biofuel assistance program that unites the economy's agriculture and downstream petroleum sectors. According to the policy, "biofuel" refers to fuels derived from biomass, such as ethanol and biodiesel, that are mostly used in the automotive, heating, and power generation industries. We applaud this definition for eliminating the issue with individualistic definitions since it forbids outside interpretation. (Vision 20: 2020 for Nigeria)

This strategy is compliant with the Federal government's 2005 order on the automotive biomass program for Nigeria and aims to build and promote a national fuel ethanol sector using agricultural products. The task of establishing favorable conditions for the ethanol industry's growth has been assigned to the Nigerian National Petroleum Corporation. This policy aims to develop a financially viable business while gradually reducing the country's reliance on fossil fuels. The Policy lists several advantages of biofuels, including reductions in emissions and ozone pollution for the environment (Dauda & Idehen, 2021).

3.7. Renewable Energy Master Plan 2012

The Renewable Energy Master Plan (REMP) serves as a strategic roadmap for the government's commitment to creating a conducive environment for sustainable energy supply, emphasizing private sector involvement. The plan, overseen by the Federal Ministry of Environment, aims to increase renewable energy's contribution to overall energy consumption (NERC, 2020).

The initial draft of REMP, originating in 2005, was deemed extensive and underwent a streamlined review in 2015 for precision and conciseness. The policy's objectives include bolstering national energy security, expanding energy access, particularly in rural areas, advancing learning, capacity building, research, and development in renewable energy technologies, and outlining a path to a significant share of the national energy mix through renewables.

REMP acknowledges that a key hurdle to rapid technology development and adoption in renewable energy is the absence of a robust market and supportive policy, regulatory, and institutional frameworks. As a response, the government has aligned several renewable

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energy-related policies into programs spanning short term (2013-2015), medium term (2016-2020), and long term (2021-2030) timelines.

The plan details various energy policies, regulations, and institutional frameworks alongside expected activities and assigns responsible ministries with timelines for target fulfillment. Additionally, REMP proposes financing options such as drafting legislation for a fossil fuel levy act to fund renewable energy projects and establishing a renewable energy development fund. Full implementation of REMP is expected to elevate renewable electricity's share to around 20% of total electricity supply nationally.

REMP envisions continual review of policy, legal, institutional, fiscal, and regulatory instruments, envisioning a future driven by renewable energy. By mid-century, the plan aims for sustainable and affordable renewable energy to meet half of the country's total energy demand (Dauda & Idehen, 2021).

3.8 Renewable Energy Feed in Tariff (REFITS) 2016

Section 76 of the Electric Power Sector Reform Act empowers the Nigerian Electricity Regulatory Commission (NERC) to establish a methodology for determining electricity tariffs in the Nigerian Electricity supply industry. The commission issued the Multi-Year Tariff Order (MYTO), which outlines tariffs for electricity generation, transmission, and distribution (IEA, 2015).

Recognizing the significance of renewable energy, the Renewable Energy Research and Development Division of NERC developed the Renewable Energy Feed-in-Tariff (REFIT) for wind, biomass, solar, and small hydropower. These were incorporated into MYTO II in January 2012, with the regulation approved by the government in February 2016, superseding MYTO II.

The objectives of REFIT, as stated in Section 3, include boosting power supply, achieving national renewable energy targets, encouraging private sector participation in renewable power generation, developing and promoting renewable energy resources, and establishing a stable income stream and return on investment for investors. REFIT guarantees a price for renewable energy-generated electricity for a fixed period, provides priority grid access, and mandates electricity distribution companies to procure a minimum of 1000 MW of renewable-sourced electricity, with the remaining sourced from the Nigerian Bulk Electricity Trading Company (NBET) (RECP, 2020).

REFIT distinguishes between small and large generation plants, automatically integrating electricity from small plants (1 MW to 30 MW) as renewable energy. For large plants (>30 MW), NERC initiates a competitive bid process (RECP, 2020).

3.9 National Renewable Energy and Energy Efficiency Policy (NREEEP) 2015

The National Renewable Energy Efficiency Policy (NREEEP) is derived from the National Energy Policy (NEP) but distinct in its focus solely on renewable energy, contrasting with NEP's coverage of both fossil fuels and renewables. NREEEP arose from the necessity of a dedicated national policy targeting renewable energy and energy efficiency. It acknowledges fuel substitution's importance in mitigating environmental impacts, such as reducing deforestation due to wood fuel use in Nigeria (National Renewable Energy Efficiency Policy, 2015).

NREEEP's objectives are multifaceted: enhancing energy security via diversifying the energy mix, improving energy access in rural and semi-urban areas, fostering employment, and addressing environmental concerns like climate change. The policy encompasses all renewable energy sources, setting goals across short-term (2013-2015), medium-term (2016-2020), and long-term (2021-2030) periods with specific MW targets (Ogunleye, 2017).

One short-term measure is bolstering institutional and legal frameworks to promote energy efficiency and conservation. Notably, legislative progress has been slow post-2015, hindering renewable energy development. Incentives play a crucial role, including financial subsidies, grants, tax relief, duty and levy waivers, aimed at demand and supply sides, and feed-in-tariffs. Establishing net metering frameworks and a Public Benefits Fund further support renewable energy projects (NREAP, 2016). These provisions are crucial for fostering rapid renewable energy and energy efficiency advancements.

4.0 ECONOMIC IMPACTS OF RENEWABLE ENERGY ADOPTION IN NIGERIA

The transition to renewable energy is now a vital step for Nigeria, driven by the need to combat climate change, reduce carbon emissions, and improve energy security and economic prosperity sustainably (Idoko et al., 2023). This shift carries significant economic impacts, influencing national growth, employment, and industrial development. Energy is a critical element for economic advancement, particularly in developing nations like Nigeria, which heavily rely on fossil fuels and face challenges such as energy insecurity and fluctuating oil prices (Akinlo, 2008). Renewable energy presents a stable and potentially more affordable alternative that can drive economic growth. Its development can improve energy access in rural areas, leading to increased economic activities, enhanced productivity, and reduced energy expenses.

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Moreover, the renewable energy sector in Nigeria offers opportunities for job creation and industrial expansion. As the sector grows, there will be a rising demand for skilled workers in renewable energy technologies installation, maintenance, and manufacturing (Idoko, et al., 2024). This growth can stimulate the development of new industries and reduce the country's dependency on oil. Additionally, the expansion of renewable energy can attract foreign investment, providing a boost to Nigeria's economy.

Furthermore, the impact of renewable energy on Nigeria's utility sector is noteworthy. The growth of renewable energy can stabilize the national grid and reduce reliance on costly and environmentally harmful diesel-powered generators. However, the transition to renewable energy also presents economic challenges, including the substantial initial investment required for renewable energy infrastructure and the financial constraints faced by the country.

4.1 Environmental Impacts of Renewable Energy Adoption in Nigeria

The environmental consequences of implementing renewable energy policies in Nigeria are substantial and varied, reflecting the intricacies of transitioning to sustainable energy systems. These consequences are largely positive, especially when compared to the environmental drawbacks associated with traditional fossil fuel energy sources (Idoko, et al., 2024). In Nigeria, transitioning to renewable energy offers an opportunity to markedly reduce environmental degradation, particularly in regions affected by oil and gas extraction activities. Shifting to biofuels, as discussed by Ajanovic (2011), can lead to enhanced air quality and decreased greenhouse gas emissions, albeit raising concerns regarding food security and land utilization. Solar and wind energy adoption can help address these concerns by providing clean energy without competing for agricultural land. Renewable energy sources such as solar and wind have minimal environmental impacts, particularly in terms of pollutant and greenhouse gas emissions. Jacobson (2009) highlights that these technologies offer solutions to global warming and air pollution, critical issues for Nigeria and other countries. In Nigeria, reducing reliance on diesel generators, major sources of air pollution and carbon emissions, is a significant environmental benefit of renewable energy policies.

However, renewable energy's environmental impacts are not devoid of challenges. For example, the production and disposal of solar panels and wind turbine blades raise issues regarding waste management and recycling. As renewable energy technologies advance, addressing these environmental concerns becomes vital for ensuring their sustainability. In Nigeria, the development of large-scale renewable energy projects like hydroelectric dams can have notable environmental impacts such as habitat disruption and displacement of local communities. Effective management through comprehensive environmental assessments and community engagement processes is essential to mitigate these impacts (Idoko, et al., 2024).

4.2. Social Impacts of Renewable Energy Adoption in Nigeria

The adoption of renewable energy policy in Nigeria would have far-reaching and significant impacts on society, as energy systems have a profound impact on both societal dynamics and individual well-being. These effects include things like social equity, work opportunities, public health, and energy availability. Improving electricity availability is one of the main social benefits of renewable energy policy in Nigeria. According to Idoko et al. (2023), energy access is essential for promoting social development and reducing poverty. Since a large percentage of the population does not have access to dependable electricity, renewable energy especially solar and wind energy can play a major role in closing this gap. Increasing access to electricity can have a revolutionary impact on living standards, healthcare, education, and general conditions, particularly in underprivileged and rural areas.

Another significant societal influence in Nigeria is related to public healthcare. Conventional energy sources used in Nigeria, such as biomass and diesel generators, contribute to interior and outdoor air pollution, creating health problems. Transitioning to cleaner renewable energy sources has significant potential to lessen pollution-related health risks. Dincer and Rosen (2021) underline that sustainable energy systems support healthier communities by reducing pollution and lowering the burden of respiratory and cardiovascular diseases. However, the societal consequences of renewable energy policy pose issues. The shift to renewable energy demands resolving concerns about employment displacement in the existing energy sector. In Nigeria, moving away from oil and gas, key sources of employment and money may have enormous social and economic repercussions that require careful analysis and planning (Idoko et al., 2024).

5.0 ROLE OF TECHNOLOGICAL ADVANCEMENTS IN RENEWABLE ENERGY DEVELOPMENT

Technological advancements play a crucial role in accelerating renewable energy development by improving efficiency, reducing costs, and enabling innovative solutions. For instance, advancements in photovoltaic (PV) technology have significantly increased solar panel efficiency while lowering production costs, making solar energy more accessible (IRENA, 2020). Similarly, innovations in wind turbine design, such as larger rotor diameters and higher hub heights, have enhanced energy capture, especially in low-wind regions (GWEC, 2021). Energy storage technologies, particularly lithium-ion batteries, have revolutionized grid integration by

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mitigating the intermittency of renewable energy sources (REN21, 2022). Furthermore, smart grid technologies enable real-time energy management, optimizing the integration of renewables into existing energy systems (IEA, 2021). These advancements not only promote energy diversification but also support the transition toward sustainable and resilient energy systems. In the Nigerian, the potential for innovation and research in renewable energy is vast, with opportunities and challenges unique to the country's energy landscape.

6.0 CHALLENGES IN IMPLEMENTING RENEWABLE ENERGY POLICIES IN NIGERIA

The implementation of renewable energy legislation in Nigeria has encountered several hurdles. Despite the government's commitment to increasing renewable energy in the energy mix, various difficulties impede successful implementation, similar to potential challenges faced during maritime explorations (Ijiga et al., 2021).

The first significant obstacle is the lack of infrastructure for renewable energy production. According to Oseni (2012), a lack of existing infrastructure, especially in rural areas, has been a substantial hurdle to developing renewable energy technology. This includes shortcomings in transmission and distribution networks necessary for efficiently distributing renewable-generated electricity. The unreliability and poor coverage of the existing grid exacerbate the situation, hindering the effective incorporation of renewable energy systems.

Financial limitations are another important issue. The significant financial outlay needed for developing and implementing renewable energy technology is highlighted by Sambo (2009). Nigeria struggles to provide enough funding for renewable energy projects due to constrained financial resources and conflicting economic goals. Additionally, the nation's capacity to fully utilize its renewable energy potential is further constrained by the high upfront costs of renewable energy technology and the absence of enticing financial incentives for private investors (Idoko et al., 2024).

The legislative and regulatory landscape presents another crucial challenge. Akinola, Pereira, and M'kendry (2018) argue that investors and other players in the renewable energy market face uncertainty due to inconsistent energy policies and unclear regulatory frameworks. Long-term planning and investment in renewable energy projects are hindered by the lack of consistent and stable rules. Bureaucratic impediments and regulatory complications sometimes impede the implementation of renewable energy initiatives, exacerbating the problem.

Furthermore, the adoption of renewable energy is hindered by Nigeria's significant reliance on fossil fuels, particularly natural gas and oil. Nigeria's economy heavily depends on the oil and gas industry, impacting investment priorities and energy policy. Switching to renewable energy not only requires substantial investment but also a change in the current energy paradigm—an arduous task given Nigeria's economic structure (Idoko et al., 2024).

The development of renewable energy in Nigeria is also hindered by technological issues. One significant problem, as noted by Oseni (2012), is the lack of local capacity and technological know-how for creating and maintaining renewable energy systems. The nation heavily relies on foreign technologies, which can be costly to maintain and operate and are often poorly adapted to the local environment. Developing suitable technology and enhancing local capacity are crucial for the long-term growth of Nigeria's renewable energy industry. Lastly, societal issues, such as public understanding and acceptance of renewable energy, pose challenges. Public ignorance about the benefits of renewable energy can lead to opposition to new initiatives, especially when they involve altering local habitats or land usage. Overcoming these societal challenges requires involving communities and stakeholders in designing and executing renewable energy projects.

7.0. CASE STUDY OF A SUCCESSFUL RENEWABLE ENERGY INITIATIVE IN NIGERIA

In Nigeria, a nation facing substantial energy challenges, the successful execution of renewable energy projects is critical for social and economic advancement. One prominent example of such an initiative is the Solar Nigeria Programme (SNP), which has made significant strides in expanding electricity availability through solar energy. Initially launched in 2014, the SNP aimed to provide solar electricity to public buildings, such as schools and hospitals, in rural and underserved areas. Over time, the program was extended to include homes, furthering its reach and impact. The primary goal of the initiative was to reduce Nigeria’s dependency on costly and environmentally harmful diesel generators, which have been the primary source of power for many households and businesses (Idoko et al., 2024).

The geographic advantages of Nigeria, with abundant solar resources, have been instrumental in the program's design. Akuru and Okoro (2017) emphasize that the Solar Nigeria Programme capitalized on Nigeria's significant solar potential to address the country's electricity shortfall. To facilitate the program's success, incentives and subsidies were offered to encourage private sector

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participation, making it easier to install solar systems and panels across the country. This strategy was vital for accelerating the rollout of solar energy solutions to Nigeria's diverse regions.

According to Sambo (2009), strategic advancements in renewable energy are essential for maintaining national energy security, and the SNP played a significant role in this regard. By expanding the capacity of the national grid and providing an alternative to unreliable grid electricity, the program contributed significantly to Nigeria's energy security. A key achievement of the SNP was its impact on public institutions. Solar-powered schools and hospitals, especially in rural areas where grid electricity is either non-existent or unreliable, helped improve educational and healthcare outcomes. This initiative allowed many Nigerian families to transition from kerosene lamps and diesel generators to cleaner and more reliable solar electricity. In doing so, the SNP not only enhanced the quality of life for households but also made a positive contribution to environmental sustainability by reducing greenhouse gas emissions and air pollution (Idoko et al., 2024).

The economic impact of the SNP has also been noteworthy. By spurring growth in the local solar power industry, the program has created jobs and enhanced Nigeria’s capacity for solar system installation and maintenance. Furthermore, it has attracted foreign investment and fostered partnerships between Nigerian companies and international solar technology providers, thereby contributing to the growth of Nigeria’s emerging green economy sector.

Despite its successes, the SNP faced several challenges that hindered its full potential. One major issue was financial sustainability. Securing consistent and adequate funding remained critical for the program's continued expansion and long-term success. Additionally, there were difficulties in gaining customer confidence in solar technology, particularly in regions where solar power was still considered a novel and unfamiliar concept (Idoko et al., 2024).

Furthermore, while the SNP contributed to expanding solar energy access, additional efforts are needed to address Nigeria's broader energy infrastructure challenges. The program’s success in off-grid solar solutions, such as mini-grids and standalone solar systems, particularly benefited rural areas that lacked access to the national grid. However, expanding access to these systems and ensuring their sustainability require continuous investment in both infrastructure and human capital (Akuru & Okoro, 2017).

Another critical factor in the success of the SNP was the local manufacturing and assembly of solar components. This shift helped reduce dependence on expensive imports and created opportunities for technology transfer. By enhancing Nigeria's self-sufficiency in solar energy technology, the program laid the foundation for the country's future role in the global renewable energy market (Adeniji et al., 2023). In terms of policy and regulatory frameworks, the Nigerian government’s support through the Renewable Energy and Energy Efficiency Policy (REEEP) played a key role in enabling the SNP to thrive. Tax incentives, subsidies, and streamlined regulatory processes helped create a favorable environment for solar energy development (Ohunakin et al., 2014).

Furthermore, the program also contributed to social equity by addressing gender inclusion. In rural areas, women and children especially benefited from access to reliable solar energy, as it allowed them to reduce time spent collecting firewood and provided better lighting for studying at night. These benefits enhanced their quality of life and contributed to broader social and economic progress. Finally, the lessons learned from the SNP can provide valuable insights for scaling renewable energy projects not only within Nigeria but across other sub-Saharan African countries. The importance of public-private partnerships, flexible financing mechanisms, and community involvement are all key takeaways that could facilitate the success of similar programs globally (Ohiare, 2015).

CONCLUSION

The integration and development of renewable energy in Nigeria are vital for addressing the country's energy crisis, reducing reliance on fossil fuels, and fostering sustainable economic growth. While there have been notable strides in implementing renewable energy projects, such as the Solar Nigeria Programme, significant challenges remain in terms of infrastructure, financing, and technological advancements. These challenges, if not properly addressed, may impede the growth and sustainability of renewable energy solutions. However, with coordinated policy efforts, substantial investments, and a commitment to technological innovation, Nigeria can overcome these barriers and build a resilient energy sector that benefits all Nigerians.

RECOMMENDATIONS

i. Policymakers should develop unambiguous and coherent rules and laws that delineate specific goals, rewards, and criteria for renewable energy. These measures encompass feed-in tariffs, tax incentives, and regulatory clarity in order to encourage investment and guarantee market stability.

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ii. The government should promote both local and international investment in renewable energy initiatives by fostering partnerships, facilitating public-private cooperation, and offering incentives such as grants, subsidies, and low-interest loans. Create specific finances and financing structures to provide support for research, development, and deployment.

iii. Renewable energy policies should be consolidated and optimized to intentionally foster appealing investment prospects, so facilitating the involvement of both local and foreign investors. The government's fiscal, regulatory, and investment frameworks should clearly indicate that both local and foreign investors are encouraged and that their investments will be safeguarded.

iv. The incorporation of renewable energy into the national grid poses technical obstacles. The government should allocate resources towards the modernization and improvement of the grid infrastructure in order to effectively handle the fluctuating and decentralized nature of renewable energy sources. This encompasses investments in smart grid technologies and energy storage solutions.

v. The government should allocate resources towards education and training initiatives aimed at cultivating a proficient workforce capable of designing, installing, operating, and maintaining renewable energy systems. Engage in partnerships with educational institutions, industry specialists, and international organizations to facilitate the exchange of knowledge and the improvement of skills.

vi. The government should also implement public awareness initiatives to enlighten residents on the advantages of renewable energy, encompassing environmental sustainability, energy security, and economic expansion.

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